OECD Health Policy Studies

The Economic Case for Pandemic Preparedness and Response

Beyond Lockdowns



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BEYOND LOCKDOWNS



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Foreword

Pandemics are among the most disruptive risks facing societies. The COVID-19 pandemic claimed nearly 7 million lives worldwide between 2020 and May 2023 and caused global gross domestic product (GDP) per capita to contract by around 4% in 2020 relative to 2019 levels, a decline comparable to that of the 2008 global financial crisis. Rapid urbanisation, deforestation, intensive farming, extensive and often unregulated wildlife trade and rising demand for air travel are all increasing the risk of future pandemics, making the question not whether another pandemic will occur, but when.

This report demonstrates the value of investing in pandemic preparedness and response (PPR) measures that enable a rapid and effective response during the early phases of an emerging epidemic outbreak. Using the OECD Strategic Public Health Planning Model for PPR, it simulates five outbreak scenarios, including Ebola-like, avian influenza-like, influenza A-like, coronavirus-like and measles-like and quantifies the health and economic consequences of inaction. The analysis focusses on the early stages of outbreaks when no pharmaceutical interventions or vaccines are available at scale. Without effective mitigation, outbreaks could claim the lives of between more than 1% of the population in a coronavirus-like outbreak and more than 5% during an influenza A-like outbreak, with demand for critical care in the OECD exceeding available hospital capacity within one to two months. Similarly, GDP would contract by between 2.7% in a coronavirus-like outbreak and 16.2% in a measles-like outbreak.

The report also shows what works. Early implementation of non-pharmaceutical interventions (NPIs), core public health measures ranging from physical distancing, hand hygiene and mask wearing to ensuring safe domestic and international travel, with strong public support is central to protecting population health and the economy. Even the least stringent package, “Safer contact”, which combines community-based infection prevention and control (IPC) with voluntary quarantines, could avert at least 40% of deaths if effectively implemented, while limiting GDP losses. A layered approach (the “Reduced contact” package) that combines community-based IPC measures with teleworking, domestic travel limitations and mandatory quarantines, would avert most deaths, cushion economic losses and limit the need for school closures or international travel restrictions in most scenarios and countries.

Strengthening PPR capacity is both achievable and compelling. The report estimates that an investment of USD PPP 7.1 billion per year across OECD countries (USD PPP 2.6 billion per year in the EU/EEA), or around USD PPP 5.9 per capita, would be needed to reinforce country-level PPR foundations in priority areas such as building and maintaining a national stockpile of personal protective equipment and hygiene supplies, strengthening the implementation of physical contact-reducing NPIs such as physical distancing measures and strengthening disease surveillance capacity through wastewater surveillance.

Many PPR investments are inherently dual use: the same infrastructure that protects health and the economy during outbreaks also enhances routine health services, speeds detection of other health threats and builds public trust in institutions in normal times. Acting before the next crisis is therefore essential to reduce avoidable loss of life, build resilient health systems and safeguard long-term economic performance.

Acknowledgements

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The opinions expressed and arguments employed herein do not necessarily reflect the official views of the OECD Member countries or the European Union. The organisations and institutions whose data were used in this report do not bear any responsibility for the analysis or interpretation of the data.

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Executive summary

Pandemics are rare but their consequences can be dire

Pandemics and public health emergencies of international concern are low-probability, high-impact events that can disrupt every facet of society, a risk underscored by the ongoing Ebola outbreak in the Democratic Republic of the Congo. The 1918 influenza pandemic killed an estimated 40 to 50 million people worldwide. The 2002-2003 severe acute respiratory syndrome outbreak spread across 26 countries on 5 continents.

Rapid urbanisation, deforestation, intensive farming, poorly regulated wildlife trade and changing weather patterns are raising the risk of future pandemics. Scientific studies warn that the world faces a roughly one-in-two chance of another pandemic on the scale of COVID-19 within the next 25 years. Rising human infections with highly pathogenic avian influenza heighten these concerns.

The health and economic consequences of COVID-19 are likely to persist over the next two decades

The burden of COVID-19 goes beyond its immediate impacts. The crisis reshaped lifestyle-related risk factors for non-communicable diseases, including tobacco use, alcohol consumption and obesity while disrupting care pathways for people living with chronic conditions. OECD analysis across 28 OECD countries links these changes to a 2.4-month decline in average life expectancy between 2020 and 2024, compared with a hypothetical scenario in which COVID-19 did not occur. This loss translates into a 0.4% increase in average annual health expenditure and GDP losses of 0.1% per year. These impacts are projected to fade if risk factors return to pre-pandemic levels; should they persist, average life expectancy could remain 1.9 months lower by 2050, with annual health expenditure 0.6% higher and GDP up to 0.2% lower each year.

Early and effective pandemic response is the only viable strategy to avoid overwhelming health systems and destabilising economies

OECD simulations using the Strategic Public Health Planning Model for pandemic preparedness and response (PPR), assess five unmitigated outbreak scenarios, including Ebola-like, avian influenza-like, influenza A-like, coronavirus-like and measles-like outbreaks, as a stress test for health systems and economies. Without treatments or vaccines available at scale, unmitigated outbreaks could claim the lives of between 1% of the population in a coronavirus-like outbreak and more than 5% in an influenza A-like outbreak within the first nine months. Critical care capacity in OECD countries could be exhausted, on average, within one to two months. Surge capacity, the ability of health systems to expand beyond normal capacity, can provide only temporary relief.

When health systems are overwhelmed, economies stumble. Across all five outbreak scenarios, failure to mitigate outbreaks would result in sharp GDP contractions of between 2.7% in a coronavirus-like outbreak

and 16.2% in a measles-like outbreak, on average, with the scale of damage varying across countries. Transport and storage, manufacturing, and administrative and support services would consistently be among the hardest-hit sectors of the economy.

Early implementation of non-pharmaceutical interventions (NPIs) with strong public support saves lives while limiting economic damage

NPIs, core public health measures ranging from physical distancing to ensuring safe travel, can protect both population health and economic activity in the early phases of pandemics, when they are likely to be the only interventions readily available. OECD microsimulations across 51 OECD, EU/EEA and G20 countries show that:

- Early and effective implementation of NPIs can reduce the need for more restrictive interventions later. All four modelled NPI packages, ordered by their disruption to daily life, from community-based infection prevention and control (IPC) measures improved hand hygiene and mask wearing to lockdowns substantially reduce the health toll of pandemics. Even the least stringent option, the "Safer contact" package, could avert at least 40% of deaths compared with an unchecked outbreak if implemented effectively, while limiting the average GDP losses.
- A layered approach, in which measures are progressively scaled up as needed, offers a balanced strategy. The "Reduced contact" package, which combines community-based IPC measures with teleworking, domestic travel limitations and mandatory quarantines, can avert most deaths while cushioning economic losses across most scenarios. This approach can avoid resorting to school closures and international travel restrictions.
- Relying on lockdowns alone as a last resort, without strong use of less restrictive NPIs, is both the least effective strategy for saving lives and the most damaging for the economy, with average GDP declines ranging from 11.7% to 28.9%, often exceeding the losses associated with unmitigated outbreaks.
- The effectiveness of any NPI strategy depends heavily on the degree to which the public complies with recommended containment measures. Where compliance is low, more restrictive interventions, including lockdowns, may become unavoidable.

Robust disease surveillance systems and strategic stockpiling are critical for the early and effective implementation of NPIs

Policymakers can act quickly only if they can see an outbreak coming and have the supplies to respond:

- NPIs can be deployed promptly, targeted precisely and adjusted only when policymakers have timely and accurate data on how an outbreak is unfolding. OECD analysis shows that combining clinical surveillance with wastewater monitoring could enable earlier and more targeted implementation of NPIs while reducing attributable deaths and the duration of lockdowns.
- Even where surveillance signals the need for prompt action, that action can only be implemented effectively if the necessary supplies are already in place. National and regional stockpiles are the first line of defence, buffering surges in demand for healthcare services and disruptions to supply chains.

Successfully managing outbreaks also hinges on effective governance systems that guide strategic decision making during health crises, build public trust, support effective crisis communication, ensure close collaboration across sectors and establish mechanisms for international co-ordination.

Strengthening PPR capacity is affordable and delivers broad benefits

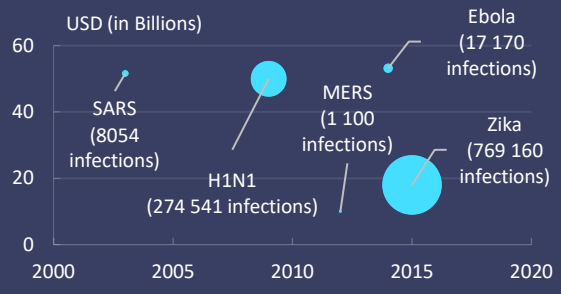
Investment in PPR is modest relative to the potential losses. OECD analysis estimates that around USD PPP 7.1 billion per year would be needed, on average, to strengthen PPR capacity in OECD countries (USD PPP 2.6 billion per year in the EU/EEA). Almost USD PPP 4.4 billion (USD PPP 3.2 per capita) would go towards national stockpiles of personal protective equipment and hygiene supplies.

The infrastructure, surveillance systems and co-ordination mechanisms built for PPR are dual use: they strengthen routine services, speed the detection of emerging threats and support public trust in institutions in normal times.

Infographic 1. Key facts and figures

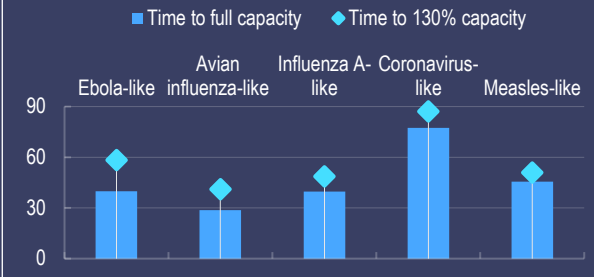
Epidemic outbreaks impose a dual toll on health and the economy

With nearly 765 million reported cases (as of May 2023) & USD 13.8 trillion in losses between 2020-2024, COVID-19 is the most damaging epidemic in recent history.



Future pandemics will put our healthcare systems under pressure

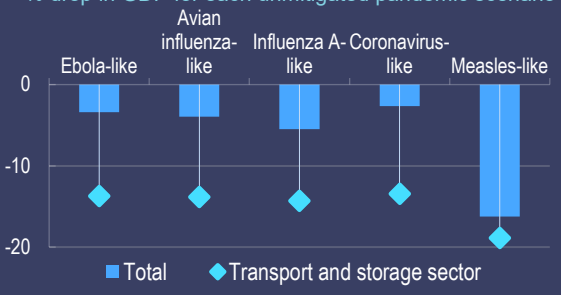
Number of days it could take to reach or exceed ICU capacity in unmitigated outbreaks as a hypothetical stress test



Most healthcare systems would struggle to meet demand for critical care within 1-2 months in all unmitigated scenarios.

When our health systems are overwhelmed, economies stumble

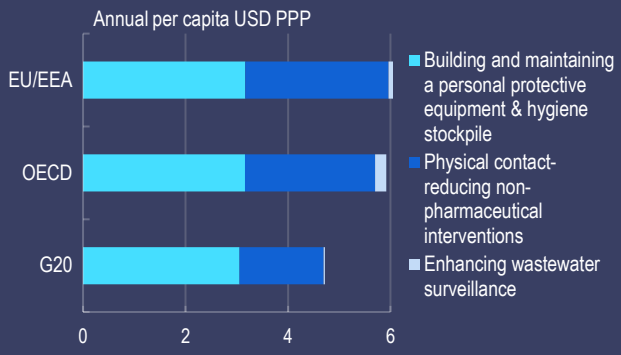
% drop in GDP for each unmitigated pandemic scenario



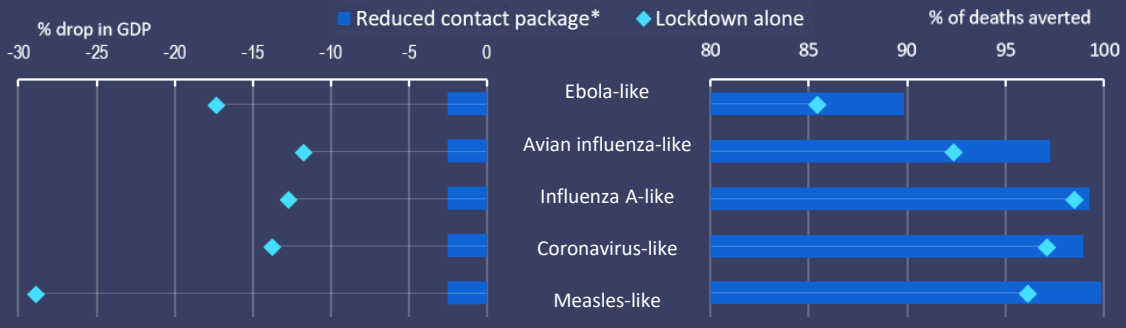
Exposure to shocks varies by sector, with transportation and storage facing the greatest disruption and service-based sectors such as education the least.

Strengthening pandemic preparedness and response is affordable

Estimated annual per capita cost of strengthening PPR capacity, USD PPP



Early and effective implementation of non-pharmaceutical interventions can limit the health and economic impacts of outbreaks



In most cases, the “Reduced contact*” package involving infection prevention and control (i.e. mask wearing, hand hygiene and indoor ventilation), mandatory quarantines of infected people, promotion of teleworking and domestic travel restrictions offers a more practical strategy to balance health and economic gains compared to lockdowns implemented alone as a last resort.

1 Assessment and recommendations

This chapter synthesises the report's key findings and sets out its policy recommendations. It provides an overview of the health and economic impact of the COVID-19 pandemic, including its indirect effect on non-communicable diseases, before reporting the potential toll of five potential pandemic scenarios including Ebola-like, avian influenza-like, influenza A-like, coronavirus-like and measles-like, using the OECD Strategic Public Health Planning for Pandemic Preparedness and Response model across 51 OECD, European Union/European Economic Area and Group of 20 countries. The chapter discusses the findings on the health and economic effects of scaling up eight non-pharmaceutical interventions and the foundations on which their effectiveness depends. The chapter concludes by reporting the investment needed to strengthen pandemic preparedness and response capacities and the returns it delivers.

In Brief

Key messages

Pandemics and public health emergencies of international concern are low-probability but high-impact events: Rare in occurrence, yet capable of disrupting every facet of society when they strike

- The 1918 influenza pandemic caused an estimated 40-50 million deaths worldwide, crippling labour markets and economic production. More recent outbreaks showed the heavy economic toll of even smaller-scale outbreaks: the 2002-2003 severe acute respiratory syndrome (SARS) outbreak cost around USD 50 billion, the 2005 highly pathogenic avian influenza A(H5N1) outbreak around USD 40 billion and the 2009 H1N1 influenza outbreak around USD 50 billion. These risks are not confined to the past. An ongoing Ebola outbreak in the Democratic Republic of the Congo shows that the threat remains current. At the same time, reports of rising human infections with another highly pathogenic avian influenza virus raise concerns about the risk of another large-scale outbreak.

The COVID-19 pandemic was the latest reminder of the disruptive capacity of pandemics

- It claimed nearly 7 million officially reported lives worldwide from 2020 to May 2023. Health systems across the globe were stretched far beyond capacity, facing acute shortages of healthcare personnel, hospital beds and essential medical supplies, while routine services for non-COVID-19 patients were severely disrupted. The global gross domestic product (GDP) per capita contracted by nearly 4% in 2020 compared with 2019 levels, a decline comparable to that experienced during the 2008 global financial crisis.
- The true burden of the COVID-19 pandemic is higher and may last for decades. The COVID-19 pandemic altered the trajectory of life-style-related risk factors (e.g. patterns in tobacco use, alcohol use and obesity) for non-communicable diseases (NCDs) and disrupted nearly every step of the care pathway for patients with chronic conditions. The OECD analysis suggests that if the changes in NCD-related risk factors observed during COVID-19 persisted, life expectancy could be 1.9 months lower than without COVID-19, on average, across 28 OECD countries by 2050. This translates into additional costs equal to 0.6% of total health expenditure each year and annual GDP losses of 0.2%.

Another pandemic is not a question of if, but when

- Since the 1940s, the frequency and intensity of smaller outbreaks have been on the rise. Today, the risk of local outbreaks escalating into global pandemics is high. Rapid urbanisation, deforestation, intensive farming, extensive and often unregulated wildlife trade and rising demand for air travel are all factors that exacerbate the risk of pandemics.
- Changing weather patterns are also contributing to a heightened risk of outbreaks. Extreme weather events such as rising temperatures and prolonged droughts are creating a more favourable environment for many diseases to flourish and expand their reach. Vector- and tick-borne illnesses are becoming more prominent threats in OECD countries.

Without efforts to mitigate pandemic outbreaks, health systems would be quickly overburdened, and the human and economic losses would be dire

- Applied to five outbreak scenarios based on pathogens similar to those with pandemic potential (i.e. Ebola-like, avian influenza-like, influenza A-like, coronavirus-like and measles-like outbreaks), the OECD Strategic Public Health Planning Model (SPHeP) for pandemic preparedness and response (PPR) shows that if not mitigated early and effectively, pandemic outbreaks can overwhelm health systems once again. All five unmitigated pandemic scenarios can potentially cause large outbreaks. While some scenarios would result in rapid and severe outbreaks, others could drag on over time.
- Without mitigation efforts, their consequences for population health could be dire, with the share of the population losing their lives ranging from 1.2% of the population in a coronavirus-like outbreak to 5.4% in an avian influenza-like outbreak, rising up to 20% in a measles-like outbreak. Even the most advanced healthcare systems would struggle to meet demand for critical care in as little as 1-2 months. Surge capacity can provide temporary relief but cannot compensate for the rapid spread of a fast-moving pathogen, rendering mitigation of the spread the only viable strategy to avoid the collapse of healthcare systems.
- When health systems are overwhelmed, economies will stumble. Without robust efforts to mitigate each outbreak, the economic fallout would be substantial, with a sharp contraction in GDP averaging between 2.7% and 16.2% over the 9-month simulation period, depending on the scenario. Impacts would be uneven across sectors. In nearly all countries and scenarios, transport and storage would be hit the hardest.

Targeted non-pharmaceutical interventions (NPIs) protect population health and economies in the early phases of pandemics

- The timing of scaling up NPIs is critical. Early and well-implemented NPIs reduce the need to rely on lockdowns. Using lockdowns as a last resort without promoting other NPIs is both the least effective at saving lives and the most damaging option for the economy (11.7%-28.9% decline in GDP), often leading to GDP contractions larger than those caused by unmitigated outbreaks. In most outbreak scenarios, lockdowns can be avoided with robust and timely implementation of less restrictive measures.
- All modelled NPI packages substantially reduce the health toll of pandemics. Even the least stringent option, involving community-based infection prevention and control and voluntary quarantines (the “Safer contact” package), could avert at least 40% of deaths that would have occurred in an unchecked outbreak with moderate impacts on the economy (2.5%-8.6% decline in GDP). However, the effectiveness of NPIs relies heavily on the extent to which the public complies with the recommended public health actions. In cases where compliance is low, lockdowns may be necessary.
- A layered approach to implementing NPIs at increasing levels of stringency as needed can protect population health without substantially straining the economy. Layering teleworking arrangements, domestic travel limitations and mandatory quarantines (the “Reduced contact” package) would be sufficient to avert the vast majority of deaths. This approach would also cushion economic losses in all outbreak scenarios.
- When implemented early and effectively, escalating from the “Safer contact” package to the “Reduced contact” package can avoid the need for school closures and international travel restrictions that deliver only marginal health gains but carry higher economic costs.

- The effectiveness of NPIs both in terms of safeguarding population health and the economy depends heavily on the buy-in from the general public.

PPR capacity can be greatly strengthened when NPIs are backed by solid foundations

- Wastewater surveillance can greatly enhance the protective impacts of NPIs by enabling earlier and more targeted action. For example, in a coronavirus-like outbreak, using wastewater surveillance to guide the implementation of the "Safer contact" package could prevent an additional 41% of deaths that would have otherwise occurred compared to a scenario where data gathered only through clinical surveillance are used. Wastewater surveillance can eliminate the need for lockdowns altogether in many cases and support more targeted lockdowns, when they are needed, reducing their duration by up to 90% in certain scenarios and thereby minimising social and economic disruption.
- Stockpiling is a key component of timely and effective pandemic preparedness and response capacity. National and regional stockpiling of critical medical goods serves as a first line of defence in health emergencies, providing a buffer when demand surges and supply chains falter. Beyond pandemics, stockpiling supports responses to natural disasters, chemical, biological, radiological and nuclear threats, as well as the threat of antimicrobial resistance. Effective stockpiling policies require clear governance structures, sustainable funding, effective management of risks and inventory.

Improving PPR capacity is affordable

- Investments in PPR yield "dual-use" benefits. When PPR systems are in place, countries can respond to outbreaks more efficiently by relying on established structures rather than building new ones. The same infrastructure, surveillance systems and co-ordination mechanisms that protect populations and the economy during outbreaks also enhance routine care, accelerate detection of other health threats and help improve public trust in institutions in "normal times".
- OECD analyses show that across OECD countries alone, an average investment of USD PPP 7.1 billion (USD PPP 5.9 per capita) per year is estimated to be necessary to improve country-level preparedness for the next outbreak. This is aligned with the range of estimates generated by previous global PPR costing exercises from USD 1.4 to 5.4 per capita annually. The largest share of annual PPR investment would go toward building and maintaining national stockpiles of personal protective equipment and hygiene supplies (USD PPP 3.2 per capita in the OECD), followed by activities to strengthen the implementation of physical contact-reducing NPIs such as physical distancing measures (USD PPP 2.5 per capita in the OECD). Enhancing wastewater surveillance comes at a much lower cost, with most countries spending less than USD PPP 1 per person annually on these efforts.

1.1. Another pandemic is not a question of if, but when

Pandemics and public health emergencies of international concern are classic examples of low-probability but high-impact events: rare in occurrence, yet capable of disrupting every facet of society, a risk also underscored by the ongoing Ebola outbreak in the Democratic Republic of the Congo. Prior to COVID-19, several pandemics exposed how disease outbreaks can severely disrupt both health systems and economies. The 1918 influenza pandemic led to about 40-50 million deaths worldwide, crippling labour markets and disrupting economic production (Beach, Clay and Saavedra, 2022[1]). The 1957 and 1968 influenza pandemics were less deadly but still caused losses in investment and productivity. The

2003 SARS outbreak, though limited in scale, had outsized economic effects with the global losses reaching USD 50 billion (Lee and McKibbin, 2004[2]).

The COVID-19 pandemic was the latest reminder of the disruptive capacity of pandemics. It claimed around 7 million officially reported lives worldwide from 2020 to May 2023 when the World Health Organization (WHO) declared that it was no longer a public health emergency of international concern (WHO, 2026[3]). Health systems across the globe were stretched far beyond capacity, facing acute shortages of healthcare personnel, hospital beds, essential medical supplies, while routine services for non-COVID-19 patients were severely disrupted. Global gross domestic product (GDP) per capita contracted by nearly 4% in 2020 relative to 2019, a decline comparable to that experienced during the 2008 global financial crisis (World Bank Group, 2025[4]).

The risk of another pandemic is rising. A widely cited study suggests that the cumulative probability of experiencing another COVID-19-scale pandemic over the next 25 years is roughly 50% (Madhav et al., 2023[5]). Findings from the same study suggested that the cumulative 25-year risk of a pandemic that could be caused by a respiratory virus lies between 14% and 80% depending on its severity, with higher-fatality pandemics being less likely. Rapid urbanisation, deforestation, intensive farming, extensive and often unregulated wildlife trade and rising demand for air travel all exacerbate the risk of pandemic outbreaks (Global Preparedness Monitoring Board, 2024[6]). The increasing occurrence of extreme weather events adds another layer of risk (Box 1.1). Recent evidence also shows that the number of human infections with highly pathogenic avian influenza viruses has been on the rise, raising concerns about the risk of another large-scale outbreak (Rolfes et al., 2025[7]).

Box 1.1. Extreme weather events are reshaping the landscape of communicable diseases

Extreme weather events create new pathways for diseases to emerge, spread and thrive

Extreme weather events such as heatwaves, heavy precipitation, prolonged droughts, wildfires and coastal flooding are becoming more frequent and intense worldwide, creating a more favourable environment for many diseases to flourish and expand their reach. One recent review showed that weather-related factors have aggravated 58% of all known communicable diseases that impact human health (218 out of 375 diseases) (Mora et al., 2022[8]). In Europe, nearly two-thirds of the pathogens affecting humans and domestic animals are shaped by climate conditions (McIntyre et al., 2017[9]). To name a few examples:

- **Warmer temperatures** led to an expansion in the distribution of many vectors in new geographic areas such as Lyme disease in Northern European (Estrada-Peña and Fernández-Ruiz, 2020[10]) and the West Nile virus in Europe (Semenza and Paz, 2021[11]) and increase the contamination of food with dangerous bacteria, such as salmonellosis across Europe, Australia and the United States (Morgado et al., 2021[12]; D'Souza et al., 2004[13]; Kovats et al., 2004[14]).
- **Extreme rainfall and flooding** can create new breeding sites for mosquitoes which can serve as habitats for vectors such as *Aedes aegypti*. Heavy precipitation and floods can overwhelm sanitation and sewage systems, washing pathogens from contaminated land and sewers into drinking water resources, rivers and recreational waters.
- **Warmer water temperatures** promote the growth and proliferation of many water-borne pathogens. Over the last 40 years, the portion of the Baltic and the United States Northeast coastlines suitable for *Vibrio* bacteria, increased from 47.5% to 86.3% (Romanello et al., 2022[15]).
- **Prolonged droughts** can also increase the risk by concentrating pathogens in smaller bodies of water and leading to unsafe water storage practices.

Vector and tick-borne diseases are becoming a more prominent source of infections in OECD and European countries

After decades of near absence, many vector and tick-borne diseases are gaining ground in Europe. France, Spain and Croatia have all reported locally acquired dengue or chikungunya infections since 2010. A central driver of these trends has been suggested to be warmer and wetter conditions that allow mosquito vectors to survive and breed in new geographic regions.

Source: More et al. (2022[8]), "*Over half of known human pathogenic diseases can be aggravated by climate change*", http://doi.org/10.1038/s41558-022-01426-1; McIntyre et al. (2017[9]), "*Systematic Assessment of the Climate Sensitivity of Important Human and Domestic Animals Pathogens in Europe*", http://doi.org/10.1038/s41598-017-06948-9; Estrada-Peña and Fernández-Ruiz (2020[10]), "*A Retrospective Assessment of Temperature Trends in Northern Europe Reveals a Deep Impact on the Life Cycle of Ixodes ricinus (Acari: Ixodidae)*", http://doi.org/10.3390/pathogens9050345; Semenza and Paz (2021[11]),*"Climate change and infectious disease in Europe: Impact, projection and adaptation",* http://doi.org/10.1016/j.lanepe.2021.100230; Morgado et al. (2021[12]), *"Climate change, extreme events, and increased risk of salmonellosis: foodborne diseases active surveillance network (FoodNet)*", http://doi.org/10.1186/s12940-021-00787-y; D'Souza et al. (2004[13]), "*Does Ambient Temperature Affect Foodborne Disease?*", http://doi.org/10.1097/01.ede.0000101021.03453.3e; Kovats et al., (2004[14]), "*The effect of temperature on food poisoning: a time-series analysis of salmonellosis in ten European countries*", http://doi.org/10.1017/s0950268804001992; Romanello et al. (2022[15]), "*The 2022 report of the Lancet Countdown on health and climate change: health at the mercy of fossil fuels*", http://doi.org/10.1016/s0140-6736(22)01540-9.

Despite the lessons of COVID-19, more needs to be done to strengthen pandemic preparedness and response (PPR) capacities around the globe (Box 1.2). Many countries have scaled back the funding available for strengthening their PPR capacity, with the global PPR spending standing at USD 230 billion in 2022 following its peak at USD 267 billion in 2021 (Penn et al., 2025[16]). Health systems around the globe continue to face chronic workforce shortages and underinvestment in surveillance of emerging health threats (OECD/European Commission, 2024[17]). Global supply chains for essential medical goods remain fragile (OECD, 2024[18]). The global architecture for health emergency prevention, preparedness and response remains underfunded and fragmented (WHO, OECD, WB, 2025[19]) and investments in research and development (R&D) for novel vaccines, diagnostics and treatments remain suboptimal, with the spending on global health R&D declining from USD 13 billion in 2021 to USD 10 billion in 2022 (Penn et al., 2025[16]).

Box 1.2. Global progress on pandemic preparedness and response since COVID-19

In the wake of the COVID-19 pandemic, a range of reflection processes provided important lessons to learn from the failures of the international response to the crisis and to increase resilience to future health shocks. Foremost among these has been the Independent Panel for Pandemic Preparedness and Response, which called for systemic reforms across the global health system and the G20 High Level Independent Panel on Financing the Global Commons for Pandemic Preparedness and Response, which focussed on filling an estimated USD 15 billion per year financing gap to strengthen surveillance, health systems, vaccine supply, and governance for health security, with the most significant gaps identified in the developing countries (G20 High Level Independent Panel, 2021[20]). In 2025, the COVID-19 Global Evaluation Coalition brought together evaluation units from countries, multilateral institutions, and United Nations organisations to generate evidence-based lessons and good practices for future global crises (OECD, 2025[21]).

These initiatives all underscored the need for improved international co-operation and co-ordination to deal with global health threats. In 2022, at the request of the G20, World Bank's Board of Directors establish the Pandemic Fund, the first multilateral financing mechanism dedicated exclusively to strengthening critical pandemic prevention, preparedness, and response capacities at the local,

regional, and global levels, with a focus on low- and middle-income countries. In recent years, the G20s Joint Finance-Health Task Force has requested international organisations to provide annual updates of the Global Report on the Framework for Health, Social and Economic Vulnerabilities and Risks Related to Pandemics, accompanied by an Operational Playbook for Pandemic Response Financing (a non-binding reference tool that aims to enhance the speed, scale, and co-ordination of financing for future pandemic responses) (FMCBG, 2025[22]). In 2025, under South Africa's G20 Presidency, the OECD, World Bank and World Health Organization also delivered a new report focussed on the sustainability of health and PPR financing, focussing on the urgent need for new and innovative funding sources in an era of increasing fiscal constraint and rapid decline in ODA financing (Penn et al., 2025[16]).

In May 2025, the World Health Assembly adopted the Pandemic Accord, opening the pathway for signature and ratification by member states. In addition, International Health Regulations amendments have now entered into force, recognising the increasing risks of infectious diseases and other public health risks and the need for improved international co-ordination (WHO, 2025[23]; WHO, 2025[24]).

Yet as highlighted in a new report by the G20 High Level Independent Panel, reconvened under South Africa's G20 Presidency, much work remains, including around improving the measurement and management of PPR financing going forward. In this context, the 2026 United Nations High-Level Meeting on Pandemic Prevention, Preparedness and Response will be critical in ensuring a renewed focus on agreeing and operationalising PPR reforms in an era of complex global challenges (G20 High-Level Independent Panel, 2025[25]).

Source: G20 High Level Independent Panel (2021[20]), "*A Global Deal for Our Pandemic Age: Financing the Global Commons for Pandemic Preparedness and Response"*, https://www.g20.utoronto.ca/2021/G20-HLIP-Report.pdf; OECD (2025[21]), *"Strategic Joint Evaluation of the Collective International Development and Humanitarian Assistance Response to the COVID-19 Pandemic*", http://doi.org/10.1787/680e2786-en; FMCBG (2025[22]), "*Finance Track Communiqué 3rd Finance Ministers & Central Bank Governors Meeting*", https://g20.org/g20-media/3rd-finance-ministers-central-bank-governors-meeting/; Penn et al. (2025[16]), "*Smart spending to combat global health threats: Tracking expenditure on prevention, preparedness, and response, and other global public goods for health*", http://doi.org/10.1787/166d7c57-en; WHO (2025[23]), "*Amended International Health Regulations enter into force*", https://www.who.int/news/item/19-09-2025-amended-international-health-regulations-enter-into-force; WHO (2025[24]), *"Pandemic prevention, preparedness and response agreement*", https://www.who.int/news-room/questions-and-answers/item/pandemic-prevention--preparedness-and-response-accord; G20 High-Level Independent Panel (2025[25]), *"Closing the Deal: Financing Our Security Against Pandemic Threats"*, https://nam.edu/pandemic-financing/.

This report aims to make a strong economic case for investing in the PPR capacity in 51 OECD, EU/EEA and G20 countries and beyond. This chapter brings together the key findings and policy recommendations of the report. It estimates the impact of COVID-19 on population health and healthcare systems, including its indirect influence on non-communicable diseases (NCDs) through lifestyle changes. It explores the risk of future pandemics, analysing potential outbreak scenarios using the OECD's Strategic Public Health Planning (SPHeP) model for PPR and evaluates the effectiveness of eight non-pharmaceutical interventions (NPIs). The chapter also highlights the role of wastewater surveillance as an early warning tool. It also compares PPR indices and emphasises the importance of national stockpiling. It concludes by estimating the investment needed to strengthen PPR capacities.

1.2. Taking stock of the impact of the COVID-19 pandemic on population health, healthcare systems and economies

1.2.1. The detrimental health impact of COVID-19 endures in many OECD countries

By the end of the emergency phase in May 2023, the COVID-19 pandemic had claimed nearly 7 million lives worldwide (WHO, 2026[3]). The human toll has translated into demographic impacts that persist to this day. In 2020, average life expectancy across the OECD fell by seven months, the steepest decline in decades (OECD, 2021[26]). By 2023, 13 OECD countries had yet to recover to pre-pandemic levels (OECD, 2025[27]). Moreover, the life expectancy loss across OECD countries, measured as the gap between the 2019 life expectancy level and the lowest level reached by each country during the pandemic years, was 0.9 years.

1.2.2. The COVID-19 pandemic shaped the longer-term trajectory of chronic diseases

The COVID-19 pandemic acted as both a stress test and a mirror for societies' health behaviours. For some, it reinforced positive habits, while for others, it deepened risk factors for NCDs. Changes in the risk factors combined with severe disruptions in screening, diagnosis and treatment have created the conditions for a possible rise in NCDs over the coming years (Xu et al., 2024[28]). The OECD analysed the potential indirect impact of COVID-19 in terms of the health and economic burden of NCDs (Box 1.3).

Box 1.3. From daily habits to hospital wards: How COVID-19 reshaped the NCDs burden

COVID-19 had mixed impacts on lifestyle factors that influence the burden of NCDs

The COVID-19 pandemic led to significant changes in some lifestyle-related risk factors associated with NCDs. On average across 28 OECD countries, the prevalence of tobacco use was around 10% higher than projections based on pre-pandemic linear trends, suggesting that COVID-19 slowed the decline in overall smoking prevalence. By contrast, in the same period and set of countries, overall per capita alcohol consumption was 4% lower than predicted. The impact on obesity is estimated to be marginal, less than 1% higher than expected on average, possibly due to the lag between changes in energy balance and observable weight shifts, compounded by the short assessment period.

COVID-19 disrupted nearly every step of the care pathway for patients with chronic conditions

Hospital admissions for life-threatening cardiovascular events plummeted in the early months of 2020, by an average of 26% for several cardiovascular conditions across 17 OECD countries and by an average of 24% for acute stroke in 11 OECD countries. Even when patients reached hospitals, care was often delayed. These interruptions carried heavy consequences. For example, mortality from heart attacks and strokes surged by around 45% in Spain (Rodríguez-Leor et al., 2020[29]), the United States (Mefford et al., 2021[30]) and Lithuania (Čelutkienė et al., 2022[31]).

Cancer care faced a similar collapse. Screening programmes were suspended in many OECD countries (Fujisawa, 2022[32]), cutting procedures by roughly 26% across 6 OECD countries over several months in 2020 compared to the prior year's levels. Cancer surgeries declined by around 15% across 5 OECD countries and waiting times lengthened as hospitals struggled with backlogs and staff shortages. Previous studies signalled a 26.5% decline in median overall survival among metastatic colorectal cancer patients in France from May to September 2020 (Thierry et al., 2021[33]) and by around three months for esophagogastric cancer patients from March to September 2020 in Scotland (Baxter et al., 2023[34]).

The SPHeP-NCDs model was used to quantify the long-term health and economic impacts of COVID-19 on NCDs

To capture the long-term consequences of COVID-19, the OECD modelled two hypothetical pandemic scenarios reflecting the changes in lifestyles and healthcare delivery. Both scenarios assume changes in exposure to key risk factors (i.e. tobacco use, alcohol consumption and obesity) and temporary declines in cancer survival. In the temporary shock scenario, these disruptions are short-lived: risk factors change through 2021, remain stable until 2023 and return to pre-pandemic levels by 2024. From a practical standpoint, this scenario implies that individuals who had altered their habits during the COVID-19 pandemic would revert to their previous lifestyles by 2024. The second scenario (i.e. a permanent shock) assumes persistent shifts: risk factors change through 2021 and remain permanently at that level through 2050, assuming that lifestyle changes adopted during the pandemic would persist throughout the duration of the simulation.

COVID-19 could have lingering impacts on the NCD burden, healthcare spending and the economy (Figure 1.1). In the short term (i.e. between 2020 and 2024), COVID-19-related lifestyle changes and temporary reductions in cancer survival are estimated to have reduced life expectancy and healthy life expectancy by 2.4 months and 2.5 months, respectively, across the 28 OECD countries analysed. This health burden translates into an average 0.4% increase in annual health expenditure and annual GDP losses of 0.1%.

Figure 1.1. Indirect health and economic impacts of COVID-19 on NCDs

Average per year over 2020-2024 (short-term impact) and 2025-2050 (long-term impact), 28 OECD countries included in the analysis

COVID-19 scenarios	Reduction in life expectancy (in months)	Reduction in healthy life expectancy (in months)	Additional health expenditure (as a share of total health expenditure)	Losses in gross domestic product (as a share of GDP)
Short-term impact	-2.4	-2.5	0.4%	-0.1%
Long-term impact from temporary shock	-0.2	-0.3	0.0%	0.0%
Long-term impact from permanent shock	-1.9	-2.4	0.6%	-0.2%

Note: The "short-term impact" estimates the NCD-related impact of COVID-19 over the period 2020-2024, assuming disruptions to several key risk factors and declines in cancer survival this time. The "long-term impact" estimates the NCD-related impact of COVID-19 over the period 2025-2050 under two scenarios, a "temporary shock" in which disruptions to risk factors are short-lived until 2024 and a "permanent shock" which assumes persistent shifts for the duration of the model to 2050. The temporary shock can be interpreted as a lower-bound approximation of the NCD-related impact of COVID-19, while the permanent shock can be interpreted as an upper-bound approximation.
Source: OECD analyses based on the OECD SPHeP-NCDs model.

In the long term (i.e. between 2025 and 2050), the detrimental impact of COVID-19 on health and the economy fades over time if risk factors and behaviours gradually return to pre-pandemic levels (i.e. the temporary shock scenario). However, if changes in risk factor prevalence levels observed during COVID-19 persist permanently, life expectancy could remain, on average, 1.9 months lower in 28 OECD countries by 2050 compared to a scenario where no COVID-19 occurred. Annual healthcare expenditure on NCDs could remain 0.6% higher, and GDP could be as much as 0.2% lower, each year, on average, across 28 OECD countries in 2025-2050.

Source: Rodríguez-Leor et al. (2020[29]), *"Impact of COVID-19 on ST-segment elevation myocardial infarction care. The Spanish experience"*, http://doi.org/10.1016/j.rec.2020.08.002; Mefford et al. (2021[30]), "*Rates of Acute Myocardial Infarction During the COVID-19 Pan*demic", http://doi.org/10.7812/TPP/21.074; Čelutkienė et al. (2022[31]), "*Collateral effect of the COVID-19 pandemic on cardiology service provision and cardiovascular mortality in a population-based study: COVID-COR-LT*", http://doi.org/10.1007/s00392-022-02033-y; Fujisawa et al. (2022[32]), "*Impact of the COVID-19 pandemic on cancer care in OECD countries*", http://doi.org/10.1787/c74a5899-en;Thierry et al. (2021[33]), "*Association of COVID-19 Lockdown With the Tumor Burden in Patients With Newly Diagnosed Metastatic Colorectal Cancer*", http://doi.org/10.1001/jamanetworkopen.2021.24483; Baxter et al. (2023[34]), *"Diagnosis, treatment, and outcome of patients with oesophagogastric cancer during the COVID-19 pandemic: national study*", http://doi.org/10.1093/bjs/znad003.

1.3. Future pandemics will carry a dual toll: Heavy loss of life and deep economic disruptions

To assess the potential health and economic consequences of future pandemics, the OECD SPHeP-PPR model simulates how diseases could spread across 51 OECD, EU/EEA and G20 countries (Box 1.4). The analysis period covers the first nine months of five simulated outbreaks where it is assumed that no effective pharmaceutical interventions or vaccines are available at scale.

Box 1.4. The SPHeP-PPR model quantifies the health and economic impact of pandemics

To better understand the health and economic impacts of pandemic outbreaks, the OECD developed the SPHeP-PPR model, a next-generation analytical framework that integrates epidemiological and macroeconomic modelling. The model builds on the classic infectious disease modelling approach, extending it to reflect the complexity of real-world outbreak dynamics.

It is country-specific and age-stratified and uses contact matrixes and spatial population density expressed in 5x5km grids, allowing detailed analyses of how a pathogen spreads through different population groups, how many individuals may become severely ill and how many lives could be lost. The model integrates each country's demographic profile and social contact patterns between people in various settings (e.g. school and work) (Centre for the Mathematical Modelling of Infectious Diseases COVID-19 Working Group, 2021[35]), providing a detailed picture of how infections could evolve and affect populations. Beyond tracking infections and deaths, the model incorporates health system capacity constraints including the number of available hospital beds and intensive care unit (ICU) resources. This enables assessment of how surges in healthcare demand evolve over time and whether health systems are likely to face bottlenecks. The model also allows assessing the impact of NPIs on health outcomes.

The OECD SPHeP-PPR model brings epidemiological, demographic, health system and economic information together within a single analytical framework, enabling consistent assessment of the potential consequences of outbreaks and of the containment measures taken in response. As with any model, it remains a simplification of real-world dynamics and the OECD estimates carry a degree of uncertainty. Observed impacts may vary more widely than the analysis suggests. the estimates presented throughout the report should be interpreted as indicative rather than precise. Realised impacts may prove more variable than projected.

To capture the economic dimension of pandemics, the OECD collaborated with the French Observatory of Economic Conjunctures (FOEC) at Sciences Po. The FOEC macroeconomic model translates the epidemiological outputs into economic shocks, tracing how disruptions in labour supply, production capacity and consumer demand propagate across sectors (Dauvin and Sampognaro, 2021[36]). This integrated approach captures both supply-side constraints (e.g. reduced workforce participation due to illness) and demand-side reactions (e.g. lower consumption during containment measures). The

economic impacts should be interpreted in the unique circumstances of each country's economic structure. The headline macroeconomic indicators may be influenced by a number of factors including sectoral concentration, export activity or the presence of multinational enterprises. As a result, estimated economic impacts may not fully capture changes in domestic economic welfare. Nevertheless, they provide a consistent basis for cross-country comparison. The economic estimates captured by the FOEC model should be considered as a conservative measure of the total economic loss, because the model does not capture the long-run loss of future output due to premature mortality.

Together, these linked models can assess the consequences of pandemics under different scenarios. The results offer a clearer picture of the co-benefits of protecting population health and the economy, helping countries plan more resilient and evidence-based responses for future outbreaks.

Source: Centre for the Mathematical Modelling of Infectious Diseases COVID-19 Working Group, 2021 (2021[35]), *"Projecting contact matrices in 177 geographical regions: An update and comparison with empirical data for the COVID-19 era"*, https://doi/org/10.1371/journal.pcbi.1009098; Dauvin and Sampograno (2021[36]), "*Dan les coulisses du confinement: modelisation de chocs simultanes d'offre et de demande. Une application au confinement du mois d'avril 2020 en France*", https://www.ofce.sciences-po.fr/pdf/dtravail/OFCEWP2021-05.pdf.

The pandemic scenarios were selected strategically to ensure they represent a spectrum of credible threats, making the findings directly applicable to real-world PPR efforts. A set of criteria guided the selection process. First, the pathogens modelled in each scenario align with pathogens identified by the WHO as having significant pandemic potential. Second, they reflect current and pressing policy concerns for OECD, EU/EEA and G20 countries, focussing on threats that are actively monitored (e.g. avian influenza). Third, each scenario is based on a foundation of high-quality scientific evidence, allowing for robust modelling of their distinct epidemiological characteristics.

The selected outbreak scenarios include:

- **An Ebola-like outbreak** represents a pathogen with lower transmission but extremely high severity, testing healthcare systems' ability to manage critical cases.
- **An avian influenza-like outbreak** models a new animal-to-human influenza strain with a high hospitalisation and case fatality rate.
- **An influenza A-like outbreak** simulates a highly transmissible but less severe flu virus, representing a classic fast-spreading pandemic.
- **A coronavirus-like outbreak** is a simulation of a novel coronavirus similar to SARS-CoV-2, characterised by asymptomatic spread and age-dependent severity.
- **A measles-like outbreak** is the most extreme scenario, featuring a hyper-infectious pathogen in a non-immune population, causing widespread severe illness.

Each scenario in the OECD model is based on the epidemiological characteristics of a real pathogen but the parameters are not meant to recreate those diseases exactly. Instead, they represent a set of plausible outbreak archetypes, ranging in how easily they spread, how severe they are and how much strain they place on health systems. Simulations were conducted on a naïve population, assuming no prior immunity to the diseases considered. This approach allows the model to explore the breadth of pandemic risks rather than replicating the trajectory of past outbreaks.

1.3.1. Unmitigated pandemics cause high mortality and overwhelm healthcare systems

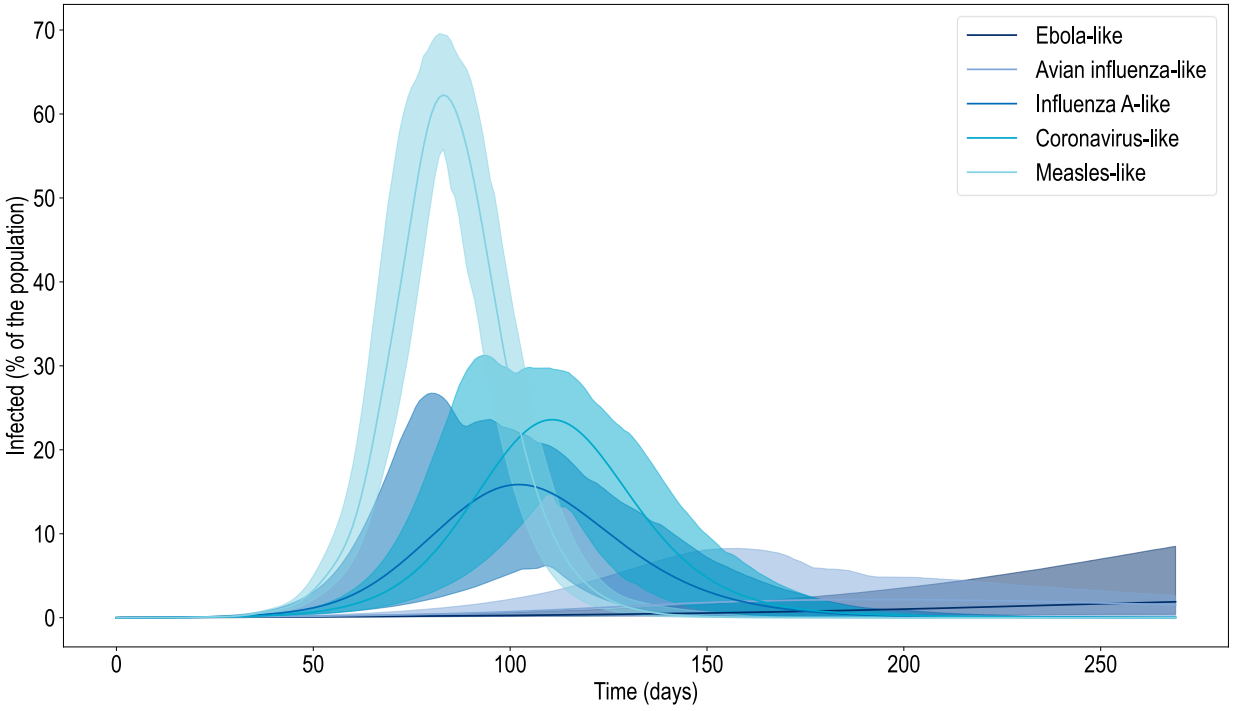
As the first step, the SPHeP-PPR model was used to model unmitigated outbreak scenarios, assuming no NPIs are implemented in the simulation period. An unmitigated pandemic is unlikely in the real world, as individuals and governments would inevitably react. This expectation is aligned with the evidence showing that people adapted their behaviours beyond legally mandated restrictions during the COVID-19 pandemic,

with observed behaviours correlating with local COVID-19-related mortality (Goolsbee and Syverson, 2021[37]). But modelling this "worst-case" approach establishes a baseline for understanding the magnitude of each threat and measuring the potential effectiveness of countermeasures. The unmitigated pandemic scenarios also function as a stress test for healthcare systems, identifying breaking points and vulnerabilities in a simulated environment.

The results of the modelling exercise reveal the severe consequences of unchecked pandemics, showing markedly different trajectories depending on the pathogen's characteristics and country-specific factors such as demographic composition. Some of the key results for the 51 countries included in the analysis include:

- In any unmitigated scenario, a significant portion of the population becomes infected, with the progression of the outbreak depending on the pathogen's transmissibility and population characteristics (Figure 1.2). A measles-like pathogen represents the worst-case scenario, reaching its peak in just 83 days and infecting 62% of the population. At the other extreme, an Ebola-like outbreak would be a slow-burning crisis, without peaking within nine months of its onset. All other scenarios fall in between these extremes.

Figure 1.2. How a pandemic unfolds in the case of unmitigated response depends on the pathogen and population characteristics



Note: The figure presents the cross-country average across the 51 OECD, EU/EEA and G20 countries included in the analysis, with the shaded areas indicating cross-country variability range. Evolution of the pandemic is expressed in days. Each outbreak is simulated to last for 9 months.
Source: Results from the SPHeP-PPR model.

- The different pandemic trajectories translate directly into vastly different mortality rates across countries. The measles-like scenario is by far the most devastating, with a projected mortality rate approaching 20% of the entire population. This finding suggests that a hyper-infectious agent such as the one in the measles-like scenario spreads so fast that it infects a huge portion of the population. As a result, the sheer number of cases drives the high death toll. In comparison, the

death toll of an extremely lethal agent, such as the one in the Ebola-like outbreak, could yield a lower number of deaths at around 3.4% of the population dying because it spreads more slowly. A highly transmissible influenza A-like outbreak, while less lethal, would still result in a staggering death toll of 4-5% of the population. The other scenarios produce more varied but still severe outcomes.

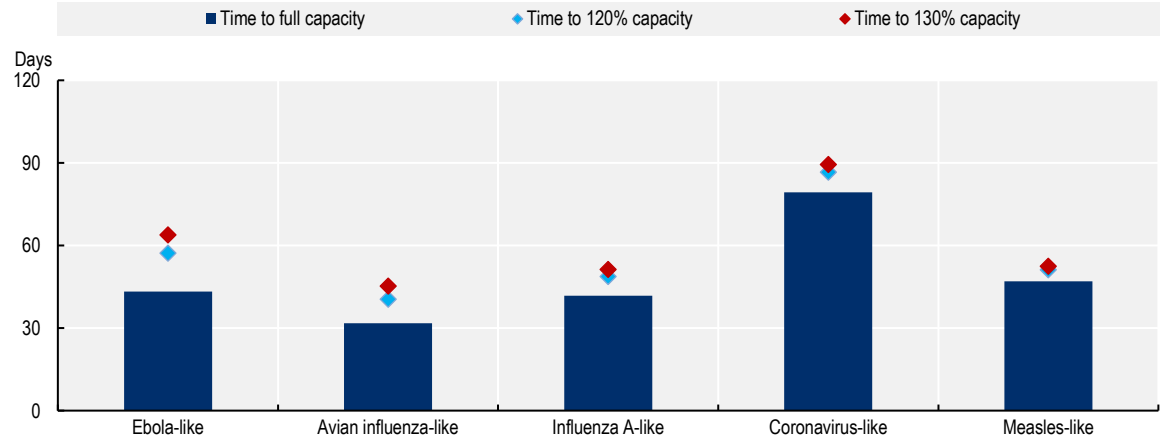
In an unmitigated context, all outbreak scenarios place immense, unsustainable pressure on healthcare systems in the 51 countries included in the analysis, though the speed of collapse differs considerably as follows (Figure 1.3):

- In each outbreak scenario, ICU capacity across the OECD countries would be exhausted within as little as 9 to 139 days, depending on the scenario. Outbreaks caused by highly transmissible influenza strains would be among the most dangerous. On average, ICU beds would reach full capacity in a little over a month in an avian influenza scenario and in around 42 days for an influenza A-like outbreak.
- In a measles-like scenario, ICUs in the OECD would still face saturation within around six weeks (47 days on average). A coronavirus-like outbreak would place health systems under less immediate strain, but ICU beds would still reach full capacity in roughly 80 days on average.

Even a 130% surge in ICU bed capacity, an extraordinary effort, would only slightly extend the healthcare systems' ability to manage the simulated outbreaks, by approximately an additional 5.5 to 20.6 days compared to the baseline 100% capacity scenario, depending on the outbreak. Regardless of the timing, once ICUs are full, mortality rises for all patients needing critical care.

Figure 1.3. All unmitigated outbreak scenarios place immense pressure on healthcare systems

Average number of days it takes to reach ICU capacity in the OECD, unmitigated pandemics



Note: The figure above shows the average number of days required to reach full, 120% and 130% hospital capacity across OECD countries included in the analysis under a given outbreak scenario (e.g. a value of 43.3 in the Ebola-like outbreak scenario means it would take on average 43.3 days to reach 100% ICU capacity during an Ebola-like outbreak in OECD countries). Each outbreak is simulated to last for 9 months.
Source: OECD analysis based on the OECD SPHeP-PPR model.

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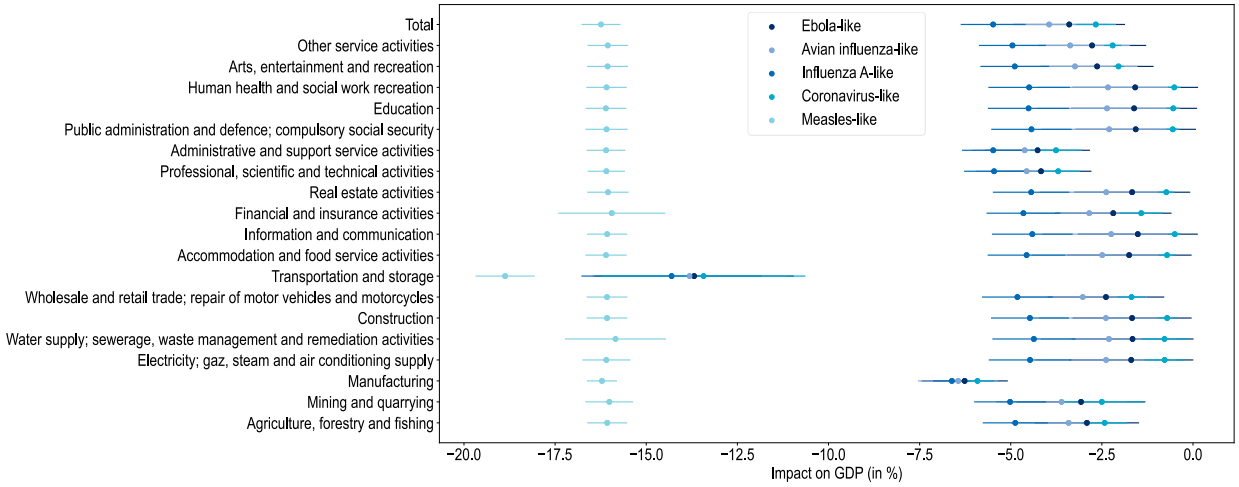
Findings from this analysis confirm that surge capacity can provide temporary relief but cannot compensate for the rapid spread of a fast-moving pathogen. Therefore, mitigation of the spread is the only viable strategy to avoid the collapse of healthcare systems.

1.3.2. When health systems are overwhelmed, economies stumble

The economic fallout of an unmitigated pandemic could be severe. OECD analysis suggests that during the first nine months of an unmitigated outbreak, GDP could fall, on average, between 2.7% and 16.2%, depending on the scenario across the 50 countries included in the analysis (Figure 1.4). The most devastating scenario would be a measles-like outbreak, which would trigger an economic collapse across nearly all sectors, with output contracting by around 16% or more. In comparison, a coronavirus-like outbreak would produce a milder but still significant contraction of around 2.7% on average. Other outbreak scenarios, such as those driven by Ebola-like or influenza A-like pathogens, would fall between these extremes, leading to average GDP declines of 3.4% to 5.5%.

Figure 1.4. If no action is taken during a pandemic, the economy takes a major hit

Percentage of GDP contracted by sectors under each pandemic scenario



Note: The figure presents the average drop in GDP by sectors across the 50 OECD, EU/EEA and G20 countries included in the analysis.
Source: Analysis based on the SPHeP-PPR and the FOEC models.

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Pandemic shocks ripple unevenly across sectors depending on how exposed they are to demand and supply disruptions (Figure 1.4). The economic output of sectors that depend on physical proximity or discretionary spending (e.g. transport) is hit the hardest. Transport and storage would face the steepest losses, with output falling between 13.4% and 18.9%, depending on the outbreak, while manufacturing would contract by between 5.9% and 16.2% as global supply chains stall. Administrative and support services and professional, scientific and technical activities would also experience deep downturns, shrinking by 4% to almost 6% in milder scenarios and up to 16% in the most severe. These losses reflect not only collapsing demand as households cut spending and mobility declines, but also the cascading impacts of supply shortages and bottlenecks in production.

By contrast, sectors that deliver essential services or those that can operate remotely seem to be more insulated from immediate shocks. In most scenarios, service-based sectors such as education, health and social care, public administration and information and communication would see modest contractions: typically between 0.5% and 4.5% for education and health and 1.5% to 4.4% for public administration and information services. Yet even these sectors are not immune to severe outbreaks. In a measles-like outbreak, these sectors would suffer double-digit declines, with activity dropping by around 16%, highlighting that when a pandemic grows large enough, its economic reach becomes truly universal.

1.4. Targeted non-pharmaceutical interventions protect population health and economies in the early days of pandemics

NPIs refer to a set of public health measures aiming to contain the spread of disease outbreaks. Effective implementation of NPIs is especially important during the early phases of disease outbreaks when pharmaceutical interventions/vaccines may not be readily available at scale or when there is uncertainty about their effectiveness. Broadly, NPIs can curb the spread of infections either by reducing person-to-person contacts (e.g. by promoting teleworking) or by making contacts safer (e.g. by promoting the use of face masks).

NPIs have long been part of the public health responses to outbreaks. Before COVID-19, NPIs played a key role in containing the 2003 SARS outbreak, the 2009 H1N1 influenza pandemic and the 2012 MERS-CoV epidemic. Yet it was the COVID-19 pandemic that brought these measures into unprecedented focus, testing their effectiveness, limits and their cost to the broader economy. Countries adopted widely different combinations of NPIs including physical distancing, community-based infection prevention and control (IPC) measures such as hand hygiene, mask wearing and respiratory etiquette. Some governments imposed strict nationwide restrictions, while others relied more heavily on voluntary compliance and community engagement. Regardless of the combination of NPIs implemented, it is generally understood that NPIs are most effective when rolled out as a policy package rather than as single interventions, especially when community transmission is high (Rizvi et al., 2021[38]).

The OECD modelled the effectiveness of eight NPIs that can help limit the health and economic impacts of pandemic outbreaks (Table 1.1). These NPIs were selected based on three main criteria: they align with international guidelines on supporting PPR; they were widely implemented across OECD countries during the COVID-19 pandemic; and there is robust, high-quality evidence available to inform their modelling and assessment. The analysis concentrates on how these interventions mitigate transmission within communities rather than their potential role in preventing cross-border spread.

Table 1.1. Summary of key characteristics of the NPIs included in the OECD analysis

Intervention	Level of intervention				Intervention is activated when at least one of the thresholds below is reached	Key characteristics
	L1	L2	L3	L4		
Community-based IPC measures					• 10% of hospital beds that were unused at the beginning of the simulation become occupied by patients or • 1 death per 100 000 population or • 0.5% infection rate *(wastewater-based surveillance)*	• Community-based IPC measures are generally considered an effective tool to tackle infections • High compliance in the general public is crucial to generate substantial benefits to the economy
Voluntary quarantine measures						• Voluntary quarantine refers to recommendations for symptomatic individuals to limit contact with others for a specified period
Teleworking policies					• 30% of hospital beds that were unused at the beginning of the simulation become occupied by patients or • 2.5 deaths per 100 000 population or • 1% infection rate *(wastewater-based surveillance)*	• Teleworking helps curb the spread of an outbreak by limiting employee commuting • Teleworking was effective in curbing the spread of SARS-CoV-2 infections and has been instrumental in lifting physical distancing measures without inducing a rise in the number of new cases (Burzyński et al., 2021[39]).
Domestic travel restrictions						• Domestic travel restrictions have emerged as important means to control the spread of outbreaks • They help delay the spread of pathogens from geographic areas with high transmission rates to other areas with lower transmission

Intervention	Level of intervention				Intervention is activated when at least one of the thresholds below is reached	Key characteristics
	L1	L2	L3	L4		
Mandatory quarantine measures						• Mandatory quarantine refers to the requirements for symptomatic individuals to isolate themselves for a fixed period.
Temporary school closures					• 60% of hospital beds that were unused at the beginning of the simulation become occupied by patients or • 5 deaths per 100 000 population or • 2% infection rate *(wastewater-based surveillance)*	• Closing schools can prevent transmission between infected and susceptible children/school staff • School closures reduce R_0 by 39-73% (Mendez-Brito, El Bcheraoui and Pozo-Martin, 2021[40])
International travel restrictions						• International travel restrictions, including quarantines when entering a country and border closures, have been frequently used to slow the spread of the outbreak across countries
Lockdown only					• 90% of hospital beds that were unused at the beginning of the simulation become occupied by patients or • 10 deaths per 100 000 population or • 5% infection rate *(wastewater-based surveillance)*	• Lockdowns refer to a set of measures aimed to maintain a physical distance between people • Physical distancing measures were associated with 37-88% reductions in R_0, 44-96% reduction in the incidence of SARS-CoV-2 and 31-76% reduction in attributable mortality (Nussbaumer-Streit et al., 2020[41])

Notes: IPC = infection prevention and control; R_0 = basic reproduction number; L = level.
"Safer contact" package
"Reduced contact" package
"Targeted closures and restrictions" package
"Lockdown alone" package
Source: Based on a comprehensive review of the available evidence by the OECD.

During the COVID-19 pandemic, many OECD countries introduced COVID-19 alert systems to help monitor outbreak trends and guide the policy decisions around the implementation of NPIs (OECD, 2021[42]). These alert systems differed in the indicators they used and the policy triggers. Many alert systems relied on a mix of indicators such as COVID-19 incidence, hospital admission rates, ICU capacity and deaths to inform policy decisions related to implementing NPIs (Yang et al., 2021[43]). For example, New Zealand, South Africa and the United Kingdom implemented national frameworks with three to five alert levels that combined data on infections, hospitalisations, deaths and healthcare capacity (UK Health Security Agency, 2022[44]; Resolve to Safe Lives, 2020[45]). South Africa's system integrated economic and health considerations whereas New Zealand focussed primarily on public health.

Reflecting the scientific evidence and real-world experiences, the OECD analysis grouped the NPIs into four escalating levels, shown in colour patterns, according to the degree of disruption imposed on daily life and mobility (Table 1.1). The "Safer contact" package (level 1, green) includes community-based IPC measures such as hand hygiene, mask wearing and indoor ventilation, as well as voluntary quarantines. The "Reduced contact" package (level 2, orange) entails the implementation of "Safer contact" measures and introduction of restrictions on physical interactions with greater stringency through measures such as promoting teleworking and limiting domestic travel to essential needs. Quarantines are now assumed mandatory. The "Targeted closures and restrictions" package (level 3, blue) includes all "Reduced contact" interventions and extends restrictions to include school closures and the closure of borders. Finally, the "Lockdown alone" package (level 4, red) represents the most stringent level of interventions with strict enforcement of lockdowns that impose severe limitations on mobility. For comparison, the OECD analysis also looks at the marginal impact of adding lockdowns on top of the less stringent interventions.

The ordering of interventions from Level 1 through Level 4 reflects the degree of disruption posed by each NPI, which is understood as the combination of how far a measure restricts daily activities and mobility. It

mirrors the sequence in which countries typically escalated NPIs during the COVID-19 pandemic (Hale et al., 2021[46]). A higher level denotes a more restrictive measure, not necessarily one with a greater impact on transmission. Because the measures are applied cumulatively across levels, the effectiveness of a given level is not a single pre-specified value but the combined effect of all measures active at that level.

The intervention thresholds are illustrative modelling parameters and they were chosen to implement a consistent escalation rule across the analysis. Applying identical thresholds to every scenario ensures that variation in outcomes is attributable to the epidemiological characteristics of each pathogen and to the properties of the NPIs rather than to the decision rule itself. The thresholds draw on empirical experience and policy practice, but they are not intended to be interpreted as empirically validated operational triggers. Their application in a given national context would require validation against the pathogen's characteristics, health system capacity and prevailing policy objectives.

The OECD analysis also assumes that the implementation of the selected NPIs is informed by wastewater-based surveillance, which emerged as a powerful tool for monitoring of infections in the community (Box 1.5).

Box 1.5. Wastewater surveillance can enable early action, bolstering the effectiveness of disease surveillance systems and the implementation of NPIs

Disease surveillance and early warning systems are a foundational pillar for effective PPR. Countries were already transitioning from paper-based to digital platforms before COVID-19. The pandemic accelerated this shift, spurring the adoption of big data and artificial intelligence to forecast outbreaks and monitor population mobility (WHO, 2023[47]).

During the COVID-19 pandemic, wastewater surveillance emerged as effective strategy to support the clinical-based surveillance efforts

As many pathogens are excreted in bodily fluids before or during infection, testing wastewater for biological or chemical markers can reveal the presence of disease in a community long before cases appear in clinical settings. Prior to COVID-19, wastewater surveillance was used to detect "silent" transmission of polio in Israel (Bonanno Ferraro et al., 2021[48]) and norovirus in Sweden (Hellmér et al., 2014[49]). During COVID-19, SARS-CoV-2 was detected in Italy's sewage systems weeks before the first confirmed cases were reported (La Rosa et al., 2021[50]).These findings demonstrate that wastewater surveillance can serve as an early warning system for disease transmission within communities, enabling policymakers to take timely and targeted action. This proactive approach supports the implementation of less restrictive interventions, yielding substantial benefits for both public health and the economy.

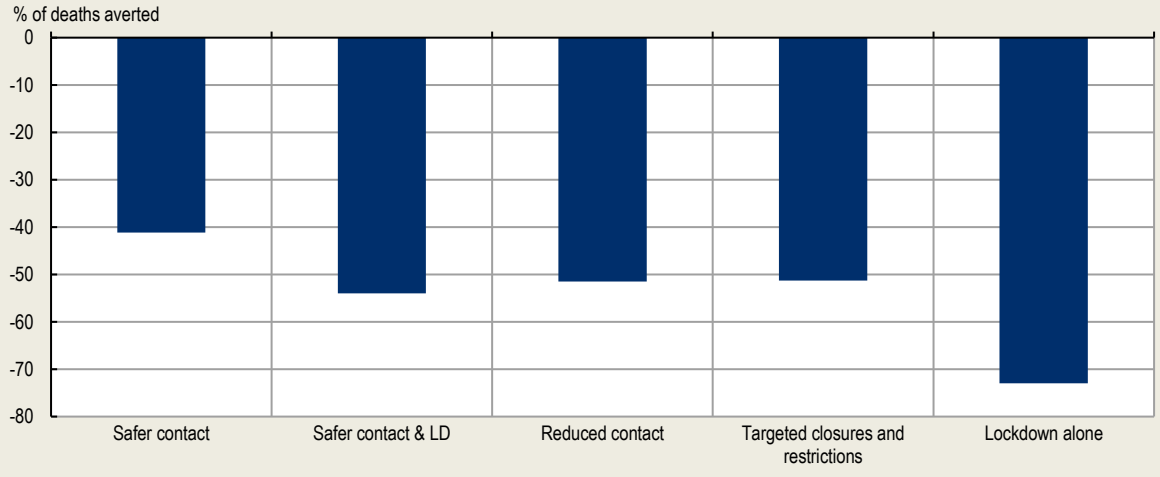
It is important to note that wastewater surveillance is subject to important limitations. Viral signals indicate the trends in transmission but translate poorly into case numbers (Wang et al., 2026[51]; Li et al., 2021[52]). Because signals are aggregated across a catchment area, they cannot identify infected individuals or be readily disaggregated by age, risk group or setting. This limitation makes wastewater surveillance a complement to, rather than a substitute for, clinical surveillance (National Academies of Sciences, Engineering, and Medicine, 2023[53]). Sensitivity falls when a disease is rare or a sewer network serves a large population (Ahmed et al., 2022[54]). In the absence of standardised protocols, results are difficult to compare across sites and laboratories (Davis et al., 2023[55]; Wilhelm et al., 2023[56]; Aßmann et al., 2025[57]). The wastewater surveillance requires connection to centralised sewer infrastructure such that unconnected populations fall outside monitored catchments (Li et al., 2021[52]; Shrestha et al., 2021[58]).

Considering the real-world experiences with wastewater surveillance, the OECD assessed the potential impact of integrating wastewater surveillance as part of efforts to strengthen PPR capacity across 51 OECD, EU/EEA and G20 countries. The effectiveness of each NPI level was assessed under two surveillance approaches. In the clinical surveillance-based approach, the model incorporated clinical surveillance data only, using the preceding three days of reported hospitalisations and mortality to project outcomes over the subsequent two weeks. This approach is similar to those used by OECD countries (Yang et al., 2021[43]). In the wastewater-based approach, the same forecasting framework was applied, but projections were also informed by wastewater surveillance which sheds light onto the number of infections in the community.

The OECD analysis suggests that wastewater surveillance can strengthen the protective impacts of NPIs and lockdown policies (Figure 1.5). In a coronavirus-like outbreak, using wastewater surveillance to guide the implementation of the "Safer contact" package could prevent around 41% of deaths that would have otherwise occurred under the clinical surveillance-based approach. The benefits would further increase under the "Reduced contact" package, with averted deaths reaching 51%. Even the "Lockdown alone" package alone would become markedly more effective when supported by wastewater surveillance, averting around 73% of deaths that would have occurred when lockdowns are guided only by the clinical surveillance-based approach. Several factors likely contribute to these outcomes, with a central one being the enhanced ability of policymakers to anticipate the epidemic's trajectory and apply targeted interventions. Early implementation of measures, before the outbreak reaches exponential growth, helps contain its spread more effectively. Likewise, timely data enables earlier relaxation of restrictions, reducing the duration of societal and economic constraints.

Figure 1.5. Wastewater surveillance accentuates the protective impacts of NPIs in a coronavirus-like outbreak

Share (%) of deaths averted by clinical surveillance coupled with wastewater surveillance that would have otherwise occurred using clinical-surveillance based alone, by levels of NPI package, during a coronavirus-like outbreak



Notes: "Safer contact" package = community-based IPC and limited quarantine measures; "Safer contact" package & LD ("Safer contact" package with lockdown) = community-based IPC, voluntary quarantine measures and lockdowns. "Reduced contact" package = community-based IPC, mandatory quarantine measures, promoting teleworking and introducing restrictions on domestic travel; "Targeted closures and restrictions" package = community-based IPC, mandatory quarantine measures, promoting teleworking, introducing restrictions on domestic travel, school closures and international travel restrictions. "Lockdown alone" package severely limits mobility, permitting movement only

for essential workers. In the coronavirus outbreak, lockdowns are not triggered once the "Reduced contact" package is in place. This is because once these interventions are activated, the simulated outbreaks never reach the threshold values listed earlier to trigger lockdowns.
Source: Analysis is based on the OECD SPHeP-PPR model.

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As NPIs become more effective when their implementation is guided by wastewater surveillance, the need for prolonged lockdowns declines sharply. In all three outbreaks caused by respiratory pathogens, integrating wastewater surveillance to the layered implementation of NPIs including up to the "Targeted closures and restrictions" package reduces the strain on population and healthcare systems to such an extent that policymakers might no longer need to rely on lockdowns to control the spread of the disease. Only in Ebola-like and measles-like outbreaks would policymakers still need to consider adding lockdowns to the "Targeted closures and restrictions" package, depending on their health objectives and healthcare system capacity. Even then, the number of days that would need to be spent in lockdowns would be reduced by upwards of 90% compared with implementing these interventions based solely on data gathered through clinical surveillance only.

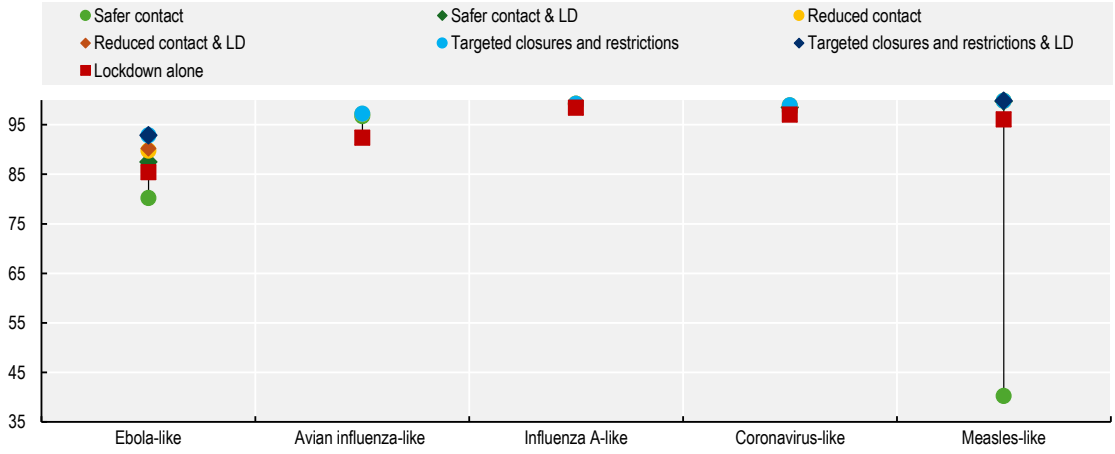
Source: WHO (2023[47]), "*Future surveillance for epidemic and pandemic diseases: a 2023 perspective*", https://www.who.int/publications/i/item/9789240080959; Boanno Ferraro et al. (2021[48]), "*A State-of-the-Art Scoping Review on SARS-CoV-2 in Sewage Focusing on the Potential of Wastewater Surveillance for the Monitoring of the COVID-19 Pandemic*", http://doi.org/10.1007/s12560-021-09498-6; Hellmér et al. (2014[49]), "*Detection of Pathogenic Viruses in Sewage Provided Early Warnings of Hepatitis A Virus and Norovirus Outbreaks*", http://doi.org/10.1128/aem.01981-14; La Rosa et al. (2021[50]), "*SARS-CoV-2 has been circulating in northern Italy since December 2019: Evidence from environmental monitoring*", http://doi.org/10.1016/j.scitotenv.2020.141711; Wang et al. (2026[51]), "*From wastewater to epidemiological insights: A systematic review of modelling strategies for infectious disease surveillance*", http://doi.org/10.1016/j.watres.2025.124977; Li et al. (2021[52]), "*Uncertainties in estimating SARS-CoV-2 prevalence by wastewater-based epidemiology*", http://doi.org/10.1016/j.cej.2021.129039; National Academies of Sciences, Engineering, and Medicine (2023[53]), "*Wastewater-based Disease Surveillance for Public Health Action*", https://www.nationalacademies.org/projects/DELS-WSTB-21-02/publication/26767; Davis et al. (2023[55]), "*Evaluation of intra- and inter-lab variability in quantifying SARS-CoV-2 in a state-wide wastewater monitoring network*", http://doi.org/10.1039/d2ew00737a; Wilhelm et al. (2023[56]), "*Interlaboratory comparison using inactivated SARS-CoV-2 variants as a feasible tool for quality control in COVID-19 wastewater monitoring*", http://doi.org/10.1016/j.scitotenv.2023.166540; Aßmann et al. (2025[57]), "*Augmentation of wastewater-based epidemiology with machine learning to support global health surveill*ance", http://doi.org/10.1038/s44221-025-00444-5; Shrestha et al. (2021[58]), "*Wastewater-Based Epidemiology for Cost-Effective Mass Surveillance of COVID-19 in Low- and Middle-Income Countries: Challenges and Opportunities",* http://doi.org/10.3390/w13202897; Yang et al. (2021[43]), "*Design of COVID-19 staged alert systems to ensure healthcare capacity with minimal closures*", http://doi.org/10.1038/s41467-021-23989-x.

1.4.1. Lockdowns are the last-resort measures for achieving health and economic goals but can be avoided with robust and timely implementation of less restrictive measures

Lockdowns are a last-resort intervention that can be used to mitigate uncontrolled epidemics, but they represent one of the least efficient approaches. When used alone, lockdowns (the "Lockdown alone" package) yield the smallest reductions in mortality in most scenarios except in Ebola-like and measles-like outbreaks where lockdowns could save more lives than introducing community-based IPC measures and voluntary quarantines (the "Safer contact" package) alone. But in all outbreak scenarios, introducing lockdowns alone would fall short of the health gains that could be achieved through the timely implementation of the "Reduced contact" package (Figure 1.6). In most outbreak scenarios, adding lockdowns on top of the NPI packages (i.e. up to the "Targeted closures and restrictions" package) offers only marginal health gains.

Figure 1.6. Early and well-implemented NPIs save lives

Percentage of averted deaths that would have occurred in uncontrolled pandemic scenarios, by level of intervention



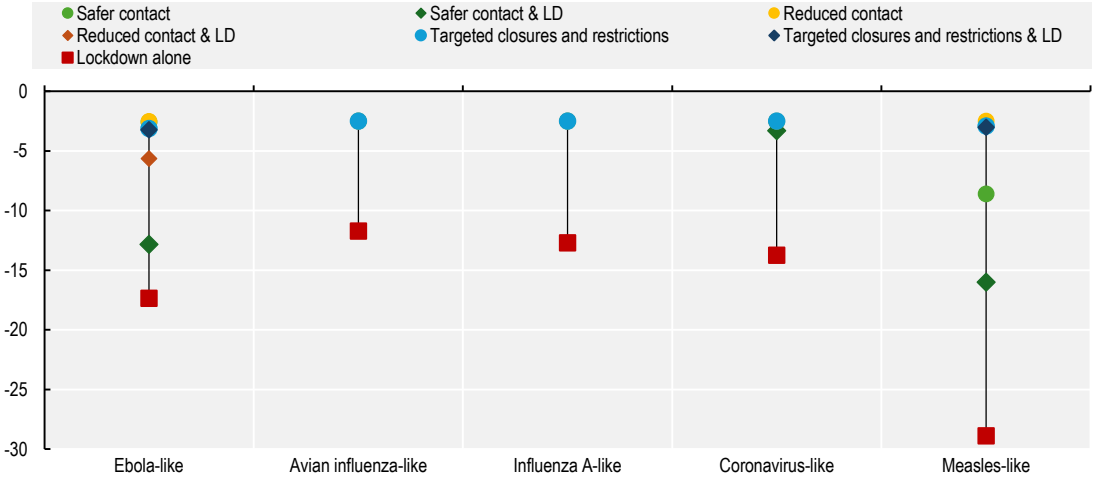
Notes: "Safer contact" package = community-based IPC and limited quarantine measures; "Safer contact" package &LD ("Safer contact" package with lockdown) = community-based IPC, voluntary quarantine measures and lockdowns. "Reduced contact" package = community-based IPC, mandatory quarantine measures, promoting teleworking and introducing restrictions on domestic travel; "Reduced contact" package &LD ("Reduced contact" package with lockdown) = community-based IPC, mandatory quarantine measures, promoting teleworking and introducing restrictions on domestic travel and lockdowns; "Targeted closures and restrictions" package = community-based IPC, mandatory quarantine measures, promoting teleworking, introducing restrictions on domestic travel, school closures and international travel restrictions. "Targeted closures and restrictions" package &LD ("Targeted closures and restrictions" package with lockdown) = community-based IPC, mandatory quarantine measures, promoting teleworking, introducing restrictions on domestic travel, school closures and international travel restrictions and lockdowns. "Lockdown alone" package severely limits mobility, permitting movement only for essential workers. In the OECD analysis, the lockdowns were not triggered in avian influenza-like and influenza A-like outbreak scenarios once the "Safer contact" package is implemented and in the coronavirus outbreak once the "Reduced contact" package is in place. This is because once these interventions are activated, the simulated outbreaks never reach the threshold values listed earlier to trigger lockdowns.
Source: Analysis is based on the OECD SPHeP-PPR model.

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Using lockdowns as a last resort comes with steep economic costs. When implemented alone, lockdowns are associated with an 11.7% reduction in GDP in an avian influenza-like outbreak and up to 28.9% in a measles-like outbreak over the 9-month simulation period (Figure 1.7). In most cases, layering lockdowns on top of the modelled interventions further deepens the economic losses. Adding lockdowns to the "Safer contact" package, for example, raises GDP contractions from 2.6% to 12.8% in an Ebola-like outbreak and from 8.6% to 16% in a measles-like outbreak. In every outbreak scenario, lockdown-only policies reduce economic output more than an unmitigated pandemic.

Figure 1.7. NPIs reduce the steep economic impact of outbreaks

Percentage drop in GDP under each outbreak scenario, by level of intervention



Notes: "Safer contact" package = community-based IPC and limited quarantine measures; "Safer contact" package &LD ("Safer contact" package with lockdown) = community-based IPC, voluntary quarantine measures and lockdowns. "Reduced contact" package = community-based IPC, mandatory quarantine measures, promoting teleworking and introducing restrictions on domestic travel; "Reduced contact" package &LD ("Reduced contact" package with lockdown) = community-based IPC, mandatory quarantine measures, promoting teleworking and introducing restrictions on domestic travel and lockdowns; "Targeted closures and restrictions" package = community-based IPC, mandatory quarantine measures, promoting teleworking, introducing restrictions on domestic travel, school closures and international travel restrictions. "Targeted closures and restrictions" package &LD ("Targeted closures and restrictions" package with lockdown) = community-based IPC, mandatory quarantine measures, promoting teleworking, introducing restrictions on domestic travel, school closures and international travel restrictions and lockdowns. "Lockdown alone" package severely limits mobility, permitting movement only for essential workers. In the OECD analysis, the lockdowns were not triggered in avian influenza-like and influenza A-like outbreak scenarios once the "Safer contact" package is implemented and in the coronavirus outbreak once the "Reduced contact" package is in place. This is because once these interventions are activated, the simulated outbreaks never reach the threshold values listed earlier to trigger lockdowns.
Source: Analysis is based on the OECD SPHeP-PPR model.

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1.4.2. Community-based IPC measures are the first line of defence during outbreaks

Early and well-implemented NPIs can markedly reduce the mortality burden of the pandemic. The least stringent NPI package, "Safer contact", which involves community-based IPC measures and voluntary quarantines alone, could avert on average 80% of deaths that would have occurred in an uncontrolled Ebola-like outbreak assuming they are implemented early and effectively, suggesting that these measures provide the foundation for an effective pandemic response and need to be implemented promptly (Box 1.6). In outbreaks caused by agents similar to avian influenza, influenza A and coronavirus, implementing the "Safer contact" package alone would help avoid the vast majority of deaths. But when the disease transmission is high, solely relying on these measures does not suffice. This would be the case in a measles-like outbreak, where the "Safer contact" package alone would avert only around 40% of deaths that would have occurred in an unchecked outbreak (Figure 1.6).

Box 1.6. Community-based IPC measures are the first line of defence during pandemics

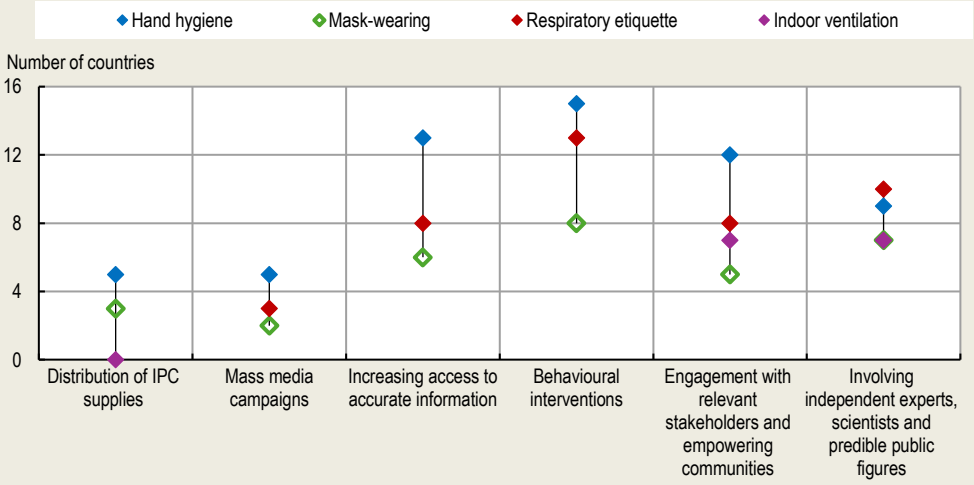
The importance of community-based IPC measures is widely recognised but there are crucial gaps in their timely implementation

The COVID-19 pandemic put a spotlight on community-based IPC measures as a crucial strategy to curb the spread of outbreaks. The 2023-2024 OECD survey on Maintaining IPC Measures in the Community gathered information on 4 community-based IPC measures: i) hand hygiene, ii) respiratory etiquette, iii) mask wearing and iv) indoor ventilation. A total of 24 countries, including 22 OECD Member countries and 2 accession countries participated in the survey.

The 2023-2024 OECD survey showed that all 24 corresponding countries promoted hand hygiene, mask-wearing, respiratory etiquette and indoor ventilation during the COVID-19 pandemic. Today, most OECD Members and accession countries that participated in the OECD survey recognise the vital role of community-based IPC measures but there are important gaps in their implementation.

In general, countries report higher activity in educational campaigns and behavioural interventions in public spaces, such as visual cues (Figure 1.8). Many also engage relevant stakeholders including, for example, local communities and experts, to ensure programmes are evidence-based and effectively implemented. In contrast, fewer countries report action on distributing IPC supplies and conducting mass media campaigns. Overall, interventions promoting hand hygiene appear more common than those encouraging mask use or respiratory etiquette. In fact, across various questions, countries were twice as likely to report hand hygiene initiatives compared to other policy areas. The only exception is expert involvement, which shows similar levels of engagement across all three areas.

Figure 1.8. Following COVID-19, OECD Members and partners rely frequently on educational campaigns and behavioural interventions to promote community-based IPC measure



Notes: No data reported on the distribution of IPC supplies relevant to respiratory etiquette. No data reported on mass media campaigns, access to accurate information, behavioural interventions for indoor ventilation. IPC = infection prevention and control.
Source: Country self-assessment responding to the 2023-2024 OECD survey on Maintaining Infection Prevention and Control Measures in the Community OECD.

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The “Safer contact” package also helps avoid the deeper contractions in the economy associated with unmitigated outbreaks. On average, the GDP losses associated with the “Safer contact” package alone remain moderate: from around 2.5% in a coronavirus-like outbreak to 8.6% in a measles-like outbreak (Figure 1.7). In all outbreak scenarios, introducing the “Safer contact” package could help reduce the detrimental impact of an unmitigated outbreak on the economy.

1.4.3. In many cases, a layered approach to implementing NPIs protects population health without adding substantial strain on the economy

Adding teleworking, domestic travel limitations and mandatory quarantines (the “Reduced contact” package) delivers substantial health and economic benefits in certain outbreak contexts. In an Ebola-like outbreak, for example, this layered approach could avert up to 90% of deaths compared with about 80% under the “Safer contact” package alone. This approach also helps cushion economic losses. The average decline in GDP would ease slightly from 2.6% to 2.5% in Ebola-like, from just over 2.5% to just below 2.5% in a coronavirus-like and from 8.6% to 2.5% in measles-like outbreaks compared with the “Safer contact” package alone (Figure 1.7). The potential economic gains would be more modest in avian influenza-like and influenza A-like outbreaks.

1.4.4. School closures and international travel restrictions can be avoided

Closing schools and restricting international travel (the “Targeted closures and restrictions” package) add little to the health gains already achieved through less stringent NPIs once the outbreak is already established within the country. In most outbreak scenarios, these stricter policies prevent less than 1% of additional deaths (Figure 1.6). Even in an Ebola-like outbreak, the deaths averted would rise only modestly, by about 3 percentage points (p.p.). The economic costs, however, would increase substantially. Escalating to the “Targeted closures and restrictions” package from the “Reduced contact” package (Level 1-2) consistently deepens economic losses across all outbreak types, with GDP contractions rising from 2.5% to 3.1% in Ebola-like and from 2.5% to 2.9% in measles-like scenarios (Figure 1.7). It is also worth noting that school closures would have effects on human capital formation that are not captured in this analysis, as it covers only the first nine months of an outbreak. These potential effects would accrue over a longer horizon.

1.5. PPR capacity can be greatly strengthened when NPIs are backed by solid foundations

1.5.1. Strategic stockpiling offers an important short-term buffer during outbreaks

In addition to strong disease surveillance and early warning systems (Box 1.5), strategic stockpiling of personal protective equipment (PPE) is another key enabler for the effective and timely implementation of NPIs, particularly in the context of community-based IPC measures. Stockpiles act as a first buffer during public health emergencies to ensure critical supplies are readily available in the early stages of a health emergency when there is a gap between immediate needs and time required to ramp up manufacturing and production capacity. Experiences from OECD and partner countries highlight several core policy dimensions that influence the effectiveness of stockpiling systems (OECD, 2024[18]):

- **Strategic planning and risk assessments:** A central challenge in strategic stockpiling lies in deciding what to stockpile, in what quantities and for which type of health emergencies. National stockpiles typically include a mix of medicines, PPE, medical devices, vaccines and other countermeasures. Many countries now base their stockpile composition on risk assessments conducted by expert groups or national security boards. For example, in Australia, the key decision

making committee for health emergencies advises on managing the stockpile (Australian Department of Health and Aged Care, 2023[59]) whereas in Korea, the Ministry of Food and Drug Safety develops a list of essential products which must be stockpiled and other stockpiled products are informed by priority diseases identified by Korea's Centres for Disease Control and Prevention (Ministry of Food and Drug Safety, 2019[60]).

- **Governance model and management:** Strategic stockpiling requires clear governance and oversight structures. In a previous review, France, Latvia, Lithuania, the Netherlands and Norway all reported having strategic stockpiles mainly held by governments whereby stockpiling practices are guided by national legislation that defines storage responsibilities and renewal procedures (HIQA, 2023[61]). In some countries, hospitals and other healthcare institutions also maintain their own reserves to complement the national systems. Decentralised stockpiling combined with central oversight is also recommended to ensure timely access in case of emergencies (HIQA, 2023[61]). This is already the case in the United States and in Australia where decentralised stockpiles are strategically distributed in various locations to facilitate timely deployment and both countries centrally co-ordinate their stockpiles.
- **Funding and reimbursement arrangements:** Strategic stockpiling is a long-term investment that demands sustainable funding. Funding models vary across countries. Some countries allocate dedicated budgets within the Department/Ministry of Health while others use funds from the central government or pool resources from across various ministries.
- **Inventory management and logistics:** Sound inventory management and logistics underpin every effective stockpiling system. Typically, national agencies with prior experience in stockpiling and preparedness oversee the procurement process, though hospital procurement groups may also be involved. Further to stock management, operational delivery, such as stockpile distribution, generally takes place through defined mechanisms guided by the ministry of health and in some cases inter-ministerial collaboration, as well as through wholesaler distribution networks and national emergency medical services.

Designing resilient stockpiling strategies requires balancing financial sustainability, adaptability, operational efficiency and co-ordination. Maintaining strategic reserves demands consistent long-term funding, yet these costs are modest compared with the inflated prices governments face when procuring supplies during a crisis (OECD, 2024[18]). Because health threats are unpredictable, ranging from pandemics to natural disasters and chemical, biological, radiological and nuclear events, stockpiling plans must remain flexible and regularly updated through risk assessments. Effective rotation, waste reduction and timely distribution depend on strong logistics systems and clear operating procedures. Seamless co-ordination among national and local authorities, healthcare providers and industry partners is also essential, as poor communication can slow delivery and undermine an otherwise well-prepared response.

1.5.2. Successfully managing outbreaks also hinges on effective governance, economic and social factors

Equally important is the ability to assess national vulnerabilities to guide strategic decision making. PPR capacity is typically measured with indices that assess and compare readiness to health shocks. Well-designed and evidence-based PPR indices provide a practical tool for decision makers to:

- detect early threats and allocate resources more effectively, by highlighting gaps in detection, surveillance and response capacities,
- benchmark performance against international standards and peers and
- contribute to stronger global collaboration and security, by offering a shared language and measurement framework that facilitate the sharing of experiences and resources across countries.

The OECD examined the key features of six key PPR indices developed before the COVID-19 pandemic: Epidemic Preparedness Index (EPI), Global Health Security Index (GHSI), Infectious Disease Vulnerability Index (IDVI), INFORM Risk Index, Joint External Evaluation (JEE) and the International Health Regulations (IHR) State Party Self-Assessment Annual Report (SPAR). These indices were selected for analysis because each of them examines a country's general preparedness for pandemics across multiple dimensions, rather than focussing on a single aspect and they all enable international comparisons.

Although the six PPR indices included in the OECD analysis have similar overall objectives, they differ in their scope and structure, and they use different methodologies to evaluate how well countries prevent, detect and respond to future pandemics. They typically rely on secondary and/or self-reported data to capture the broad picture of national readiness.

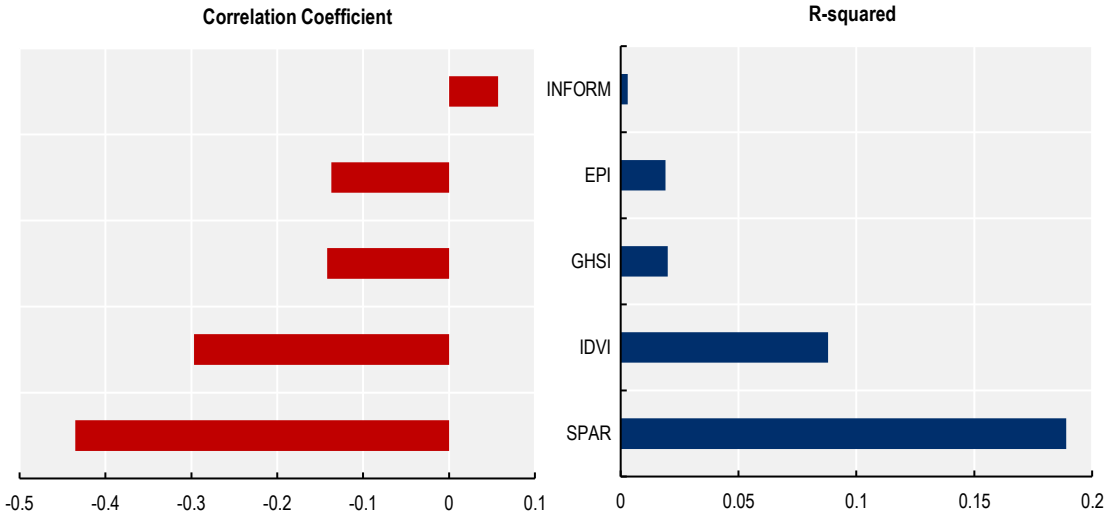
The PPR indices typically cover a broad set of themes, often overlapping in core areas such as healthcare capacity, infrastructure, surveillance and response capabilities. But each index emphasises certain themes according to its design and purpose. Co-ordination and governance are key dimensions of most PPR assessments. The GHSI, IDVI, JEE and SPAR pay particular attention to compliance with international norms, especially those set by the IHR. Common indicators include participation in international agreements, IHR reporting and cross-border co-ordination mechanisms. However, in line with previous works, the OECD analysis also showed that most indices overlook crucial social and cultural dimensions (e.g. level of trust in the government and community behaviours that may influence the level of compliance with NPIs) (Kachali et al., 2022[62]).

The reviewed PPR indices vary considerably when it comes to assessing vulnerable populations and coping capacity. The GHSI, JEE and SPAR are among the most comprehensive tools covering a wide range of dimensions of PPR capacity, but the GHSI and JEE do not include explicit measures of vulnerable populations or their capacity to cope with crises. Key indicators (e.g. literacy rates) which are essential for understanding vulnerabilities are often absent. In comparison, the IDVI, though narrower in scope, excels in capturing health disparities and vulnerabilities within populations.

The OECD analysis suggested that the PPR indices developed prior to COVID-19 often failed to match the actual performance of countries during the outbreak. The experience of COVID-19 revealed both the value and limits of existing measures of PPR capacity. The OECD examined how well the six pre-pandemic indices predicted a country's performance during the COVID-19 crisis. Performance was measured by the percentage change in life expectancy between 2019 and 2021, an indicator that captures both direct mortality from the outbreak and the indirect health impacts of overwhelmed health systems.

The OECD analysis revealed that the predictive power of PPR indices was moderate to low (Figure 1.9). Among the six indices reviewed, the SPAR showed the strongest but moderate link to changes in life expectancy during COVID-19. Its correlation coefficient of -0.44 indicates a negative relationship whereby countries with higher SPAR scores, meaning stronger PPR capacity, generally experienced smaller drops or even gains in life expectancy. How well a country scored on SPAR explained roughly 19% of the differences in life expectancy changes across countries. The IDVI also showed a meaningful, though much weaker association (correlation coefficient -0.3; R-squared = 0.09). INFORM and EPI captured little of how life expectancy changed during the pandemic. The EPI's correlation coefficient of -0.14 and R-squared value of 0.02 suggests only a minimal link, whereas the same metrics for INFORM indicate almost no association (correlation coefficient 0.06; R-squared = 0.003).

Figure 1.9. Predictive strength of PPR indices and percentage change in life expectancy, 2019-2021



Note: R-squared values ranging from 0 to 1 indicate the extent to which changes in life expectancy are explained by each index. A higher R-squared value reflects a stronger ability of the index to predict changes in life expectancy. The R-squared values indicate the proportion of variance in life expectancy change explained by each index, with higher values reflecting stronger predictive power (e.g. an R-squared value of 0.02 for the GHSI means that this index explains 2% of the variation in life expectancy and around 98% of the variation in this outcome is due to other factors that are not captured in the analysis). Correlation coefficients describe the direction and strength of the relationship. Negative values indicate that countries ranked as better prepared (lower index scores) generally experienced smaller declines in life expectancy, while positive values suggest little or no meaningful relationship. EPI = Epidemic Preparedness Index, GHSI = Global Health Security Index, IDVI = Infectious Disease Vulnerability Index, JEE = Joint External Evaluation, SPAR = State Party Self-Assessment Annual Report.
Source: OECD analysis.

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The mixed predictive performance of the pre-COVID-19 indices coupled with evidence from the COVID-19 pandemic suggests the next generation of PPR indices can be strengthened in several ways including:

- **PPR capacities must be judged in context.** The COVID-19 pandemic showed that many pre-COVID-19 PPR indices tended to favour high-income countries, even though certain low-income or smaller countries often outperformed expectations. One reason for this mismatch is that PPR indices often failed to fully account for country characteristics that could influence the response capacity such as geographic connectivity, demographic composition, prior experience managing health crises, local level and community capacity and cohesion, governance variables, ability to co-ordinate a cross-sectoral response, as well as various dimensions of vulnerability (e.g. health, social, economic, institutional and cognitive). Future indices can make a stronger effort to incorporate these factors into their assessment frameworks to improve their predictive power.
- **Integrate measures of operational readiness.** During health emergencies, speed of action saves lives. Among pre-COVID indices, SPAR stood out for capturing a country's ability to act quickly (i.e. operational readiness) in case of a health shock by assessing, for example, whether systems for public health risk communication and reporting and compliance with international regulations are in place. The IDVI complemented this operational lens with structural factors such as governance stability and socio-economic context. Future indices can go further by evaluating not only whether response mechanisms exist but how quickly they can be activated and scaled in real time.

- **Reinforce the role of disease surveillance.** Surveillance remains the cornerstone of effective response to outbreaks. Early warning systems can facilitate the detection of outbreaks quickly, though the effectiveness of these systems depends heavily on timely access to high-quality, real-time information. Yet, one OECD survey fielded just before COVID-19 showed that only a handful of countries (i.e. Denmark, Estonia, Korea and Latvia) had the infrastructure to achieve near real-time data reporting across key areas such as hospital in-patients, emergency care, primary care, long-term care and prescription medicines prior to COVID-19 (Oderkirk, 2021[63]). Luxembourg also reported having similar health data structures in place before the pandemic. Robust laboratory capabilities are another critical component of disease surveillance for accurate diagnostics and monitoring. Health systems should also be able to track both symptomatic and asymptomatic cases effectively, for example, through wastewater surveillance.
- SPAR's inclusion of indicators to capture laboratory capacity and surveillance helped explain its stronger predictive performance. In comparison, INFORM and EPI placed limited emphasis on surveillance. INFORM focussed mainly on general disaster vulnerability, while EPI emphasised the structural aspects of preparedness (e.g. healthcare systems and resources) without assessing disease detection speed or outbreak tracking capacities. None of the PPR indices examined the role of the readiness of health information systems.
- **Incorporate socio-economic and governance dimensions.** Trust in institutions, social cohesion and leadership quality, including at the local level, proved decisive during COVID-19 but these dimensions were often absent from PPR assessments. The ability to communicate risks clearly and consistently during health emergencies can influence public compliance and trust. SPAR was one of the few frameworks that explicitly assessed public health risk communication capacity. Expanding this dimension, for example, by evaluating transparency and community engagement would provide a more accurate picture of socio-economic and governance dimensions that influence PPR capacity.
- **Strengthen the dimensions of international co-operation.** No country can face a pandemic alone. The early months of COVID-19 exposed weaknesses in global co-ordination, ranging from fragmented supply chains to inconsistent travel and data-sharing policies. Future indices should explicitly measure a country's capacity and readiness to co-operate internationally, including mechanisms for information exchange, joint procurement and rapid mutual assistance.
- **Adopt a One Health lens**. The rising threat of zoonotic diseases means efforts to capture PPR capacities need to go beyond focussing solely on human health. Many emerging pathogens originate in animals and are amplified by land-use change, food production practices and environmental degradation. Future indices should adopt a One Health lens by incorporating animal health surveillance, environmental monitoring and human-wildlife interactions to identify risks early and prevent outbreaks before they reach human populations.

1.6. Investing in PPR capacities delivers dividends far beyond moments of crisis

When pandemics strike, countries with stronger PPR systems are better equipped to respond quickly and avoid the steep health and economic toll of the outbreak. While PPR spending may appear costly upfront, neglecting it only shifts and magnifies the expenses that would be incurred during the response phase. This was the case during COVID-19 when insufficient stockpiles led to a global scramble for PPE. Similarly, building essential public health systems from scratch during an emergency is vastly more expensive and less efficient than establishing them beforehand.

Beyond crisis management, PPR investments yield "dual-use" benefits. The same infrastructure, surveillance systems and co-ordination mechanisms that protect populations and the economy during outbreaks also enhance routine care, accelerate detection of other health threats and improve public trust

in institutions in "normal times". Wastewater surveillance, for example, can monitor seasonal influenza and other endemic diseases while stronger stockpiles can be mobilised for other health emergencies. In this sense, preparedness is not merely an insurance policy, but a long-term investment in the stability and efficiency of health systems.

The OECD estimated investments necessary to bolster country-level PPR capacity in 51 OECD, EU/EEA and G20 countries for the next 10 years, using the OECD SPHeP Costing Tool. Table 1.2 describes the key features of the interventions included in the assessment.

Table 1.2. Key design features of components of the PPR package

Intervention		Key activities	Key cost items in preparedness phase	Key cost items in response phase
Building a national stockpile for PPE and hygiene supplies		Establishing the national stockpile	• Procurement of essential PPE and hygiene items (e.g. respiratory masks and hand sanitisers) in quantities to cover 20% of the population aged >12 years for 3-months (WHO, 2020[64])	• Additional procurement of PPE and hygiene supplies to meet increased demand during an outbreak (10% of the supply procured in preparedness phase; OECD assumption)
		Stockpile management	• Development, regular updating and implementation of SOPs and best practice guidelines • 10% of the stockpile is assumed to be distributed every year within the health system and replenished (OECD assumption) • Recruitment and salaries of staff responsible for stockpile management and logistics (e.g. managers, administrative staff, procurement specialists and warehouse workers) • Putting in place and maintaining an inventory management information technology (IT) system • Purchase of operational equipment (e.g. laptops and barcode scanners) • Planning and operating transportation and distribution arrangements	• Temporary expansion of staff capacity to support higher distribution volumes (+30% of preparedness phase; OECD assumption) • Purchase of additional equipment to support increased staffing levels • Higher transportation activity associated with expanded distribution (+10% of preparedness phase; OECD assumption)
		Warehouse management	• Leasing, maintenance and operation of warehouse facilities	• Same as preparedness phase
		Monitoring and evaluation (M&E)	• Annual external audits to verity stock levels and compliance with procedures	Not applicable
Physical contact-reducing NPIs	**Ensuring greater compliance with physical distancing measures**	Developing and implementing operational guidance	• Development, regular updating and implementation of SOPs and best practice guidelines, informed by expert consultations • Identification and assignment of staff responsible for co-ordinating the development and rollout of operational guidance	• Temporary expansion of staff capacity to manage intensified implementation and oversight (+30% of preparedness phase
		Improving public access to accurate information	• Development and ongoing maintenance of a public information website • Establishment and routine operation of a public health hotline including staff, basic equipment (e.g. laptops, headsets) and initial training	• Large-scale public communication campaigns, including design and placement of weekly television and radio public announcements, placement of poster and signage in public spaces • Temporary expansion of hotline workforce (+30% of preparedness phase), with additional equipment and training sessions

Intervention		Key activities	Key cost items in preparedness phase	Key cost items in response phase
		Enforcement	Not applicable	• Salaries of civil security officer salaries to support enforcement of physical distancing requirements
		Monitoring and evaluation	• Assigning staff to monitor implementation, compliance and performance of physical distancing measures	• Increased M&E capacity to increase compliance levels in the public
	Ensuring educational continuity	Developing and implementing operational guidance	• Development, regular updating and implementation of SOPs and best practice guidelines, informed by expert consultations • Identification and assignment of staff responsible for co-ordinating the development and rollout of operational guidance	• Temporary expansion of staff capacity to manage intensified implementation and oversight (+30% of preparedness phase)
		Strengthening readiness for online education	• Set-up subscription of learning management systems (LMS) in schools • Offer online training sessions for teaching staff on best practices in remote learning	• Procurement of laptops for primary and secondary school students from disadvantaged backgrounds • Additional teacher training sessions to support remote teaching during school closures • Continued LMS subscription and use throughout the response period
	Facilitating innovative workplace solutions	Developing and implementing operational guidance	• Development, regular updating and implementation of SOPs and best practice guidelines, informed by expert consultations • Identification and assignment of staff responsible for co-ordinating the development and rollout of operational guidance	• Temporary expansion of staff capacity to manage intensified implementation and oversight (+30% of preparedness phase)
	Ensuring safe domestic and international travel	Developing and implementing operational guidance	• Developing, revising and implementing standard operating procedures and best practice guidelines, based on expert consultations • Identifying staff who would co-ordinate the development and implementation of SOPs and best practice guidelines	• Temporary expansion of staff capacity to manage intensified implementation and oversight (+30% of preparedness phase)
		Improving public access to accurate information	• Development and ongoing maintenance of a public information website to disseminate up-to-date information on guidelines to travelling high risk areas in terms of disease outbreaks	• Large-scale public communication campaigns, including placement of poster and signage in major travel hubs, regular updates of travel advisory on the dedicated public website and placement of weekly television and radio public announcements
		Enforcement	Not applicable	• Salaries of civil security officer salaries to support enforcement of travel requirements in major travel hubs
Enhancing wastewater surveillance		Developing and implementing operational guidance	• Developing, revising and implementing standard operating procedures and best practice guidelines, based on expert consultations • Identifying staff who would co-ordinate the development and implementation of SOPs and best practice guidelines	• Temporary expansion of staff capacity to manage intensified implementation and oversight (+30% of preparedness phase)
		Strengthening laboratory capacities	• Procurement of sampling kits and transport materials for wastewater treatment plants • Laboratory equipment and consumables (e.g. RT-qPCR kits)	• Sampling frequency to increase from two to three per week • Procurement of additional laboratory consumables to support expanded testing capacity

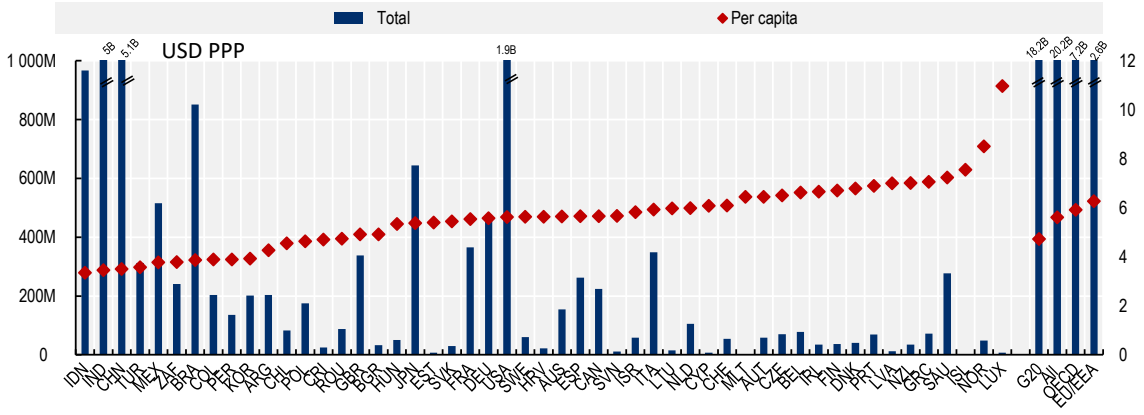
Intervention	Key activities	Key cost items in preparedness phase	Key cost items in response phase
	Strengthening research and data sharing capacities	• Development and maintenance of an online dashboard to facilitate data sharing	• Expanded dashboard maintenance and support

Note: LMS = learning management systems; M&E = monitoring and evaluation; PPE = personal protective equipment; RT-qPCR = reverse transcription-quantitative polymerase chain reaction; SOP = standard operating procedures.
Source: Based on OECD review of the available literature.

1.6.1. In the OECD, strengthening PPR capacity would require nearly USD PPP 6 per person per year

The OECD estimates that PPR capacity would require an average annual investment of over USD PPP 20 billion across the 51 countries included in the analysis, equivalent to about USD PPP 5.6 per person (Figure 1.10). Within the OECD, this translates to an average of USD PPP 7.2 billion per year or roughly USD PPP 5.9 per capita, while the corresponding figure for EU/EEA countries is around USD PPP 2.6 billion annually or USD PPP 6.3 per capita. Among the G20 economies, the estimated annual cost averages more than USD PPP 18 billion, which corresponds to around USD PPP 4.7 per capita. Substantial cross-country variation exists in investment needs, with per capita costs per year ranging from USD PPP 3.3 in Indonesia to as high as USD PPP 11 in Luxembourg.

Figure 1.10. In the OECD, strengthening PPR capacity would require nearly USD PPP 6 per capita each year



Note: PPP = purchasing power parity; B = billions; M = millions.
Source: OECD analysis based on the OECD SPHeP Costing Tool.

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Across OECD countries, strengthening PPR capacity is estimated to require about USD PPP 5.9 per person each year. Around one-third of these additional resources would go toward start-up investments to strengthen the essential systems (e.g. developing standard operational procedures, data and management systems), institutions and infrastructure that underpin preparedness. A similar amount would be needed each year to cover operational costs that maintain these systems over time. It is important to note that these cost estimates represent an upper bound, based on the assumption that countries begin with limited PPR capacity for the interventions included in the analysis. Countries at a more advanced stage that have some elements of these systems in place would benefit from a reduction in the overall

investment requirements. For example, if countries already have 30% of the PPR capacity in place, the average annual PPR cost would fall to USD PPP 6.4 billion (USD PPP 5.3 per capita) for OECD, to USD PPP 2.4 billion (USD PPP 5.7 per capita) for EU/EEA and to USD PPP 17.7 billion (USD PPP 4.2 per capita) for the G20 countries.

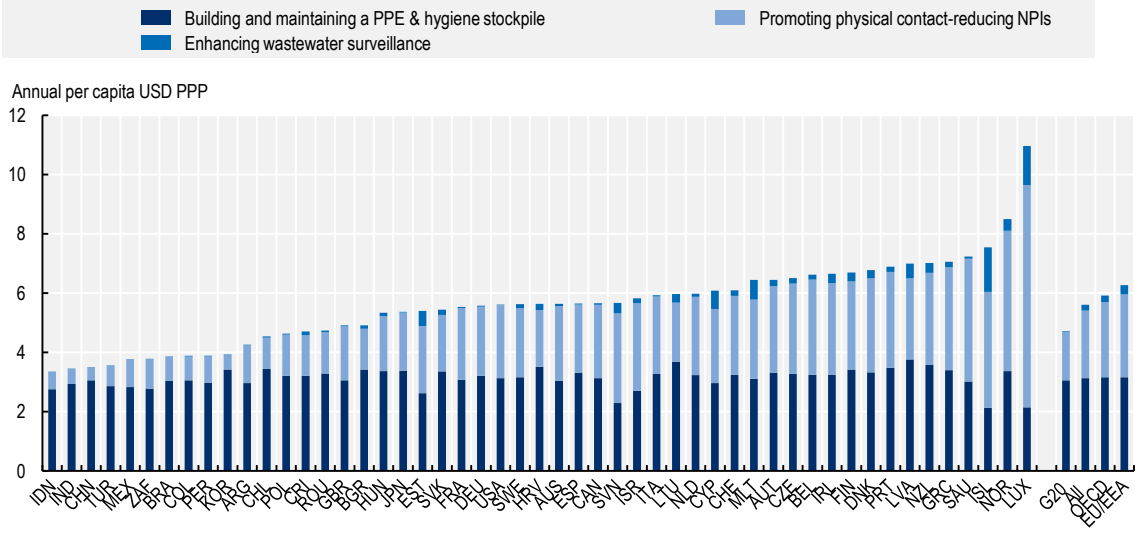
In comparison, the response phase, when capacities are expanded to address an active outbreak rather than built from scratch, would average around USD PPP 1.7 per capita per year in the OECD. This lower figure underscores a key point. When preparedness systems are in place, countries can respond more efficiently by relying on established structures rather than building new ones amid crises.

1.6.2. Building a national stockpile is the costliest component of the PPR package

Building and maintaining a national stockpile of PPE and hygiene supplies is by far the most expensive component, with an annual average cost of almost USD PPP 4.4 billion (USD PPP 3.2 per capita) for OECD countries (Figure 1.11). This finding is not surprising considering the complexities around building and maintaining stockpiles. A substantial portion of this cost is driven by the procurement of supplies. This is not a one-time expense, because it requires continuous investment in replenishment and rotation of supplies, although items nearing expiration can be released to the market and used, reducing overall costs, as is already practised in many countries. Another driver of the cost is the ongoing management of the stockpile (e.g. staff salaries, secure warehouses, logistical systems), which reflects that a stockpile is a complex logistical operation and not simply a warehouse of medical goods.

Figure 1.11. Annual average cost of PPR by intervention

Annual average cost of PPR by component



Notes: Physical contact-reducing NPIs include 1) promoting higher compliance with physical distancing measures, 2) ensuring innovative workplace solutions, 3) ensuring educational continuity and 4) encouraging safe international and domestic travel. EU/EEA = European Union/European Economic Area, G20 = Group of 20; NPIs = non-pharmaceutical interventions; PPE = personal protective equipment; PPP = purchasing power parity.
Source: OECD analysis based on the OECD SPHeP Costing Tool.

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The annual cost of activities aiming to strengthen the implementation of physical contact-reducing NPIs, such as promoting physical distancing measures and ensuring innovative workplace solutions, would on average cost almost USD PPP 2.8 billion (USD PPP 2.5 per capita) in the OECD, around USD PPP 1.1 billion (USD PPP 2.8 per capita) in the EU/EEA and nearly USD PPP 4.2 billion (USD PPP 1.6 per capita) across the G20 countries. Efforts to scale up wastewater surveillance are relatively inexpensive, with the estimated per capita average cost of facilitating enhanced wastewater surveillance remaining below USD PPP 1 per year in nearly all countries included in the analysis.

1.7. Conclusions

This report shows that investing in PPR capacity saves lives and shields economies from the consequences of future outbreaks. Set against the potential health and economic toll of uncontrolled outbreaks, the estimated PPR investment is modest. As the chapter highlighted before, the cumulative probability of experiencing another pandemic on the scale of COVID-19 within the next 25 years is estimated at roughly 50% (Madhav et al., 2023[5]), yet the OECD analysis showed that building the PPR capacity to respond is estimated to average only about USD PPP 5.6 per person per year across the 51 countries included in the analysis. The return on that outlay is large. In the most severe scenarios, an outbreak without well-implemented and timely NPIs could claim the lives of one in five people and reduce GDP by between 11.7% and 28.9% within its first nine months. Against potential losses of this magnitude and an increasing risk of facing them within a generation, the economic case for prioritising PPR is compelling.

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2 The COVID-19 pandemic could have lingering impacts on population health and the economy

This chapter focusses on the impact of COVID-19 on health and societies, as the most recent among emerging pandemics. It starts by outlining the health burden of COVID-19, both direct and indirect through disruptions in care pathways. It then explores the social burden and effects on key risk factors for non-communicable diseases (NCDs). Recognising the significant societal disruptions, the chapter, then, presents an analysis estimating the long-term impact of COVID-19 on NCDs across 28 OECD and 5 non-OECD European Union/European Economic Area countries, using the OECD Strategic Public Health Planning for NCDs model.

In Brief

Key messages

COVID-19 has had an enormous impact on health and societies

- COVID-19 claimed the lives of nearly 7 million people worldwide by the end of its emergency phase in 2023, and placed immense strain on healthcare systems, societies and economies. Globally, the estimated full death toll associated directly or indirectly with the pandemic was approximately 14.9 million excess deaths by the end of 2021. During its peak period between 2020 and 2022, OECD countries alone recorded an additional 6 million deaths compared to the years prior to the COVID-19 pandemic. Countries with higher reported COVID-19 death rates also typically had larger increases in excess deaths, more pronounced reductions in life expectancy and larger contractions in gross domestic product (GDP).
- COVID-19 also had a significant negative impact on the mental health and well-being of populations. For example, modelled estimates from the Institute for Health Metrics and Evaluation indicate that the share of the population with major depressive disorders and anxiety increased by around 25% and 19%, respectively, on average across OECD countries in 2021 compared with 2019 levels and has remained elevated or continued to rise in some countries in 2023.
- The broader morbidity from COVID-19 continues, with around 5% to 15% of people who contracted COVID-19 exhibiting symptoms corresponding to long COVID – a chronic condition that develops following SARS-CoV-2 infection and lasts for at least three months. The impacts of long COVID vary across countries yet recent OECD analysis suggests that it could continue to cost health systems around USD 11 billion per year across OECD countries over the next decade, with annual GDP losses expected to range between 0.1 and 0.2%.
- COVID-19 negatively impacted care pathways for chronic diseases. In the first months of the crisis, hospital admissions for cardiovascular diseases temporarily declined in many OECD countries, and even when patients reached hospitals, care was often delayed. Cancer care was similarly affected, with major interruptions to screening and diagnosis likely to worsen prognoses and excess cancer deaths in the coming years. Cancer surgeries also declined, and waiting times lengthened as hospitals struggled with backlogs and staff services. While healthcare systems adapted to preserve access for patients with chronic conditions, postponed elective procedures and medical appointments created a backlog, disproportionately affecting older patients with multimorbidity and potentially increasing long-term health burdens.
- The overall burden of COVID-19 extends well beyond health. The COVID-19 pandemic has exacerbated socio-economic inequalities, job insecurity, negative educational outcomes and beyond. The pandemic also had significant employment and labour impacts; for example, unemployment across OECD increased by 32% on average between 2019 and 2020, while GDP reduced by 5%.

COVID-19 had mixed impacts on lifestyle factors that influence the burden of non-communicable diseases (NCDs)

- The COVID-19 pandemic led to significant social, behavioural, and economic disruptions, altering some lifestyle-related risk factors associated with the burden of NCDs. To better

understand the pandemic's potential impact, observed post-pandemic trends in major NCD risk factors were compared with projections based on pre-pandemic linear trends. On average across 28 OECD countries, the prevalence of tobacco use was around 10% higher than predicted, suggesting that COVID-19 slowed the decline in overall smoking prevalence. By contrast, in the same period and set of countries, per capita alcohol consumption was 4% lower than predicted. The impact on obesity was marginal, less than 1% higher than expected on average, possibly due to the lag between changes in energy balance and observable weight shifts, compounded by the short assessment period.

COVID-19 could have lingering impacts on the NCD burden, healthcare spending and the economy

- Potential shifts in major NCD risk factors, together with disruptions in the healthcare pathway for chronic disease patients during COVID-19, raise concerns about an increased long-term risk of developing NCDs such as cardiovascular disease, cancer and diabetes. To capture the long-term consequences of COVID-19, the OECD modelled two hypothetical pandemic scenarios reflecting the changes in lifestyles and healthcare delivery. Both scenarios assume changes in exposure to key risk factors (i.e. tobacco use, alcohol consumption and obesity) and temporary declines in cancer survival. In the temporary shock scenario, these disruptions are short-lived: risk factors change through 2021, remain stable until 2023 and return to pre-pandemic levels by 2024. From a practical standpoint, this scenario implies that individuals who had altered their habits during the COVID-19 pandemic would revert to their previous lifestyles by 2024. The second scenario (i.e. a permanent shock) assumes persistent shifts: risk factors change through 2021 and remain permanently at that level through 2050, assuming that lifestyle changes adopted during the pandemic would persist throughout the duration of the simulation.
- COVID-19 could have lingering impacts on the NCD burden, healthcare spending and the economy:
  - In the short term (i.e. between 2020 and 2024), COVID-19-related lifestyle changes are estimated to have reduced life expectancy and healthy life expectancy by 2.4 months and 2.5 months, respectively, across the 28 OECD countries analysed. This health burden translates into an average 0.4% increase in annual health expenditure and annual GDP losses of 0.1%.
  - In the long term (i.e. between 2025 and 2050), the detrimental impact of COVID-19 on health and the economy fades over time if risk factors and behaviours gradually return to pre-pandemic levels. However, if changes in risk factor prevalence levels observed during COVID-19 persist permanently, life expectancy could remain, on average, 1.9 months lower in 28 OECD countries by 2050 compared to a scenario where no COVID-19 occurred. Annual health expenditure could remain 0.6% higher, and GDP could be as much as 0.2% lower, each year, on average, across 28 OECD countries in 2025-2050.

2.1. COVID-19 has had an enormous impact on health and societies

COVID-19 was the latest reminder of the disruptive capacity of pandemics. By the end of its emergency phase in 2023, it had directly claimed nearly 7 million lives worldwide (WHO, 2025[1]). Health systems across the globe were stretched far beyond capacity, and routine services for non-COVID-19 patients were severely disrupted. Across OECD countries, the immense strain placed on healthcare systems, societies and economies resulted in an estimated additional 6 million deaths between 2020 and 2022 compared with pre-pandemic years (Morgan et al., 2023[2]). COVID-19 disrupted nearly every step of the care pathway for patients with chronic conditions such as cardiovascular diseases and cancer, leading to delayed care and worsening health outcomes that may persist for years. Mental health also deteriorated, with an estimated 25% and 19% increase in the prevalence of depressive disorders and anxiety across OECD countries in 2021 compared to pre-pandemic levels, with prevalence remaining elevated in subsequent years (IHME, 2025[3]). The broader morbidity of COVID-19 continues, with around 5% to 15% of people who contracted the virus exhibiting symptoms of long COVID – a chronic condition that can last for at least three months after infection (OECD, 2026[4]). The overall burden of the pandemic extends well beyond health, deepening social inequalities and driving economic losses, with unemployment across OECD countries by 32% on average between 2019 and GDP falling by around 5% (OECD, 2021[5]).

The chapter is organised as follows: Section 2.1 outlines the health burden of COVID-19, from its impact on mortality, to mental health and well-being, and the continuing broader morbidity of long COVID – a chronic condition that develops following SARS-CoV-2 infection and lasts for at least three months. It then explores the impact on care pathways for non-communicable diseases, such as cardiovascular diseases and cancer, before touching on the social burden. Section 2.2 presents an analysis of the COVID-19 impact on key risk factors for non-communicable diseases (NCDs). Recognising the significant societal disruptions, Section 2.3, then, presents an analysis estimating the long-term impact of COVID-19 on NCDs across 28 OECD and 5 non-OECD European Union (EU)/European Economic Area (EEA) countries, using the OECD Strategic Public Health Planning for Non-Communicable Diseases (SPHeP-NCDs) model.

2.1.1. Mortality burden

COVID-19 has been the latest among several large-scale disease outbreaks over the last century, claiming the lives of nearly 7 million people worldwide by the end of the emergency phase of the pandemic in May 2023, and placing immense strain on healthcare systems, societies and economies (WHO, 2025[1]). Between 2020 and 2022, more than 3 million COVID-19 deaths were recorded across OECD countries, with COVID-19 accounting for almost 1 in 5 of all weekly deaths in the OECD at the peak of the pandemic in 2021. Across this same three-year period OECD countries recorded an additional 6 million deaths (i.e. excess deaths) compared to the years prior to the pandemic (Box 2.1) (Morgan et al., 2023[2]). The number of additional all-cause deaths and COVID-19 deaths peaked in early 2021, followed by a steep decline and several spikes during the following two years (Figure 2.1). A 7-month fall in OECD-average life expectancy was seen in 2020 alone (OECD, 2021[5]), with life expectancy still below pre-pandemic levels in 13 OECD countries in 2023 (OECD, 2025[6]).

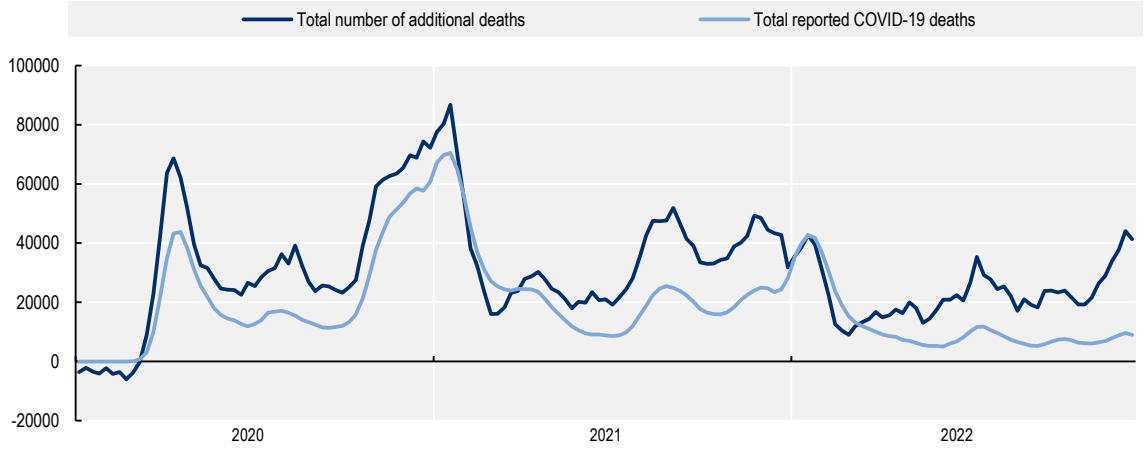
Box 2.1. Defining excess mortality

Excess mortality is defined as the difference between the observed number of deaths (either from all causes or a specific cause of death) over a defined period (ranging from a week to a multi-year period) compared to an estimate of the *expected* numbers of deaths for the same period (Morgan et al., 2023[2]). The excess mortality indicator is often used to reflect the magnitude of a crisis, such as an infectious disease outbreak or pandemic, by quantifying the number of additional deaths observed in comparison to the expected rate (WHO, 2025[7]). As an estimate of the overall COVID-19 mortality burden, it is a more comprehensive measure compared to the confirmed COVID-19 death count alone, as it additionally captures COVID-19 deaths that were not correctly diagnosed and reported, as well as deaths from other causes that can be attributed to the over-arching crisis condition (Eurostat, 2025[8]). It is considered a more objective and comparable measure that accounts for both the direct and indirect impacts of the pandemic.

Source: Morgan et al. (2023[2]), *Examining recent mortality trends: The impact of demographic change*, https://dx.doi.org/10.1787/78f69783-en; WHO (2025[7]),*Global Excess Deaths Associated with the COVID-19 Pandemic,* https://www.who.int/news-room/questions-and-answers/item/global-excess-deaths-associated-with-the-COVID-19-pandemic, Eurostat (2025[8]), *Statistics Explained*, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Excess_mortality.

Figure 2.1. The number of additional all-cause deaths and COVID-19 deaths peaked in early 2021

Total weekly deaths above the 2015-2019 average and total reported COVID-19 deaths, 34 OECD countries, 2020-2022



Note: Weekly data unavailable for Ireland, Japan, Korea and Türkiye. Additional deaths compared to the weekly deaths during 2015-2019.
Source: Morgan et al. (2023[2]), *Examining recent mortality trends: The impact of demographic change*, Figure 2.2, https://dx.doi.org/10.1787/78f69783-en.

Globally, estimates from the World Health Organization (WHO) indicate that the full death toll associated directly or indirectly with the COVID-19 pandemic by the end of 2021 was approximately 14.9 million excess deaths (range 13.3 million to 16.6 million) (WHO, 2022[9]). Geographically, most of the excess deaths (84%) were distributed across Southeast Asia, Europe and the Americas. Lower-middle-income and upper-middle-income countries carried the highest burden, accounting for 53% and 28% of the total 14.9 million excess deaths accordingly (ibid). Moreover, the COVID-19 pandemic disproportionately affected men compared to women in terms of excess mortality (OECD, 2021[5]). Statistics on the excess mortality from 29 OECD countries show that deaths for men increased by 15% over the first year of the pandemic, compared to 2015-2019 averages, compared to only 12% for women (ibid). Furthermore, individuals with chronic conditions, such as cardiovascular disease, cancers and diabetes, tended to have worse and more long-term COVID-19 outcomes leading to higher rates of hospitalisation and death (Box 2.2).

Box 2.2. Non-communicable diseases influenced various COVID-19 outcomes

During the COVID-19 pandemic, patients with chronic, non-communicable diseases, such as cancer, cardiovascular diseases (CVDs) and diabetes, were at a greater of risk of becoming infected, experiencing severe outcomes and dying from COVID-19. The relative susceptibility and vulnerability towards COVID-19 was therefore unevenly distributed among population groups based on the presence of health risks and comorbidities.

COVID-19 and cancer

Scientific literature demonstrates a strong positive correlation between having a cancer diagnosis and increased vulnerability of being infected, developing severe complications, requiring mechanical ventilation or intensive care unit (ICU) admission, and dying from COVID-19. For COVID-19 infections, a cohort study including more than 4.5 million adults in Catalonia found that cancer was associated with an 8% higher risk of COVID-19 infection (adjusted hazard ratio = 1.08) (Roel et al., 2022[10]). Moreover, after being infected, patients with active or recently diagnosed and/or treated cancer were at a much higher risk of developing severe COVID-19 disease, often requiring emergency medical interventions and at times hospitalisation. Data from a systematic review and meta-analysis by Han et al. (2022[11]) showed that patients with cancer had a 49% higher risk of severe COVID-19 outcomes compared to other COVID-19 patients (pooled relative risk [RR] of 1.49). Another systematic review, which included 34 studies found that cancer was associated with a 2.84 times higher risk of severe COVID-19 disease (Gao et al., 2020[12]).

COVID-19 and cardiovascular disease

Cardiovascular disease (CVD) is one of the most well-known risk factors for COVID-19, contributing to a large portion of the overall COVID-19 health burden. Patients diagnosed with cardiovascular diseases, including hypertension, acute cardiac injury, arrhythmia, and coronary artery disease, among other CVDs, are predisposed to a higher risk of mortality and are more likely to suffer greater complications after the onset of the COVID-19 infection. Findings from a systematic review by Hessami et al. (2021[13]) found that the pooled risk odds of being admitted to an intensive care unit were much greater for patients with arrhythmia (Odds Ratio [OR]: 7.03, 95% confidence interval [CI] 2.79-17.69), acute cardiac injury (OR: 15.58, 95% CI 5.15-47.12), coronary heart disease (OR: 2.61, 95% CI 1.09- 6.26), cardiovascular disease (OR: 3.11, 95% CI 1.59-6.09), and hypertension (OR: 1.95, 95% CI 1.41- 2.68) compared to the general population. In terms of risk of mortality, a large-scale systematic review by Luo et al. (2020[14]) suggests that CVDs are associated with 2.65 times higher odds of mortality from COVID-19. Additionally, a systematic review by Harrison et al. (2021[15]) found that patients with hypertension (OR: 2.50, 95% CI 2.02-3.11) and cardiovascular disease (OR: 2.65, 95%

CI 1.86-3.78) had higher mortality compared to the general population, as well as a higher likelihood of developing severe COVID-19.

Source: Roel et al. (2022[10]), "*Cancer and the risk of coronavirus disease 2019 diagnosis, hospitalisation and death: A population-based multistate cohort study including 4 618 377 adults in Catalonia, Spain*", https://doi.org/10.1002/ijc.33846; Han et al. (2022[11]), "*Impact of cancer diagnoses on the outcomes of patients with COVID-19: a systematic review and meta-analysis*", https://doi.org/10.1136/bmjopen-2020-044661; Gao et al. (2020[12]), "*Cancer is associated with the severity and mortality of patients with COVID-19: a systematic review and meta-analysis*", https://doi.org/10.1101/2020.05.01.20087031; Hessami et al. (2021[13]), "*Cardiovascular diseases burden in COVID-19: Systematic review and meta-analysis*", https://doi.org/10.1016/j.ajem.2020.10.022; Luo et al. (2020[14]), *"The potential association between common comorbidities and severity and mortality of coronavirus disease 2019: A pooled analysis*", https://doi.org/10.1002/clc.23465; Harrison et al. (2021[15]), "*Cardiovascular risk factors, cardiovascular disease, and COVID-19: an umbrella review of systematic reviews*", https://doi.org/10.1093/ehjqcco/qcab029.

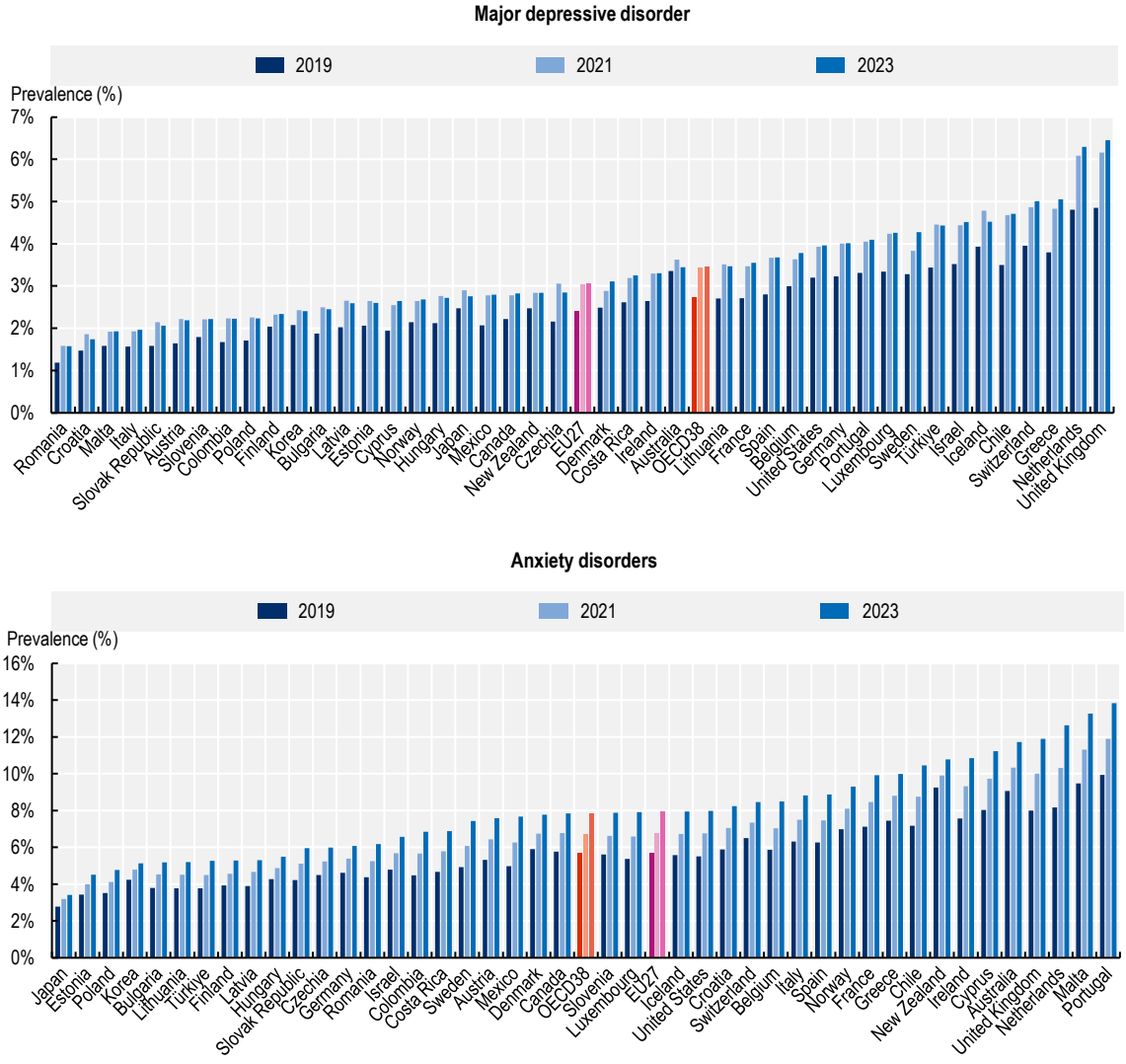
At its peak in 2021, COVID-19 was the fourth highest cause of mortality across OECD countries, accounting for 7% of all deaths, following diseases of the circulatory system (28%), cancers (21%), and diseases of the respiratory system (9%) (OECD, 2023[16]). Since then, the effects of COVID-19 have decreased yet it still accounted for around 5% of all deaths across OECD countries in 2023 (OECD, 2025[6]). A significant proportion of COVID-19 deaths are understood as "avoidable deaths" – deaths from preventable or treatable diseases that can be avoided through timely and effective healthcare interventions. It is estimated that across 26 OECD countries with available data for 2020 and 2021, over 3 million premature deaths among people aged under 75 years could have been avoided (OECD, 2023[16]). Largely explained by the immense pressures placed on healthcare systems, insufficient availability of personal protective equipment and vaccination, avoidable mortality spiked during the early stages of the COVID-19 pandemic. As a result, the pandemic reversed the trend of gradually declining mortality across the OECD, reaching a 900 deaths per 100 000 population age-standardised mortality rate in 2021 compared to 810 deaths per 100 000 in 2019 (Morgan et al., 2023[2]).

Countries with higher reported COVID-19 death rates also typically had larger increases in excess deaths, more pronounced reductions in life expectancy and larger contractions in Gross Domestic Product (GDP) (OECD, 2023[17]). One study found that in the first year of the pandemic the highest case fatality rate was observed in Mexico (8.51%), followed by China (5.17%) and Bulgaria (4.12%) (Ngatu et al., 2022[18]). However, contractions in GDP were particularly pronounced in Spain (-10.8%), the United Kingdom (-9.3%) and Greece (-9.0%) (OECD, 2023[17]).

2.1.2. Mental health and well-being

COVID-19 had a significant negative impact on the mental health and well-being of populations at a global level. More specifically, scientific literature highlights increasing trends in rates of anxiety, depression and suicide during the pandemic period (Wang et al., 2022[19]). Spikes in feelings of loneliness, division and disconnection from society continued to grow between mid-2020 and the first half of the 2021 (OECD, 2021[5]). Largely attributed to physical distancing, social and economic uncertainty – many adults reported experiencing "stress, anxiety or sadness that was difficult to cope with alone", including 33% of people in the United States, and between 23% and 26% of people in Canada, Australia, New Zealand and France, (ibid). Modelled estimates from the Institute for Health Metrics and Evaluation (IHME) indicate that the share of the population with major depressive disorders and anxiety increased by around 25% and 19%, respectively, on average across 38 OECD countries in 2021 compared with 2019 levels, and has remained elevated or continued to rise in some countries in 2023 (Figure 2.2).

Figure 2.2. Prevalence of depression and anxiety increased during the COVID-19 pandemic and has remained elevated



Source: (IHME, 2025[3]), GBD Results, https://vizhub.healthdata.org/gbd-results/.

Whilst mental health deteriorated for almost all population groups on average in 2020, women's, young people's, unemployed and migrants' mental health outcomes proved to be more vulnerable in times of the pandemic (OECD, 2021[5]). Across OECD countries, 15 to 24-year-olds, full-time students and unemployed people were at the highest risk of experiencing depression in 2020, averaging around 40% (OECD, 2021[5]) Furthermore, a representative survey of 13- to 19-year-olds in the United States found that more than one in four young people nationally reported losing sleep because of worry, feeling depressed or constantly under the strain (Margolius, 2020[20]). Exacerbated by higher rates of unemployment, job disruption and insecurity, racial and ethnic minorities from lower-income backgrounds in some cases experienced the biggest declines in mental health (OECD, 2021[21]). Data on the long-term mental health impacts of the COVID-19 pandemic remains largely fragmented, although this is expected to become clearer as additional research emerges.

2.1.3. Long COVID

The wider health impact of COVID-19 persists through cases of long COVID – a chronic condition that develops following SARS-CoV-2 infection and lasts for at least three months. Approximately 5% to 15% of people who contract COVID-19 exhibit symptoms corresponding to long COVID (OECD, 2026[4]). According to data from the OECD's 2023-2024 Patient-Reported Indicator Survey (PaRIS) of more than 107 000 primary care patients aged 45 and older in 19 countries, around 7% reported ever having long COVID and 5% were still experiencing persistent symptoms at the time of the survey (OECD, 2025[22]). Among those who reported experiencing COVID-19, almost 14% reported persistence of long COVID symptoms beyond three months, and 6.5% reported persistence beyond 12 months. Long COVID patients consistently reported poorer self-rated physical and mental health than those without long COVID (OECD, 2025[22]). Women also tend to experience higher rates of long COVID (OECD, 2021[5]; OECD, 2025[22]).

The impacts of long COVID vary across countries and evidence is still emerging. According to recent OECD modelling, an estimated 5.3% of people across OECD and EU countries were living with long COVID on average in 2021, with healthcare costs amounting to between 0.6% and 0.8% of total health expenditure (OECD, 2026[4]). Long COVID significantly affected labour markets, reducing the OECD and EU workforce by approximately 1% on average in 2021. In the coming decade, prevalence is projected to level off at between 0.6% and 1.0% of the OECD population, although long COVID may continue to cost health systems roughly USD 11 billion each year, with annual GDP losses expected to range between 0.1% and 0.2% (ibid).

2.1.4. Impact on care pathways for non-communicable diseases

Care pathways for patients with chronic conditions were significantly disrupted due to COVID-19. In OECD and EU countries, the health burden of NCDs has been of utmost concern for decades, with diseases of the circulatory system and cancer remaining the leading causes of mortality in 2021, accounting for 32% and 22% of all deaths in the EU (OECD/European Commission, 2024[23]), and 28% and 21% of all deaths across OECD countries (OECD, 2023[16]), respectively. In response to the emerging SARS-CoV-2 virus, most countries imposed far-reaching non-pharmaceutical interventions, including an extensive restructuring of health systems, stay at home orders, quarantine mandates, among others (WHO, 2020[24]). The disruption of health systems and daily life brought by the COVID-19 pandemic had unforeseen circumstances in the management and prevention of NCDs (Table 2.1).

Table 2.1. In its early stages, COVID-19 disrupted care pathways for NCDs

Cardiovascular care	Cancer care	General health services
• Decline in acute coronary syndrome admissions during first lockdowns • Decline in acute stroke admissions during first lockdowns • Decline in cardiovascular interventions • Rise in time to door-to-door treatment • Decline in median length of stay	• Decline in screening procedures in selected OECD countries • Decline in cancer diagnoses and change in stage at diagnosis • Decline in surgical procedures	• Decline in total number of doctor's consultations • Rise in unmet medical needs • Rise in foregone or postpone care

Source: OECD analysis based on review of the literature.

Cardiovascular care pathways

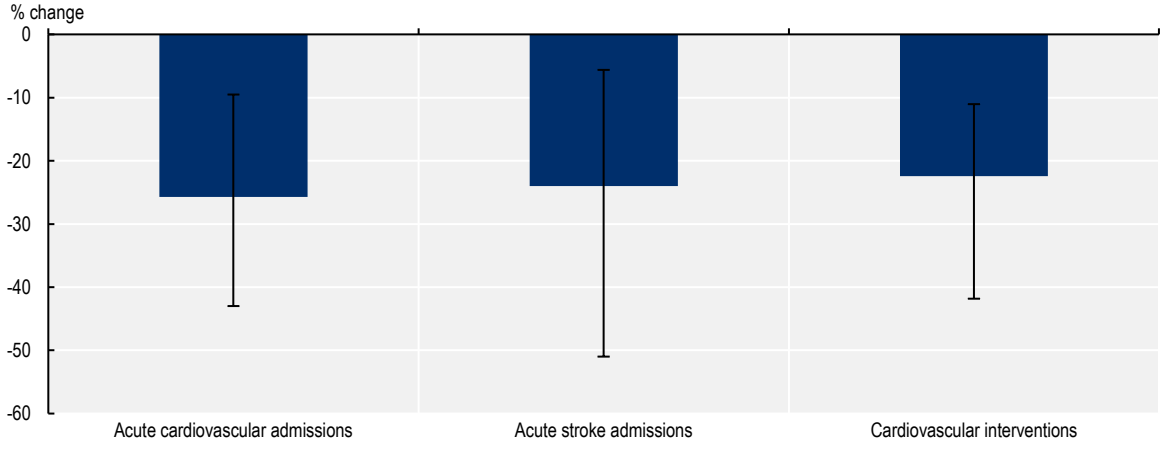
The first months of the COVID-19 pandemic brought an abrupt and dramatic decline in hospital admissions for life-threatening cardiovascular conditions. Across 17 OECD countries, admissions for several cardiovascular conditions fell by an average of 26% between March and May 2020 compared with the same period in 2019 (Figure 2.3), ranging from more moderate levels in Japan (-9.5%) (Arai et al., 2022[25])

to steeper levels in Italy (-43%) (Severino et al., 2020[26]). Admissions for acute stroke followed a similar pattern, decreasing nearly 24% on average across 11 OECD countries (Figure 2.3), with reductions exceeding 50% in Greece (Katsouras et al., 2021[27]) and 6% in Japan (Yoshimoto et al., 2022[28]).

The reductions in hospital admissions were compounded by declines in cardiovascular procedures. Across 8 OECD countries, cardiovascular interventions fell by an average of 22% during the early months of 2020 compared to the 2019 levels (Figure 2.3), with the steepest decline in the United Kingdom (Leyva et al., 2021[29]). Delays in treatment also lengthened. In Belgium, the median interval between hospital arrival and reopening a blocked artery (i.e. door-to-ballon time) increased by around 15% (Claeys et al., 2020[30]) and in France care management time for some patients with acute coronary events increased by over 40% (Lesaine et al., 2022[31]). Increases of around 11% were seen with total treatment delay for myocardial infarction patients in the Netherlands and door-to-needle times for stroke patients in Australia (Sturkenboom et al., 2022[32]; Cadilhac et al., 2021[33]). Median length of stay during March and May of 2020 for various cardiovascular patients decreased in several countries, including the United States, the United Kingdom, Israel and Germany, compared to the same period in 2019 (Bhatt et al., 2020[34]; Mafham et al., 2020[35]; Kobo et al., 2020[36]; Ueberham et al., 2021[37]).

Figure 2.3. Average percentage reduction in cardiovascular care in OECD during COVID-19 pandemic

Percent change during the first months of the pandemic compared with pre-pandemic reference period



Note: Whiskers represent the minimum and maximum reduction in cardiovascular care across OECD countries. Data come from different studies across various time periods in 2020 compared to 2019 reference periods and are not necessarily directly comparable.
Acute cardiovascular admissions (including cute coronary syndromes [ACS] and heart failure): Chart displays percentage change of hospital admissions in the first months of the COVID-19 pandemic compared to pre-pandemic reference periods (Severino et al., 2020[26]; Aldujeli et al., 2021[38]; Piuhola et al., 2020[39]; Sung et al., 2021[40]; Plat et al., 2023[41]; Lavie et al., 2022[42]; Claeys et al., 2020[30]; Rodríguez-Leor et al., 2020[43]; Mohammad et al., 2020[44]; Zeymer et al., 2023[45]) (Mafham et al., 2020[35]; Mefford et al., 2021[46]; Arai et al., 2022[25]; Kempers et al., 2023[47]; Gellert et al., 2023[48]; Kubica et al., 2021[49]). Data from Denmark is an average of four different studies focussing on ACS and atrial fibrillation admission rates from Mar-20 to May-20 (Østergaard et al., 2021[50]; Lauridsen et al., 2020[51]; Andersson et al., 2020[52]; Holt et al., 2020[53]). Data from Greece is an average of three studies focussing on ACS admissions (Papafaklis et al., 2020[54]; Katsouras et al., 2021[27]; Katsouras et al., 2021[55]).
Acute stroke admissions. Chart displays percentage change of hospital admissions in the first months of the COVID-19 pandemic compared to pre-pandemic reference periods (Yoshimoto et al., 2022[28]; Douiri et al., 2021[56]; Kempers et al., 2023[47]; Raymaekers et al., 2021[57]; Miękisiak et al., 2022[58]; Libruder et al., 2021[59]; Campanile et al., 2021[60]; Katsouras et al., 2021[27]; the Swiss Stroke Registry Investigators, 2022[61]). Data from Germany is an average from studies by (Richter et al., 2021[62]; Hoyer et al., 2020[63]; Dengler et al., 2022[64]). Data from the United States is an average from studies by (de Havenon et al., 2021[65]; de Havenon et al., 2021[66]; Sheng et al., 2021[67]; Schirmer et al., 2020[68]; Rodrigues, Jin and Pendharkar, 2022[69]; Nogueira et al., 2021[70]; Myers et al., 2022[71]).

Cardiovascular interventions: Data shows averages from different cardiovascular interventions from the first months of the COVID-19 pandemic compared to pre-pandemic reference periods (Cai, Fisher and Loa, 2021[72]; Benali et al., 2022[73]; Wood-Kurland et al., 2023[74]; Zeymer et al., 2023[45]; Connolly et al., 2021[75]; Legutko et al., 2020[76]). Data from the United States is an average of data from (Varghese et al., 2022[77]; Nogueira et al., 2021[70]; Maraey et al., 2023[78]). Data from the United Kingdom is an average of data from (Leyva et al., 2021[29]; Kwok et al., 2020[79]; Mafham et al., 2020[35]).
Source: OECD review of academic literature as above.

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These care disruptions had clinical repercussions. Mortality from cardiovascular causes increased sharply in several OECD countries. For example, Israel reported a 66% rise in in-hospital mortality from acute stroke (Libruder et al., 2021[59]), the United States saw a 44% increase in acute myocardial infarction deaths (Mefford et al., 2021[46]) and Spain a 47% rise in ACS (Rodríguez-Leor et al., 2020[43]). Broader cardiovascular mortality also rose by 8% in the United Kingdom (Wu et al., 2020[80]) and by as much as 46% in Lithuania (Čelutkienė et al., 2022[81]). Beyond hospitals, out-of-hospital cardiac arrest outcomes worsened across multiple countries (Katasako et al., 2023[82]; Hosomi et al., 2022[83]; Chan et al., 2021[84]; Baert et al., 2020[85]).

Cascade of cancer care

The cascade of cancer care, from screening and diagnosis to treatment and follow-up, was also strained. At the outset of the pandemic, 16 out of a group of 21 countries temporarily paused cancer screening programmes (Fujisawa, 2022[86]). The number of cancer screening procedures declined by roughly 26% on average across 6 OECD countries over several months in 2020 compared to the prior year's levels (Figure 2.4). Although most programmes resumed later in the year, the backlog proved difficult to recover. From 2020 to 2022, breast and cervical screening participation remained below 2017-2019 levels in the majority of OECD countries (Figure 2.5). The long-term impact on colorectal cancer screening is less pronounced, with just over half of OECD countries (11 of 20) reporting lower screening rates in 2020-2022 versus 2017-2019, although the OECD average remains stable.

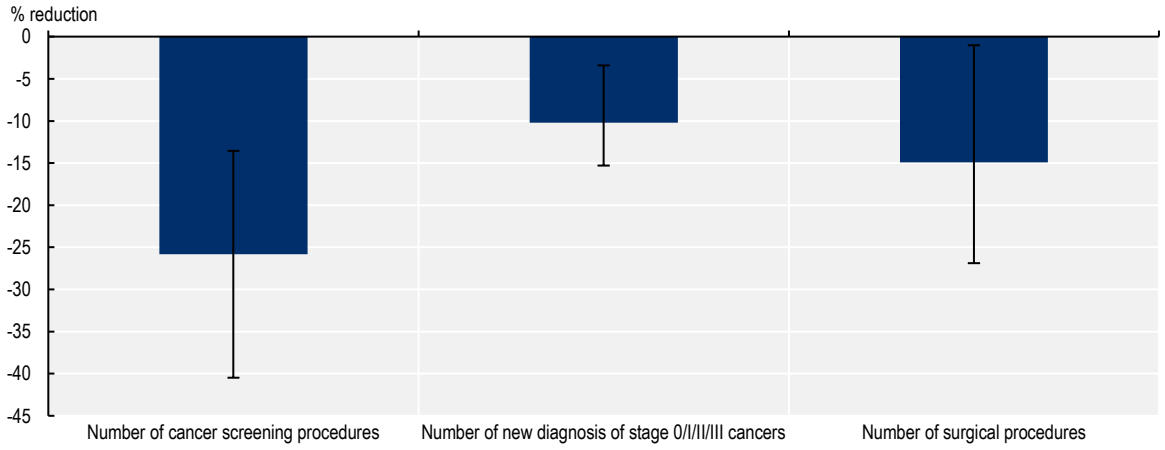
The diagnostic pathway also faltered. In the early months of the pandemic, studies showed a substantial reduction in diagnoses in many OECD countries and every cancer type compared to the same periods in 2019, ranging from a 58% reduction in the United Kingdom (Rutter et al., 2021[87]) to an 11.5% reduction in France (Blay et al., 2021[88]). Some recovery occurred later in the year, but by the end of 2020, many countries still reported fewer diagnoses than expected (Greene et al., 2022[89]; Nogueira et al., 2023[90]; Drescher et al., 2021[91]; Johansson et al., 2022[92]; Peacock et al., 2021[93]; Zagar et al., 2022[94]; Okuyama et al., 2022[95]). Emerging evidence also suggests that cancers were being diagnosed at later stages. The number of new early-stage cancer diagnoses declined by about 10% on average across 6 OECD countries (Figure 2.4), while the proportion of metastatic cancers increased in some countries such as France (Blay et al., 2021[88]), Italy (Rottoli et al., 2022[96]; Cantini et al., 2022[97]) and the Netherlands (Eijkelboom et al., 2021[98]; Deukeren et al., 2022[99]; Toes-Zoutendijk et al., 2022[100]).

Treatment was similarly disrupted. During the first months, the number of patients treated decreased according to several studies (Eijkelboom et al., 2021[98]; Blay et al., 2021[88]; Amador et al., 2021[101]; Gathani et al., 2021[102]; Morris et al., 2021[103]; Kleemann et al., 2022[104]). The number of surgical cancer procedures fell by roughly 15% across 5 OECD countries in which there are data for several cancer types, with the estimated reductions ranging from 1% in New Zealand (Gurney et al., 2021[105]) to 27% in the United Kingdom (Nossiter et al., 2022[106]) (Figure 2.4). Time from diagnosis to intervention lengthened in several systems (Kripalani et al., 2022[107]; Deukeren et al., 2022[99]), reflecting bottlenecks in testing, surgical capacity and staff availability. The few studies examining survivorship signalled a 26.5% decline in median overall survival among metastatic colorectal cancer patients in France from May to September 2020 (Thierry et al., 2021[108]), and by around three months for esophagogastric cancer patients from March to September 2020 in Scotland (Baxter et al., 2023[109]). Although the overall impact

of the pandemic on cancer mortality remains uncertain due to limited long-term data, evidence suggests that COVID-19 likely led to a substantial increase in cancer-related deaths resulting from delays in diagnosis and treatment (Lai et al., 2020[110]; Hanna et al., 2020[111]; Sud et al., 2020[112]; Jabbal et al., 2023[113]; Blay et al., 2021[88]).

Figure 2.4. Average percentage reduction in cancer care in OECD during the COVID-19 pandemic

Percent change during the first months of the pandemic compared with pre-pandemic reference period

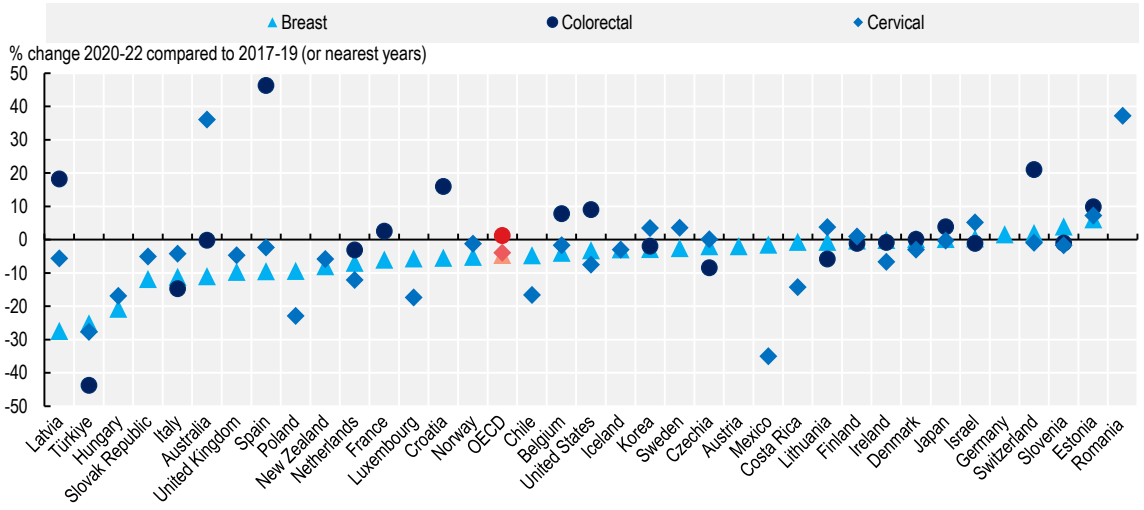


Note: Whiskers represent the minimum and maximum reduction in cancer care across OECD countries. Data come from different studies across various time periods in 2020 compared to 2019 reference periods, and are not necessarily directly comparable.
Average number of cancer screening procedures reflect oesophagogastric, breast, respiratory, gynecological, urological and colorectal cancers in 2020 compared to 2019 reference periods. For France, data average reflects oesophagogastric, breast, respiratory, gynecological, urological and colorectal cancers in 2020 compared to 2019 (Le Bihan Benjamin et al., 2022[114]). Netherlands reflects faecal test invitations for colorectal screening in 2020 compared to 2018 and 2019 average (Domper-Arnal, Hijos-Mallada and Lanas, 2022[115]). Australia reflects the number of colonoscopies in Jan-Sept 2020 compared to same period in 2019 (Williams et al., 2021[116]). Austria reflects mean rate of colonoscopies per week in Mar-Sept 2020 compared with same period 2019 (Domper-Arnal, Hijos-Mallada and Lanas, 2022[115]). Korea reflects number of breast screening in 2020 compared with 2019 (Kang et al., 2021[117]) and the United States average reflects colorectal and breast cancer screenings from Apr-Jun 2020 compared with same period in 2019 (Jabbal et al., 2023[113]; Oakes et al., 2023[118]).
Average for the number of new diagnosis of stage 0/I/II/III cancers reflect the following: Data from Iceland, Sweden, Norway and Denmark refer to the proportion of all cancers diagnosed at in situ stage (Stage 0) in March – Dec 2020 compared to same period 2019 (Johansson et al., 2022[92]). Data from Italy average the proportion of colorectal, lung and breast cancers diagnosed at Stage I to III from 2020 to 2021 compared to 2018 to Feb 2020 (Mentrasti et al., 2022[119]; Rottoli et al., 2022[96]; Cantini et al., 2022[97]; Mentrasti et al., 2022[120]). Data from the Netherlands averages the proportion of breast, prostate and colorectal cancers from March to October 2020 compared with same periods in 2018 and 2019 average (Eijkelboom et al., 2021[98]; Deukeren et al., 2022[99]; Toes-Zoutendijk et al., 2022[100]).
Majority of data on the number of surgical procedures refers to all cancers from whole 2020/from March onwards, compared to same periods 2019 (Le Bihan Benjamin et al., 2022[114]), except the following: data from Italy refers to colorectal surgeries only (Rottoli et al., 2022[96]), the Netherlands shows data from cervical cancers from the whole 2020 period (Algera et al., 2022[121]), New Zealand averages data from prostate, colorectal and lung cancers (Gurney et al., 2021[105]) and the United Kingdom shows data from prostate cancers from Mar – Dec 2020 compared with same period 2019 (Nossiter et al., 2022[106]).
Source: OECD review of academic literature as above.

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Figure 2.5. Cancer screening programmes were disrupted during the acute phase of the pandemic

Percent change in screening programmes 2020-2022 average compared to 2017-2019 (or nearest years) average



Note: Based on programme data for all countries except the United States, Spain, Switzerland and Japan that refer to survey data. Data represent the percentage differences between the averages over the 3-year period 2020 to 2022 (post-COVID-19) compared to 2017 to 2019 (pre-COVID-19). For some countries, data are available for only one or two years. Breast cancer includes to mammography screening in women aged 50-69 within the past two years; cervical cancer includes cervical cancer screening in women age 20-69 within the past three years; colorectal cancer includes colorectal cancer screening coverage of the population aged 50-74.
Source: (OECD, 2024[122]), Screening (indicator), https://data-explorer.oecd.org/s/3gp.

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Health services for NCD patients

The reorganisation of health services during the COVID-19 pandemic largely succeeded in maintaining access to care and preserving quality, but it also created a substantial backlog due to postponed elective procedures and medical appointments. This backlog disproportionately affected patients with chronic conditions, particularly older individuals with comorbidities, who are already at higher risk of severe complications and mortality (Box 2.2). On average, across 27 OECD countries, in-person consultations decreased from 2019 to 2020 by -1.1 per capita, with Italy and Lithuania seeing the most significant drops at -5.2 and -3.2 consultations per capita, respectively (OECD, 2023[17]). However, a rapid shift toward virtual care helped offset some of the pressure on hospitals (Zachrison, Yan and Schwamm, 2021[123]; Cantor et al., 2023[124]), ensuring that patients could still access healthcare remotely while reducing overcrowding of health systems.

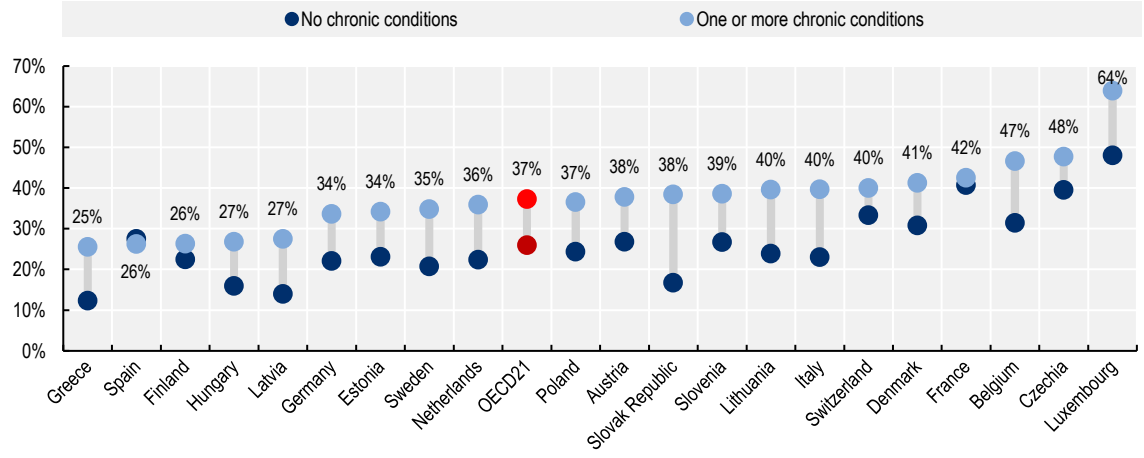
Despite efforts to adapt, the significant pressure on health services led to widespread unmet needs and disruptions to routine care. On average, across 22 OECD countries with comparable data, over one in five people (22%) reported skipping a necessary medical examination or treatment during the first year of the pandemic, ranging from 10% in Denmark, to 35% in Hungary (OECD, 2023[17]). Projections done by (Fotopoulou et al., 2022[125]) showed that if the number of COVID-19 patients remained high, delays in elective surgeries would lead to significant unmet medical care needs for non-COVID-19 patients who rely on routine care and elective procedures for the management of their conditions. A study by (Sarzynski et al., 2024[126]) showed that there was a substantial decrease in patient transfers during high-surge periods, while COVID-19-related transfers accounted for a majority of transfers, reflecting the tendency to maintain care for non-COVID patients and vital elective procedures in their respective locations. Moreover, a study by (Crombez and De Staelen, 2024[127]) found that the challenges in reorganising healthcare during the pandemic – such as maintaining quality and access to care – were influenced by each country's level

of preparedness and health system resilience before the pandemic. Additionally, pre-pandemic conditions may have also impacted the severity of COVID-19 in different countries (ibid).

Those with chronic conditions were hit hardest. During the first year of the pandemic, an average of 37% of individuals with one or more chronic conditions across 21 OECD countries reported missing or delaying appointments or clinical procedures, compared to approximately 25% of those without chronic conditions (Figure 2.6) (OECD, 2023[17]). Furthermore, the percentage of older adults with multimorbidity – defined as having two or more chronic conditions – reporting cancelled or postponed care due to COVID-19 ranged from 37% in the United States to 11% in Germany, with the OECD average among 11 countries at 11% (OECD, 2023[17]).

Figure 2.6. Proportion of people with chronic health conditions having forgone or postponed care

Percentage of people aged 50 years and over who reported forgoing or postponing medical care due to COVID-19, with and without a self-reported chronic health condition, 21 OECD countries



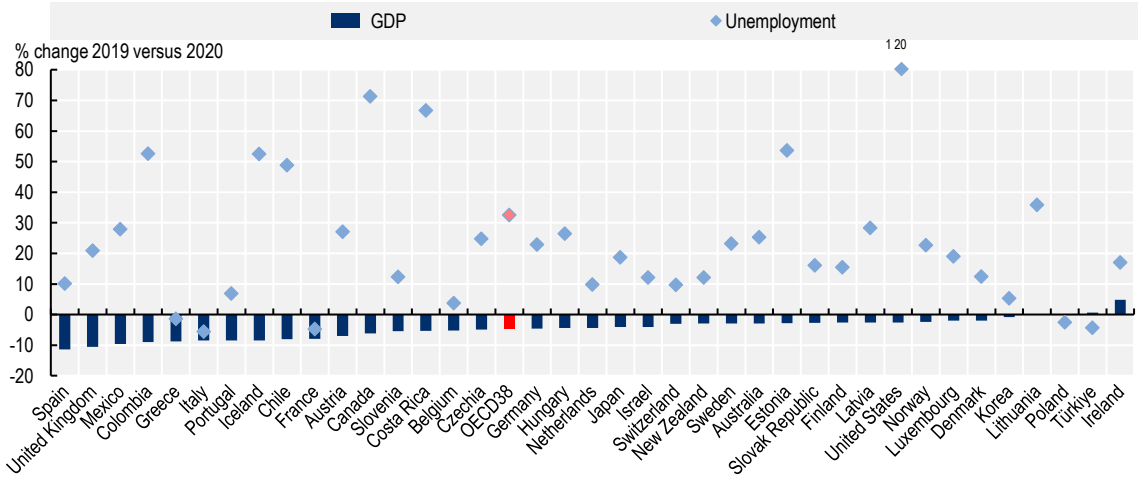
Note: Chronic conditions include: acute myocardial infarction/heart failure, high blood pressure or hypertension, high cholesterol, stroke or vascular disease, diabetes or high blood sugar, chronic lung disease, Parkinson's disease, Alzheimer's disease, dementia or other serious memory problems, rheumatoid arthritis, osteoarthritis or other rheumatism or chronic kidney disease. Data collected between June and August 2020.
Source: OECD (2023[17]), *Ready for the Next Crisis? Investing in Health System Resilience*, Figure 6.3, https://doi.org/10.1787/1e53cf80-en.

2.1.5. Social impact

The overall burden associated with the COVID-19 pandemic extends well beyond health, with profound social and economic impacts that disproportionately affected disadvantaged populations. The pandemic exacerbated socio-economic inequalities, job insecurity, and negative educational outcomes and led to spikes in discrimination (Berchet, Bijlholt and Ando, 2023[128]). Chapter 7 provides a brief overview of the impact on children and young people through temporary school closures. The onset of the COVID-19 crisis led to the closure of many activities and businesses, resulting in a varied impact on the unemployment rate across OECD countries and substantial rises in overall labour underutilisation rates (OECD, 2021[5]). Between 2019 and 2020, the average unemployment rate across OECD countries increased by around 32% (1.7 p.p.), reaching 7.1% in 2020, with particularly sharp rises in the United States and Canada (Figure 2.7). Over the same period, labour underutilisation across OECD countries rose by nearly 37%, reaching 17% in 2020 (an increase of 4.5 p.p.) (Figure 2.7), and the share of 15-29 year-olds not in employment, education or training (NEET) grew by nearly 6% (OECD, 2021[5]). GDP declined across almost all OECD countries, falling by an average of around 5% between 2019 and 2020 (Figure 2.7).

Figure 2.7. GDP and unemployment trends pre-pandemic and during

Percent change 2020 compared to 2019



Note: The OECD area unemployment rate is calculated as the total number of unemployed people in all OECD countries as a percentage of the total labour force (i.e. the unemployed plus those in employment); this is equivalent to an average of unemployment rates of all OECD countries weighted by the labour force of each country. Data for Germany in 2020 are provisional and might be subject to low reliability due to technical issues with the introduction of the new German system of integrated household surveys.
Source: Adapted from OECD (2021[5]), COVID-19 *and Well-being: Life in the Pandemic,* Figures 2.1 and 2.7, https://doi.org/10.1787/1e1ecb53-en.

In terms of broader labour impacts, 14% of workers in 19 European OECD countries felt it was "likely they would lose their job" within three months, and nearly 1 in 3 people in 25 OECD countries reported financial difficulties (OECD, 2021[5]). Greece and Latvia saw some of largest changes in job security, with roughly 10% more people fearing job loss between April-June 2020 and February-March 2021, whereas Denmark and Slovenia reported the smallest changes. Socially disadvantaged populations, including younger, less educated and individuals belonging to racial/ethnic minority groups, faced greater financial strain – often occupying low income, part-time jobs and working in more precarious working conditions. Commonly over-represented in the leisure and hospitality, tourism and retail industries these population groups faced a higher risk of job loss due to limited teleworking opportunities. Consequently, at the peak of the pandemic almost one in five OECD households struggled to make ends meet (OECD, 2021[5]).

2.2. COVID-19 had mixed impacts on lifestyle factors that influence the burden of NCDs

The COVID-19 pandemic led to significant social, behavioural, and economic disruptions, altering some lifestyle-related risk factors associated with the burden of non-communicable diseases (NCDs) (WHO, 2020[129]). To better understand the pandemic's impact, observed post-pandemic trends in major NCD risk factors were compared with projections based on pre-pandemic linear trends. Table 2.2 shows estimated changes in tobacco use, alcohol consumption, and obesity across 28 OECD and 5 non-OECD EU/EEA countries during the COVID-19 period (2020-2022), relative to projected levels. On average across the 28 OECD countries included, the prevalence of tobacco use among the population aged 15 years and older was estimated to be +1.41 p.p. higher (around a 10.9% increase) than predicted, with all countries reporting higher-than-predicted smoking prevalence despite variations in magnitude. This suggests that COVID-19 slowed the decline in overall smoking prevalence. By contrast, in the same period and set of

countries, calendar year per-capita alcohol consumption among persons aged 15 years and older was lower than predicted, averaging 0.40 litres lower (around a 3.8% decrease) compared to projections. The impact on obesity was marginal, with overall prevalence, on average, +0.11 p.p. higher (around a 0.5% increase) than predicted, possibly due to the lag between changes in energy balance and observable weight shifts, compounded by the short assessment period.

Table 2.2. Shifts in major NCD risk factors during COVID-19 from projected levels

Estimated average change in major risk factor levels in 2020-2022 (or available years) compared to what would have been expected in those years if following a linear pre-pandemic trend, based on data from 28 OECD and 5 non-OECD EU/EEA countries

	Tobacco		Alcohol consumption		Obesity	
Austria	▲	3.34	▼	-0.36	▲	0.18
Belgium	▲	0.19	▼	-0.78	▲	0.18
Czechia	▲	0.32	▼	-1.30	▲	0.20
Denmark	▲	2.95	▲	0.32	▲	0.12
Estonia	▲	1.81	▼	-0.92	▼	-0.07
Finland	▲	1.47	▲	0.38	▲	0.16
France	▲	0.14	▼	-0.84	▲	0.02
Germany	▲	1.25	▼	-0.28	▲	0.04
Greece	▲	2.50	▼	-0.93	▲	0.08
Hungary	▲	0.25	▼	-0.68	▲	0.20
Iceland	▲	4.36	▼	-0.37	▲	0.13
Ireland	▲	1.79	▼	-0.79	▲	0.07
Israel	▲	0.87	▼	-0.06	▲	0.07
Italy	▲	0.08	▼	-1.07	▲	0.09
Latvia	▲	0.62	▼	-0.47	▼	-0.02
Lithuania	▲	0.67	▲	0.50	▲	0.03
Luxembourg	▲	0.33	▼	-0.56	▲	0.12
Netherlands	▲	1.02	▼	-0.29	▲	0.08
Norway	▲	5.46	▲	0.78	▲	0.10
Poland	▲	1.35	▲	0.01	▲	0.18
Portugal	▲	0.37	▼	-1.41	▲	0.15
Slovak Republic	▲	0.66	▲	0.39	▲	0.24
Slovenia	▲	0.21	▼	-0.64	▲	0.58
Spain	▲	0.31	▼	-2.24	▲	0.02
Sweden	▲	2.95	▲	0.39	▲	0.10
Switzerland	▲	0.12	▼	-0.07	▲	0.13
Türkiye	▲	0.45	▼	-0.04	▼	-0.12
United Kingdom	▲	3.66	▲	0.04	▲	0.02
Bulgaria	▲	1.03	▼	-0.58	▲	0.03
Croatia	▲	0.34	▼	-0.62	▲	0.25
Cyprus	▲	0.86	▼	-1.34	▲	0.10
Malta	▲	0.76	▼	-1.75	▲	0.12
Romania	▲	0.36	▲	0.08	▲	0.37
OECD28	▲	1.41	▼	-0.40	▲	0.11
EU27	▲	1.03	▼	-0.58	▲	0.13

Note: Tobacco: Age-standardised prevalence of current tobacco use among the population aged 15 years and older. Alcohol: Total (recorded and unrecorded) alcohol consumption per capita among persons aged 15 years and older within a calendar year (in litres (L) of pure alcohol). Obesity: Age-standardised prevalence of obesity in persons aged 18 and over (defined as body mass index (BMI) ≥ 30 kg/m². Data show the difference between the average of observed values in 2020-2022 (or available years) and the average of values predicted for 2020-2022 based on a pre-pandemic linear trend for years 2010-2019 for alcohol and obesity and 2000-2015 for tobacco. For each risk factor, increases are coloured in red, and decreases are coloured in blue.
Increases
Decreases
Source: OECD analysis using data from The WHO's Global Health Observatory, 2024.

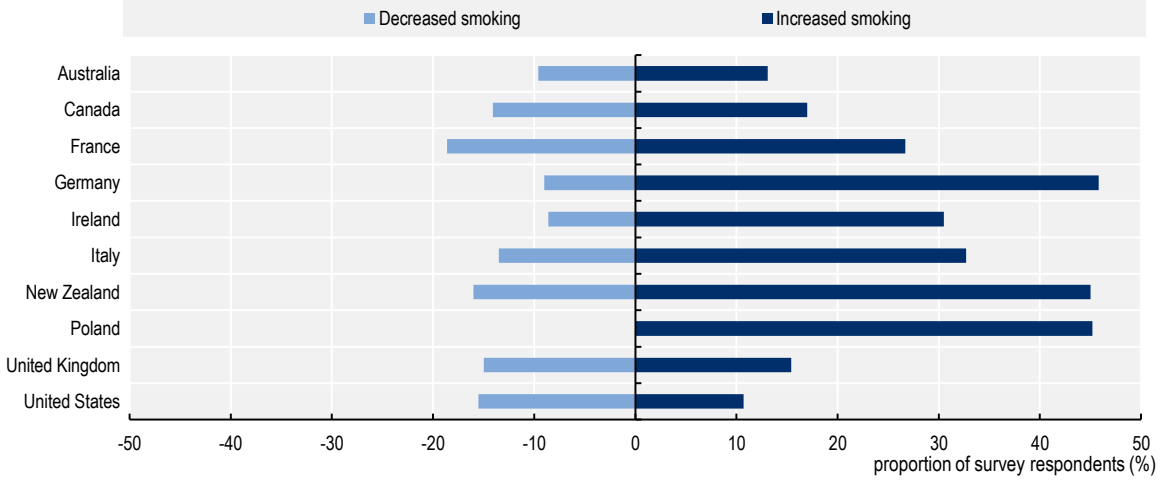
The overall changes in lifestyle-related risk factors relative to expected levels presented in Table 2.2 may be over- or underestimated and reflect the heterogeneous behavioural responses of populations during the pandemic, as highlighted in the sections below.

2.2.1. Tobacco consumption

Even before the COVID-19 pandemic, tobacco exposure was the second leading global risk factor for early death and disability, responsible for over one-fifth of all NCD-related deaths, including a substantial share of cardiovascular and respiratory diseases as well as cancers (WHO, 2023[130]).

During the pandemic, smoking behaviours shifted in complex and sometimes contradictory ways across OECD countries. In 11 OECD countries with survey data, current smokers generally reported no change in their smoking habits, but whose who did change their behaviour generally reported smoking more rather than smoking less (Figure 2.8). Across OECD countries, reductions in smoking behaviour were observed among some population groups in some countries such as Italy and Denmark, but among those who continued to smoke, daily use increased in some countries such as France and Germany (Odone et al., 2020[131]; Fosgaard, Pizzo and Sadoff, 2022[132]; Guignard et al., 2021[133]; Koopmann et al., 2021[134]).

Figure 2.8. More smokers reported smoking more than smoking less during COVID-19



Note: Data come from national survey responses to smoking habits during the first months of the COVID-19 pandemic and are not necessarily directly comparable. Italy data corresponds to regional data in Northern Italy; all other data correspond to national samples in periods ranging from March to June 2020.
Source: Australia, Canada, the United Kingdom and the United States April to June 2020: (Gravely et al., 2021[135]); France 30 March to 1 April 2020: (Guignard et al., 2021[133]); Germany 8 April to 11 May 2020: (Koopmann et al., 2021[134]); Ireland 23 April to 1 May 2020: (Reynolds et al., 2021[136]); Italy March to May 2020: (Munarini et al., 2022[137]); New Zealand 15 to 18 April 2020: (Gendall et al., 2021[138]); Poland 17 April to 1 May 2020 (Sidor and Rzymski, 2020[139]).

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Smoking patterns also varied by age group. Among adolescents and young adults, studies reported mixed results, with some studies showing reduced tobacco use (Villanueva-Blasco et al., 2023[140]; Rogés et al., 2021[141]) and others showing no change or even increases (Barrera-Núñez et al., 2022[142]; Jackson et al., 2023[143]). Among adults, smoking generally declined (Guignard et al., 2021[133]; Koyama et al., 2021[144]). Increased use was most often linked to stress, anxiety, unemployment and income loss, as well as remote work and higher education levels, all of which are factors that may have shaped daily routines and coping mechanisms (Guignard et al., 2021[133]; Wiley et al., 2022[145]; Loui et al., 2023[146]; Koyama et al., 2021[144]).

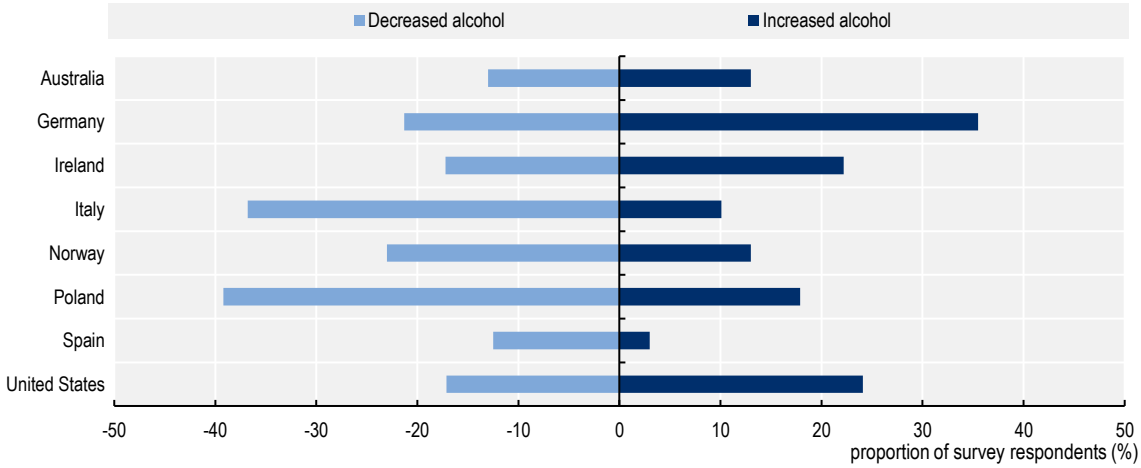
2.2.2. Harmful alcohol use

Similar to tobacco use, harmful alcohol consumption is also a major risk factor for NCD morbidity and mortality, directly linked to liver cirrhosis, pancreatitis, multiple cancers, haemorrhagic stroke, and hypertension (WHO, 2024[147]). A small group of heavy drinkers, between 4% and 14% of adults, consume between 31% to 54% of all alcohol consumed, bearing a disproportionate share of its health and social harms (OECD, 2021[148]).

The pandemic disrupted drinking patterns, but not uniformly. One OECD analysis showed that during the first wave of the COVID-19 pandemic, 44% of people across 11 OECD countries reported drinking more frequently in comparison to 25% reporting drinking less and 32% reporting no change (OECD, 2021[149]). Other findings reveal a more nuanced picture. In 8 OECD countries with survey data, most respondents reported no change in their alcohol consumption during COVID-19, but the picture was mixed for those who did change their behaviour (Figure 2.9).In terms of prevalence and average weekly use, several countries reported decreases in alcohol consumption from April 2020 to July 2020 compared to before the pandemic (Rossow et al., 2021[150]; Quadri et al., 2023[151]; Rossow et al., 2021[152]), although the United States and the United Kingdom were exceptions to this trend (Barbosa, Cowell and Dowd, 2021[153]; Rossow et al., 2021[152]).

Despite this mixed picture, the first few months of the pandemic saw an overall increase in alcohol consumption among heavier drinkers across eight European countries (defined in this study as those in the top 10% of alcohol consumption pre-pandemic), using data from the European Survey on Alcohol use and COVID-19 (Rossow et al., 2021[152]). In contrast, only small average changes in consumption were reported among other drinkers. Moreover, 7 of these countries reported a statistically significant increase in the proportion of heavy drinkers (those who drink more than 28 units per week) during the pandemic (Rossow et al., 2021[152]). This trend is consistent with emerging evidence showing an 18% pandemic-related increase in alcohol-attributable mortality across 19 EU countries compared with 2019, despite declining population-level consumption over this same time period (Rehm et al., 2025[154]). As with tobacco, factors commonly associated with increased alcohol use during the pandemic included psychosocial and economic stressors such as anxiety and depression, unemployment, reduced income, remote work, and a history of substance use disorder (Weerakoon, Jetelina and Knell, 2021[155]; Barrera-Núñez et al., 2022[142]; Booth et al., 2023[156]; Quadri et al., 2023[151]).

Figure 2.9. The impact of COVID-19 on alcohol consumption is mixed



Note: Data come from national survey responses to alcohol consumption during COVID-19 and are not necessarily directly comparable.
Source: Data from Spain corresponds to local hospital alcohol use disorder patients (Arias Horcajadas et al., 2022[157]) but results are consistent with average weekly use rates shown by (Rossow et al., 2021[152]). Rest of data corresponds to national samples from different studies in periods ranging through 2020 and 2021: Australia 16 to 30 September 2020 (Booth et al., 2023[156]); Germany 8 April to 11 May 2020 (Koopmann et al., 2021[134]) Ireland 23 April to 1 May 2020 (Reynolds et al., 2021[136]) Italy 3 to 15 April 2020 (Scarmozzino and Visioli, 2020[158]) Norway 15 to 20 April 2020 (Alpers et al., 2021[159]) Poland 8 to 18 April 2020 (Szajnoga, Klimek-Tulwin and Piekut, 2020[160]) Spain March to May 2020 (Arias Horcajadas et al., 2022[157]) United States March to April 2020, August 2020, December 2020 and April 2021 (Wittenberg et al., 2022[161]; Weerakoon, Jetelina and Knell, 2021[155]).

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2.2.3. Diet and physical activity

Unhealthy diets and physical inactivity, and their associated impacts on body mass index, are important risk factors for cardiovascular disease, diabetes, and cancers, among other NCDs (WHO, 2024[162]; OECD/WHO, 2023[163]). Unfavourable shifts in eating behaviours and physical activity patterns were accentuated by the mobility restrictions during the pandemic, potentially counteracting the gains made by policies promoting healthier lifestyles and accentuating the prevalence of overweight and obesity. Despite limited evidence, it appears that the majority of people in several countries reported a decrease in general activity levels during the initial months of the pandemic (Di Renzo et al., 2020[164]; Catucci, Scognamiglio and Rossi, 2021[165]; Granero et al., 2023[166]; Ochi et al., 2023[167]; Fearnbach et al., 2021[168]; Romero and Lv, 2022[169]). The effect on levels of physical activity among children and adolescents remains unclear, with some studies reporting a decline and others reporting no significant changes (OECD/European Commission, 2024[23]). Furthermore, studies have found that during there was an apparent trend towards more frequent, healthier, home-cooked meals during the early COVID-19 periods, but with more variable and conflicting results in regard to the increase or decrease in unhealthy snacking (Wdowiak-Szymanik et al., 2022[170]; Bennett et al., 2021[171]).

2.3. The OECD SPHeP-NCDs Model is used to assess the lasting impacts of COVID-19 on NCD burden

The COVID-19 pandemic acted as both a stress test and a mirror for societies' health behaviours. For some, it reinforced positive habits, while for others, it deepened risk factors for NCDs. Changes in the risk factors combined with severe disruptions in screening, diagnosis and treatment have created the conditions for a possible rise in NCDs over the coming years (Xu et al., 2024[172]). The OECD has developed the Strategic Public Health Planning for Non-Communicable Diseases (SPHeP-NCDs) model to quantify the impact of major risk factors on population health and the economy (see Annex 2.A for more details). The remainder of this chapter uses the SPHeP-NCDs model to estimate the impact of COVID-19 on the long-term health and economic burden of NCDs across 28 OECD and 5 non-OECD EU/EEA countries included in the analysis.

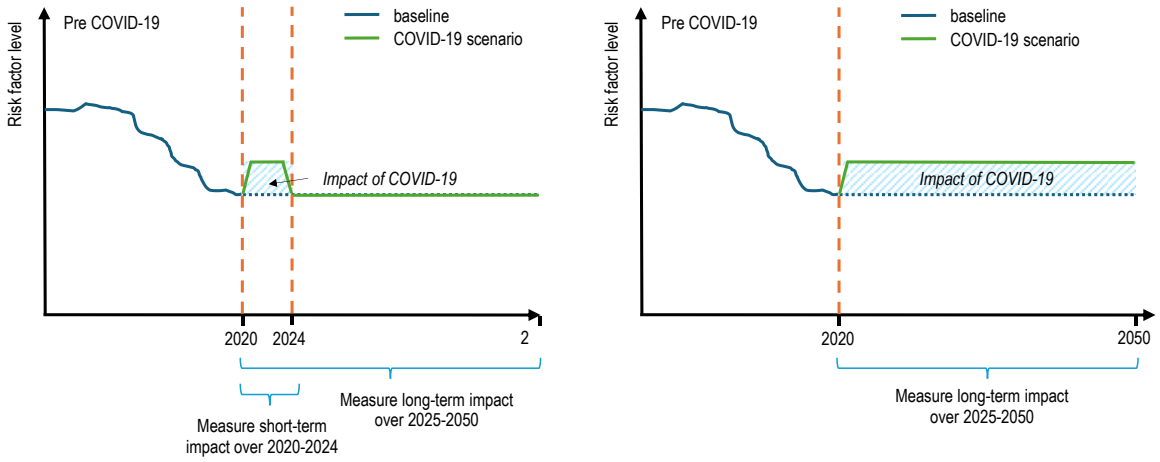
The impact of COVID-19 on the burden of NCDs – hereafter referred to as the "COVID-19-impact" – is estimated by comparing outputs of two different scenarios against a common baseline. The "baseline" scenario represents a counterfactual world without COVID-19, assuming that pre-COVID-19 risk factor levels remain unchanged and health systems continue to perform at pre-COVID-19 levels in treating NCDs. The two "COVID-19" scenarios represent alternative worlds in which exposure to key risk factors (i.e. tobacco use, alcohol consumption and obesity) are altered to reflect lifestyle changes during the COVID-19 pandemic and assume temporary declines in cancer survival due to diagnostic delays during the pandemic. This modelling exercise does not include other impacts of COVID-19, including on mental health or long COVID, and can be considered a conservative estimate with a certain degree of uncertainty. While Section 2.3 provides two illustrative scenarios, the true range of future impacts is likely to be broader, reflecting underlying uncertainties and the potential for additional economic effects, including those arising from changes in mental health and labour force participation.

The following two scenarios of "COVID-19" are modelled (see Figure 2.10):

- **Scenario 1 (temporary shock)**: The pandemic is assumed to produce only a short-lived disturbance in the population risk factors. Levels of the modelled risk factors are assumed to be altered linearly from the 2020 levels through 2021, remain stable until 2023 and return to pre-pandemic levels by 2024. Cancer survival rates are assumed to decline temporarily to reflect diagnostic and treatment delays but subsequently recover by end of 2024. From a practical standpoint, this scenario implies that individuals who had altered their habits during the COVID-19 pandemic would revert to their previous lifestyles by 2024. This scenario represents a more conservative estimate and can be interpreted as an upper-bound approximation of the NCD-related impact of COVID-19, as, even if risk factors return to pre-pandemic levels, individuals may still face an elevated long-term risk of developing NCDs.
- **Scenario 2 (permanent shock)**: The effect of the pandemic is assumed to endure through persistent shifts in risk factors. As in Scenario 1, risk factor levels are altered linearly through 2021, but remain permanently at that level through 2050, assuming that lifestyle changes adopted during the pandemic would persist throughout the duration of the simulation. Cancer survival rates are still assumed to dip temporarily, with complete recovery by end of 2024. This scenario represents a less conservative estimate and can be interpreted as an upper-bound approximation of the NCD-related impact of COVID-19.

Figure 2.10. Scenarios to model COVID-19 impact on the burden of NCDs

Modelled changes to the risk factors that impact the burden of NCDs under each scenario



Note: Illustrative, not based on real data. The green line denotes the theoretical changes to the risk factors that may influence the burden of NCDs. Under each scenario, cancer survival rates are also assumed to temporarily decline in the short-term with complete recovery by end of 2024.

The choice was made to present two scenarios of "COVID-19" to provide a hypothetical range of estimates, based on different assumptions regarding the projected duration of the impact of the pandemic while keeping the magnitude of the shock constant. These scenarios are projected into the future to be able to see the impact on NCDs, which takes time to materialise (e.g. tobacco consumption does not cause lung cancer immediately but may do so after several years). The impacts are measured over two time periods, 2020 to the end of 2024 (i.e. short-term impact) and 2025 to 2050 (i.e. long-term impact). These two time periods were chosen as Scenario 1 likely has a greater impact in the short-term than the long-term, with its impact diminishes over time, while Scenario 2 has the same impact as Scenario 1 in the short-term but has a sustained impact over the long-term. The model accounts for population ageing to avoid any misleading conclusion from demographic change.

The analysis models the impact of COVID-19-related changes to three major risk factors: tobacco smoking, harmful alcohol consumption, and obesity. The magnitude of the modelled shock to risk factors in the COVID-19 scenarios is based on the analysis presented in Section 2.2 in Table 2.2, which estimates the pandemic's impact by comparing post-pandemic trends in major NCD risk factors with projections from pre-pandemic linear trends. The overall impact on alcohol consumption in Table 2.2 was applied to moderate drinkers, while the impact applied to hazardous and harmful drinkers was extrapolated from Rossow et al. (2021[152]). It is important to note that the numbers used in the model are only estimates, and the real impact of COVID-19 on risk factor levels in some countries may be over or underestimated.

Beyond changes in risk factors, COVID-19 significantly affected care pathways for people with chronic conditions, as described in Section 2.1.4. Disruptions to cancer care, in particular, may have long-term consequences for cancer morbidity and mortality. Accordingly, in each "COVID-19" scenario the model assumes a temporary shock to 5-year cancer survival, using figures extrapolated from Sud et al.'s (2020[112]) modelling study in the United Kingdom, which estimates the impact of 3-month delays in cancer diagnosis on longer-term survival. The same shock was applied to all countries for a period of several years.

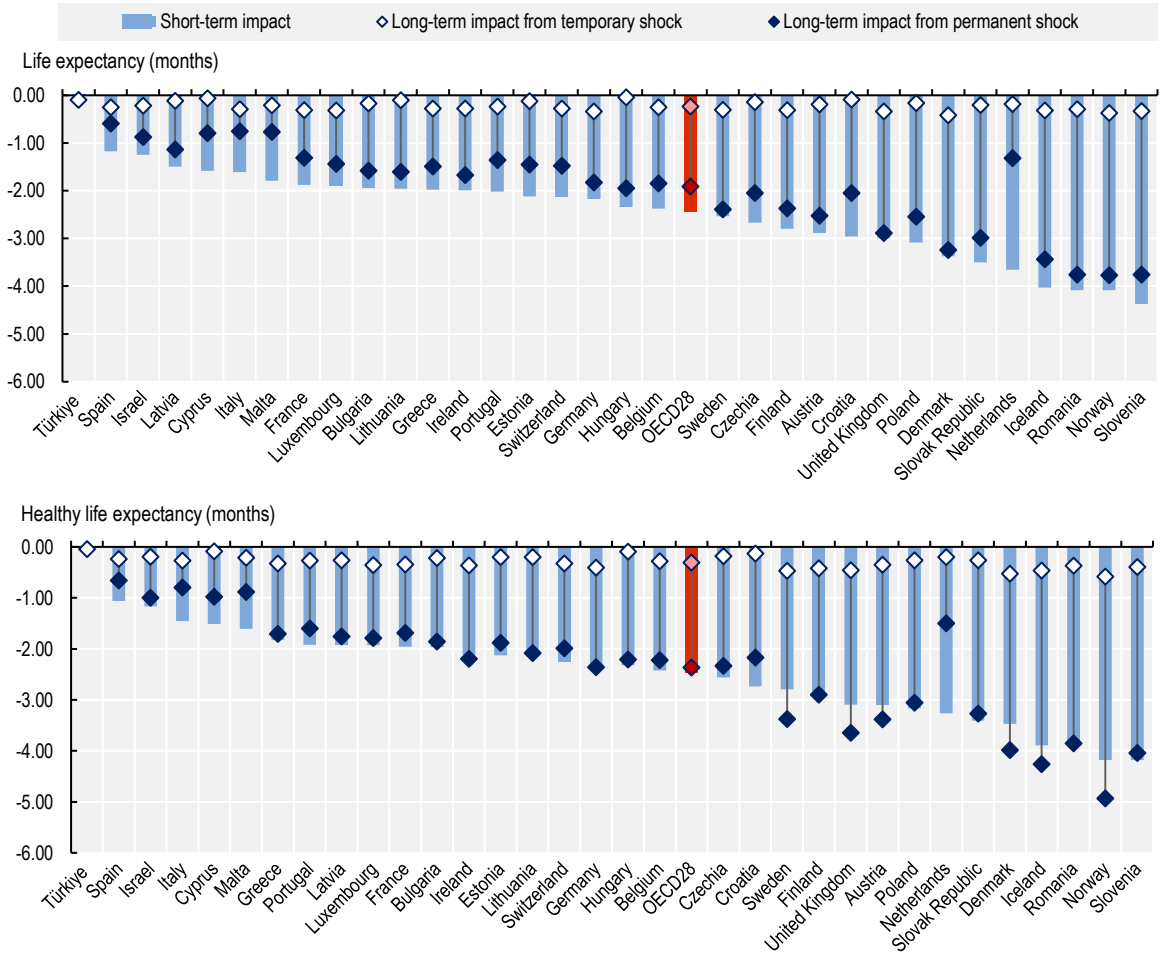
2.3.1. COVID-19s indirect effects on NCDs could shorten life expectancy

The indirect impacts of COVID-19 on NCDs is likely to have led to people living shorter lives, adding to the deaths directly caused by the virus. In the short term (i.e. between 2020 and 2024), changes in NCDs attributable to COVID-19 are estimated to have reduced life expectancy and healthy life expectancy (HALE) – a measure combining mortality and morbidity by quantifying the average number of years a person can expect to live in full health, accounting for years lived with illness or injury – by 2.4 months and 2.5 months, respectively, on average across the 28 OECD countries analysed, compared to a scenario where the pandemic never occurred (Figure 2.11). This is likely primarily driven by an increase in premature mortality from cancers and CVD over this time period. These indirect effects are considerable, representing about 20% of the overall impact of COVID-19, given that during the period 2019 to 2021 life expectancy at birth across the 28 OECD countries studied declined by around 11 months (i.e. from 81.1 years in 2019 to 80.2 years in 2021) (Eurostat, 2025[173]; OECD, 2025[174]).

In the long term (i.e. between 2025 and 2050), the detrimental impact of COVID-19 on life expectancy fades over time if risk factors and behaviours gradually return to pre-pandemic levels (i.e. the temporary shock in Scenario 1). However, if changes in risk factor levels observed during COVID-19 continue permanently (Scenario 2), life expectancy and HALE could remain lower over the long term, averaging 1.9 months and 2.4 months less, respectively, across 28 OECD countries by 2050 compared to a scenario where no COVID-19 occurred (Figure 2.11). It is important to note that changes in the modelled risk factors will also affect other NCDs not included in the model, so the estimated impact is therefore an underestimation of the overall effect.

Figure 2.11. Life expectancy and healthy life expectancy are reduced due to the indirect impact of COVID-19 on NCDs

Impact on life expectancy (LE) and health life expectancy (HALE) in months, average over 2020-2024 (short-term impact) and 2025-2050 (long-term impact)



Note: The "short-term impact" estimates the NCD-related impact of COVID-19 over the period 2020-2024, assuming disruptions to several key risk factors and declines in cancer survival over this time. The "long-term impact" estimates the NCD-related impact of COVID-19 over the period 2025-2050 under two scenarios, a "temporary shock" in which disruptions to risk factors are short-lived until 2024 and a "permanent shock" which assumes persistent shifts for the duration of the model to 2050. The temporary shock can be interpreted as a lower-bound approximation of the NCD-related impact of COVID-19, while the permanent shock can be interpreted as an upper-bound approximation.
Source: OECD SPHeP NCDs model, 2025.

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It is likely that COVID-19 may have lasting negative consequences on mental health, not only as a direct consequence from the pandemic itself (Section 2.1.2) but also indirectly through an expected rise in NCDs associated with changes in risk factors in the future. For example, analysis suggests that people with NCDs are at a higher risk of experiencing depression (Everard et al., 2025[175]). Having cancer is associated with a 15% increased risk of depression, people living with heart disease have an 18% increased risk, with diabetes an 18% increased risk, with stroke a 23% increased risk and with chronic lung disease a 27% increased risk of depression relative to those without. Multimorbidity further worsens mental health: one NCD increases the risk of depression by 21%, two by 42% and three or more by 50%.

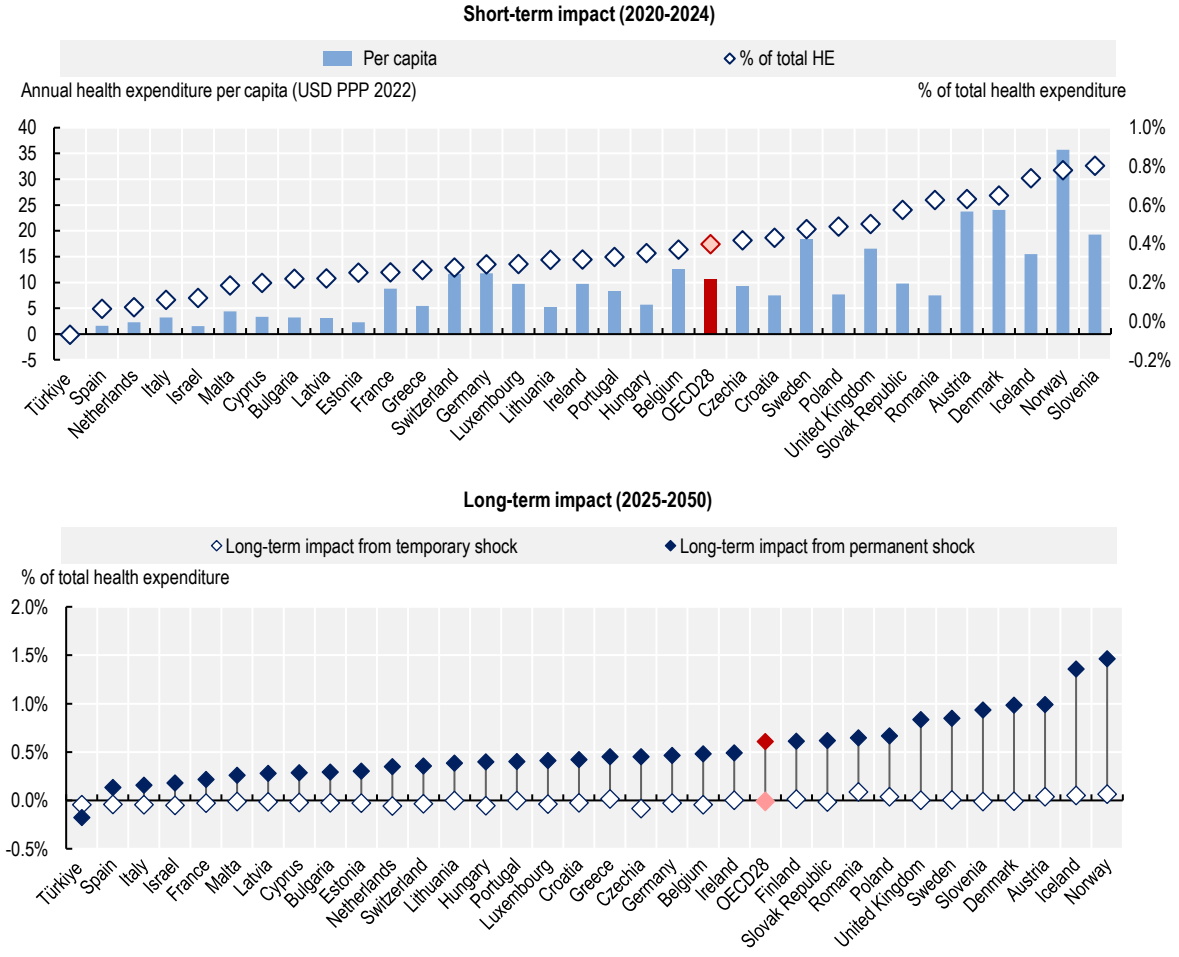
2.3.2. The lasting impacts of COVID-19 could also increase the future costs associated with NCDs

The lasting impacts of COVID-19 are expected to place additional pressure on health systems by increasing the future costs associated with NCDs. In the short term, an additional USD 11 per capita (adjusted for purchasing power parity – PPP) is projected to be spent per year, on average, across 28 OECD countries between 2020 and 2024 compared to a no-COVID baseline (Figure 2.12). This is equivalent to an increase of about 0.4% of overall annual health expenditure over this period. This can be viewed alongside the direct toll of the virus, with total health spending rising by around 8% on average across OECD countries at the peak of the pandemic in 2021, compared with a steady pre-pandemic annual growth rate of 3% (OECD, 2024[176]). The largest spending in Figure 2.12 is predicted to happen in countries with high treatment costs, greater baseline prevalence of risk factors, and larger estimated COVID-19-related risk factor changes. While in other countries, such as Türkiye, where both the level of some risk factors such as alcohol consumption, and the treatment costs are relatively low, the spending may remain broadly comparable to the baseline.

If lifestyle trends return to pre-pandemic levels by the end of 2024, the impact on health expenditure in the longer term becomes insignificant for many countries by 2050 (Figure 2.12). This is likely the result of less NCDs and a gain in a more resilient population. However, if risk factor trends observed during COVID-19 persist permanently, additional medical costs equal to 0.6% of total annual health expenditure on NCDs are projected on average across 28 OECD countries between 2025 and 2050. Higher health expenditure in the future is driven by increased morbidity as well as increasing population size.

Figure 2.12. Health expenditure will be higher due to the indirect impact of COVID-19 on NCDs

Impact on overall health expenditure of non-communicable diseases, in USD PPP 2022 per capita and as a percentage of total health expenditure, per year, average over 2020-2024 (short-term impact) and 2025-2050 (long-term impact)



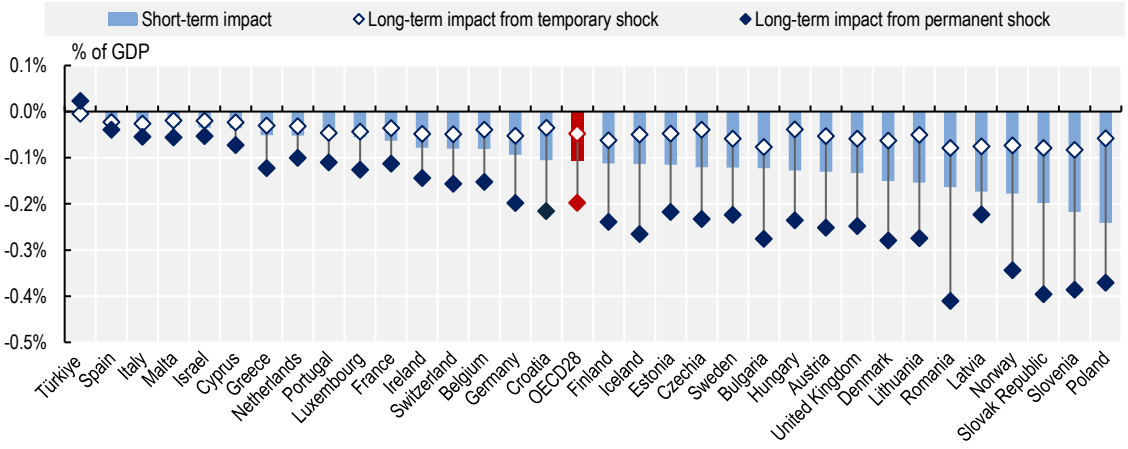
Note: Health expenditure includes curative care, rehabilitative care, preventative care, ancillary services and medical goods; and does not include long-term care. The estimates take into account the cost of other diseases as well as population dynamics. The "short-term impact" estimates the non-communicable-disease NCD-related impact of COVID-19 over the period 2020-2024, assuming disruptions to several key risk factors and declines in cancer survival this time. The "long-term impact" estimates the NCD-related impact of COVID-19 over the period 2025-2050 under two scenarios, a "temporary shock" in which disruptions to risk factors are short-lived until 2024 and a "permanent shock" which assumes persistent shifts for the duration of the model to 2050. The temporary shock can be interpreted as a lower-bound approximation of the NCD-related impact of COVID-19, while the permanent shock can be interpreted as an upper-bound approximation.
Source: OECD SPHeP NCDs model, 2025.

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On a macro level, the combined impact of NCDs on premature mortality and less people in the workforce affect a country's gross domestic product (GDP). In the short term, the indirect impact of COVID-19 on NCDs could see OECD countries experience an average 0.1% annual GDP loss between 2020 and 2024 (Figure 2.13). In the longer term, if COVID-19 trends persist permanently (Scenario 2), GDP could be as much as 0.2% lower each year, on average, across 28 OECD countries.

Figure 2.13. Losses in GDP are seen due to the indirect impact of COVID-19 on NCDs

Impact on the average annual GDP over 2020-2024 (short-term impact) and 2025-2050 (long-term impact), in percentage of GDP



Note: The "short-term impact" estimates the NCD-related impact of COVID-19 over the period 2020-2024, assuming disruptions to several key risk factors and declines in cancer survival this time. The "long-term impact" estimates the NCD-related impact of COVID-19 over the period 2025-2050 under two scenarios, a "temporary shock" in which disruptions to risk factors are short-lived until 2024 and a "permanent shock" which assumes persistent shifts for the duration of the model to 2050. The temporary shock can be interpreted as a lower-bound approximation of the NCD-related impact of COVID-19, while the permanent shock can be interpreted as an upper-bound approximation.
Source: OECD SPHeP NCDs model, 2025.

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2.4. Conclusions

This chapter outlined the enormous impact COVID-19 has had on health and societies, as only the latest among several large-scale disease outbreaks over the last century (Chapter 3). Millions of people lost their lives worldwide. Populations saw declines in mental health and well-being, care pathways for chronic diseases were severely disrupted, and there were also major impacts on employment and labour. Although available data is mixed, COVID-19 also altered the trajectory of lifestyle-related risk factors, with increases in tobacco consumption and rises in harmful alcohol use.

This chapter also assessed the potential health and economic consequences of the indirect impact of COVID-19 on NCDs. In the short term, life expectancy across 28 OECD countries is estimated to be 2.4 months lower compared to a scenario where the pandemic never occurred, with additional medical costs equalling 0.4% of overall annual health expenditure. The detrimental impact of COVID-19 on health and the economy fades over time if risk factors and behaviours gradually return to pre-pandemic levels. However, if changes in risk factors during COVID-19 continue permanently, life expectancy could remain, on average, 1.9 months lower in 28 OECD countries by 2050 compared to a scenario where no COVID-19 occurred, translating into increased medical costs equal to 0.6% of total health expenditure and annual GDP losses of 0.2%. These estimates are likely conservative, as they do not take into account other impacts of COVID-19 such as on mental health or long COVID.

The findings of the chapter highlight the need to strengthen pandemic preparedness and response capacities, not only to address immediate health needs but also to anticipate the longer-term consequences for NCDs. People living with NCDs face heightened risks of mortality and morbidity during pandemics, while, at the same time, the crises themselves can intensify the burden of NCDs, further

straining health systems and economies. Future research could further explore these longer-term dynamics, including the potential for permanent health and behavioural shocks, the impact of pandemic-driven changes in ICU capacity on healthcare workforce resilience and the implications of unmet mental health needs for life expectancy and health system costs across OECD countries.

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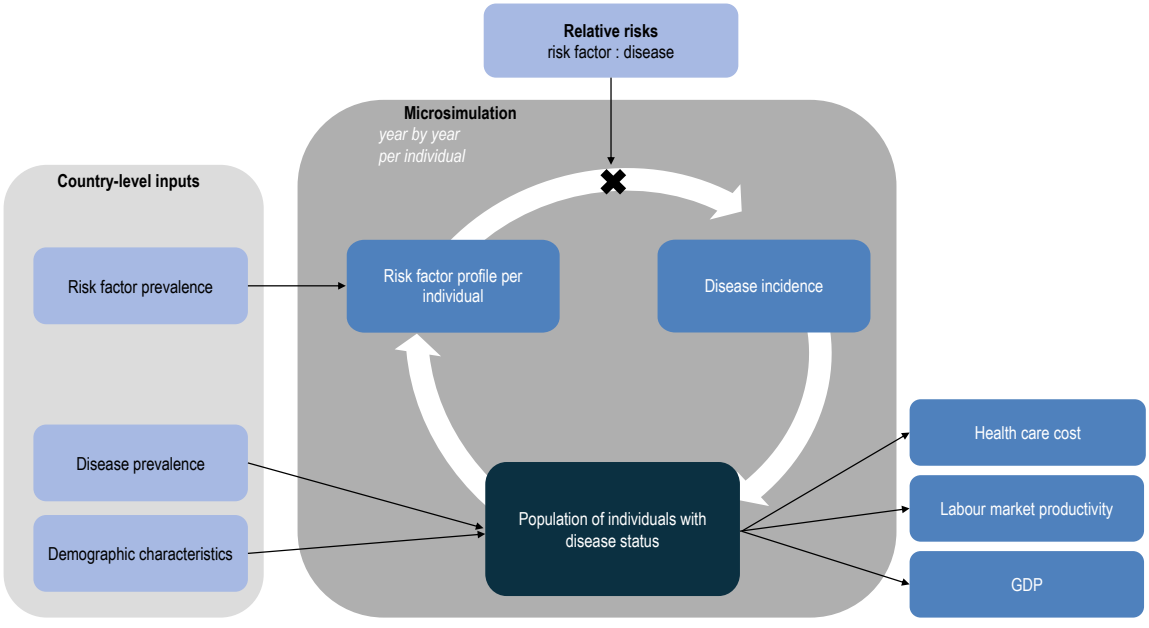
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Annex 2.A. OECD SPHeP NCDs model

The OECD Strategic Public Health Planning for Non-Communicable Diseases (SPHeP-NCDs) model is an advanced systems modelling tool for public health policy and strategic planning. It is used to predict the health and economic outcomes of the population of a country up to 2050. The model analyses a comprehensive set of key risk factors (e.g. obesity, alcohol use, tobacco, diet, air pollution and physical activity) and their associated non-communicable diseases (NCDs). The model covers 51 countries, including OECD Member countries, G20 countries, EU27 countries and OECD accession and selected partner countries. Note that the model does not take into account the impact of risk factors on communicable diseases.

For each of the countries, the model uses demographic and risk factor characteristics by age- and sex-specific population groups from international databases. These inputs are used to generate synthetic populations, in which each individual is assigned demographic characteristics and a risk factor profile (see Annex Figure 2.A.1). Based on these characteristics, an individual has a certain risk of developing a disease each year. These relative risks are based on a Global Burden of Disease study, amongst others, and only consider the direct relation between the risk factor and the disease. Note that the model uses population predictions to adjust the size and demographic profile of country populations in the future but maintains current (age- and gender-specific) rates for risk factors. In other words, it does not predict any future trends in risk factor prevalence, with the exception of those caused by demographic changes.

Annex Figure 2.A.1. Schematic overview of the OECD SPHeP-NCDs model



Note: This schematic is highly simplified and focusses on the disease component – it does not reflect some other components of the model (including births, immigration, emigration, death, remission and fatality).
Source: OECD (2019[177]), SPHeP-NCDs Technical Documentation.

For each year modelled, a cross-sectional representation of the population can be obtained, to calculate health status indicators such as life expectancy, disease prevalence, mortality, and disability-adjusted life years using disability weights. The disease and demographic profile of the population also form the basis for the healthcare cost and labour market outputs. The impact of demographic changes and labour force participation and productivity are translated into a change in GDP using the Cobb-Douglas production function, consistent with the OECD long-term economic forecast model (Guillemette and Turner, 2017[178]) and other established long-term models such as the World Bank Long Term Growth Model (Pennings and Loayza, 2022[179]).

The model consolidates previous OECD work into a single platform. It covers a set of key risk factors, including harmful alcohol consumption (OECD, 2021[149]), tobacco consumption (Devaux et al., 2024[180]), overweight and obesity (OECD, 2019[181]), physical activity (OECD/WHO, 2023[163]), air pollution and diet. For each risk factor, individuals in the model can develop associated categories of disease, including those that are directly linked to the risk factor through a relative risk. Categories of disease include type 2 diabetes, stroke, ischaemic heart disease, chronic obstructive pulmonary disorder, musculoskeletal disorders (e.g. rheumatoid arthritis, low back pain), cirrhosis, chronic kidney disease, depression, dementia, several cancers (OECD, 2024[182]), injuries and dependence disorders.

As described in Section 2.3 in the main text, the analyses presented in this chapter models the impact of COVID-19 related changes to three major risk factors – tobacco smoking, harmful alcohol consumption, and obesity – as well as cancer mortality on NCDs. Results are presented as annual averages or cumulative numbers for two time periods: 2020 to 2024 and 2025 to 2050. Single-year estimates are not used as they are affected by noise in the model. Since the scenario is introduced as a “shock” from COVID-19, rather than gradually over time, the annual average over the time periods reflects the impact in any of the years covered.

The results presented here are subject to limitations. First, the impact of each risk factor is limited to a set of major diseases that are linked directly or indirectly to the prevalence of the risk factor. However, there is emerging evidence of the impact of each risk factor on a wider range of diseases and other health and well-being outcomes. Second, some data on risk factors is self-reported, which may over- or under-estimate results. Thirdly, the data on risk factors during the COVID-19 pandemic are mixed and sometimes conflicting. Fourth, the model does not include other impacts from COVID-19 such as on mental health or long COVID.

For more information see OECD (2019[177]).

3 Future pandemics will carry a dual toll: Heavy loss of life and deep economic disruptions

This chapter examines the potential health and economic impacts of potential pandemic outbreaks. It starts by explaining the key epidemiological characteristics of pathogens of pandemic potential. Using the OECD Strategic Public Health Planning for Pandemic Preparedness and Response Model, the chapter quantifies the potential health and economic impacts of five unmitigated pandemic scenarios modelled based on the key traits of pathogens of pandemic potential, as well as data gathered for 51 OECD, European Union/European Economic Area and Group of 20 countries. The potential health burden is examined through measures of morbidity and mortality, extra burden on healthcare resources, whereas the potential impact on the economy is assessed through the estimated loss in economic output as measured by contraction in gross domestic product as a whole and by sector.

In Brief

Key messages

Another pandemic is not a question of if, but when

- Outbreaks have repeatedly disrupted societies, from the 1918 influenza pandemic to the recent COVID 19 crisis. The number of documented outbreaks has increased steadily since the 1940s and their severity intensified. Without deliberate action to interrupt the emergence and spread of outbreaks, the risk of future pandemic outbreaks is far from hypothetical.
- Even before COVID 19, outbreaks imposed enormous economic costs. The 2002 2003 severe acute respiratory syndrome (SARS) outbreak cost around USD 50 billion, the 2005 highly pathogenic avian influenza HPAI A(H5N1) outbreak around USD 40 billion and the 2009 H1N1 influenza outbreak around USD 50 billion. The COVID 19 crisis was far more disruptive: Between 2020 2024, the global economy produced USD 13.8 trillion less than projected, a shortfall roughly equivalent to one year of China's economic output.
- Many pathogens circulate without causing major outbreaks, but some have epidemiological traits with pandemic potential such as high transmissibility, severe clinical outcomes, long infectious periods and limited population immunity. Today, reports of rising human infections with another highly pathogenic avian influenza virus raise concerns about the risk of another large-scale outbreak.
- Using the OECD Strategic Public Health Planning (SPHeP) Pandemic Preparedness and Response (PPR) Model, this chapter reports estimates of the health and economic impacts of five unchecked outbreaks during their first nine months, assuming no pharmaceutical interventions are available. The outbreak scenarios broadly draw on the epidemiological traits of five pathogens with pandemic potential: Ebola-like, avian influenza-like, influenza A-like, coronavirus-like and measles-like.

Unmitigated outbreaks could threaten population health and overwhelm healthcare systems

- The OECD model indicates that all five unmitigated pandemics would spread extensively across the populations of the 51 OECD, EU/EEA and G20 countries included in the analysis. Some outbreaks (e.g. measles-like outbreak) would lead to rapid and severe outbreaks, while others (e.g. Ebola-like outbreak), could progress more slowly. In most scenarios, a significant portion of the population could be infected within the first 2 3 months, reaching as high as 62.3% in a measles-like outbreak over the 9 month simulation period.
- Health systems would face severe strain even with expanded capacity. Even the most advanced healthcare systems would struggle to meet the demand for intensive care capacity within 1 2 months, depending on the outbreak. Even with capacity increases to 120-130% of normal levels, as seen during COVID 19, surge capacity alone would not meet the demand. Resulting mortality could range from 1.2% of the population in a coronavirus-like outbreak to 5.4% in an avian influenza-like outbreak, rising up to 20% in a measles-like outbreak.

Unmitigated outbreaks threaten to destabilise entire economies, cutting across sectors

- An unmitigated measles-like outbreak could reduce gross domestic product (GDP) by an average of 16.2% across 50 countries included in the analysis, while a coronavirus-like scenario would still result in a notable average decline of around 2.7%.
- Some sectors are consistently more exposed than others. Across all outbreak scenarios, the transportation and storage sector would experience the steepest contractions, ranging from an average of around 13.4% in a coronavirus-like outbreak to 18.9% in a measles-like scenario.

3.1. The next pandemic is inevitable – are we prepared?

The emergence and re-emergence of disease outbreaks pose a significant threat to population health and economies across the globe. Over the 20th century, countries experienced several large-scale disease outbreaks, including the 1918 influenza pandemic, 1957-1958 influenza pandemic, 2002-2003 severe acute respiratory syndrome (SARS) pandemic, avian influenza outbreaks in 1997, 2003 and 2018, and most recently, the COVID-19 pandemic (D'Adamo et al., 2023[1]). Combined, these outbreaks claimed the lives of millions of people worldwide and imposed a heavy cost on economies.

Emerging evidence suggests that the risk of local outbreaks escalating into global pandemics has increased in recent years, driven by a number of factors such as climate change, expansion of global travel and trade networks and rapid urbanisation. More recently, the number of human infections with highly pathogenic avian influenza viruses has been on the rise, driven by sustained circulation in bird and mammal populations and occasional spillover into humans (Rolfes et al., 2025[2]). This trend has heightened concerns among public health authorities about the possibility of wider human-to-human transmission and the associated risk of a large-scale outbreak.

To date, several attempts have been made to identify the pathogens that can potentially cause pandemics in the future. For example, the World Health Organization (WHO) Research and Development Blueprint for Epidemics, a global research strategy and pandemic preparedness plan, identified several pathogens of pandemic potential, including new variants of COVID-19 and the Ebola virus disease (EVD) (WHO Research and Development Blueprint, 2024[3]). Broadly, previous efforts to identify pathogens of pandemic potential relied on several criteria to assess the pandemic potential of each pathogen such as the ability to spread between people rapidly and across geographic areas, the capacity to result in severe illness and mortality among the infected people and no or very little pre-existing immunity in the community, as well as the lack of effective pharmaceutical treatments or vaccines to limit the spread of infections. Considering the high risk of disease outbreaks in the future (Box 3.1), it is imperative to examine the factors that contribute to the emergence and spread of pathogens of pandemic potential to help efforts to better prepare for and respond to future health emergencies.

Box 3.1. The risk of new pandemic outbreaks is high

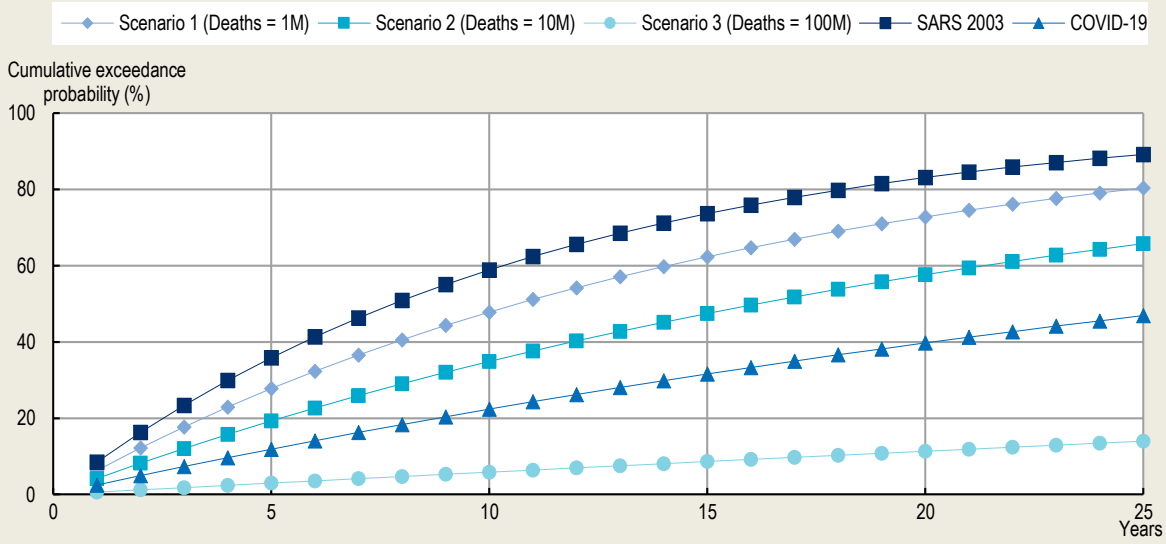
The likelihood of another major outbreak is far from hypothetical

The number of outbreaks has increased steadily since the 1940s (Meadows et al., 2023[4]; Smith et al., 2014[5]; Jones et al., 2008[6]) and their severity has intensified. One recent analysis found that the number of deaths attributable to outbreaks and spillover events caused by SARS-CoV-1, filoviruses and Machupo virus and Nipah virus grew at an exponential rate between 1963 and 2019. This study concluded that without deliberate action to interrupt the emergence and spread of these outbreaks, these

pathogens could cause 12 times more deaths in 2050 than in 2020 (Meadows et al., 2023[4]). Another forward-looking study estimated that globally, the cumulative probability of experiencing another pandemic on the scale of COVID-19 is roughly 50% in the next 25 years (Figure 3.1). The same study suggested that for respiratory pathogens, the probability of another pandemic ranged considerably from 14% to 80% depending on its severity (Madhav et al., 2023[7]).

Figure 3.1. The risk of a new pandemic occurring within the next two decades is high

Exceedance probability estimates for various historical and hypothetical pandemic scenarios



Note: Exceedance probability refers to the probability that an event of a given severity or worse will begin within a given year. Seasonal and endemic diseases, such as seasonal influenza and seasonal coronaviruses, are not included in the analysis.
Source: OECD estimates based on Tables 6 and A13 in (Madhav et al., 2023[7]).

StatLink https://stat.link/wap3uh

A number of interlinked factors continue to elevate the risk of future pandemics. Human activity, ranging from rapid urbanisation and deforestation to intensive farming practices and an often-unregulated wildlife trade, creates more opportunities for pathogens to spill over from animals to humans (Global Preparedness Monitoring Board, 2024[8]). At the same time, global mobility is accelerating, which in turn enables pathogens to circulate across regions at a much faster pace than ever seen before (AITA, 2023[9]). The demand for air travel is growing at roughly 3.4% per year and is expected to double by 2040 compared to 2019 levels. Adding to these factors, the increasing frequency of extreme weather events is amplifying the conditions under which new infectious threats can emerge (see Chapter 4).

Source: Meadows et al. (2023[4]), *"Historical trends demonstrate a pattern of increasingly frequent and severe spillover events of high-consequence zoonotic viruses"*, http://doi.org/10.1136/bmjgh-2023-012026; Smith et al. (2014[5]), "*Global rise in human infectious disease outbreaks"*, http://doi.org/10.1098/rsif.2014.0950; Jones et al. (2008[6]), "*Global trends in emerging infectious diseases*", http://doi.org/10.1038/nature06536; Madhav et al. (2023[7]), "*Estimated Future Mortality from Pathogens of Epidemic and Pandemic Potential"*, https://www.cgdev.org/sites/default/files/estimated-future-mortality-pathogens-epidemic-and-pandemic-potential.pdf; Global Preparedness Monitoring Board (2024[8]), "*The Changing Face of Pandemic Risk: 2024 Report*", https://www.gpmb.org/reports/m/item/the-changing-face-of-pandemic-risk-2024-report; AITA (2023[9]), "*Global Outlook for Air Transport: Highly Resistant, Less Robust*", https://www.iata.org/en/iata-repository/publications/economic-reports/global-outlook-for-air-transport----june-2023/.

This chapter focusses on the potential health and economic impacts of pathogens of pandemic potential. It starts by taking stock of the health and economic impacts of large-scale outbreaks over the last two decades. It then provides an overview of key epidemiological traits of pathogens that give them the potential to cause pandemics, with examples of past disease outbreaks. Next, the chapter presents results from a novel analysis of the potential health and economic impacts of five unmitigated pandemic scenarios across 51 OECD, EU/EEA and G20 countries, using the OECD Strategic Public Health Planning (SPHeP) for Pandemic Preparedness and Response (PPR) Model. The pandemic scenarios modelled in this chapter are 1) consistent with disease agents highlighted by WHO as pathogens of pandemic potential, 2) relevant to the current policy concerns highlighted by OECD, EU/EEA and G20 countries and 3) based on high-quality quantitative evidence on the key model parameters that were used as inputs in the OECD model. The chapter concludes by summarising the key findings.

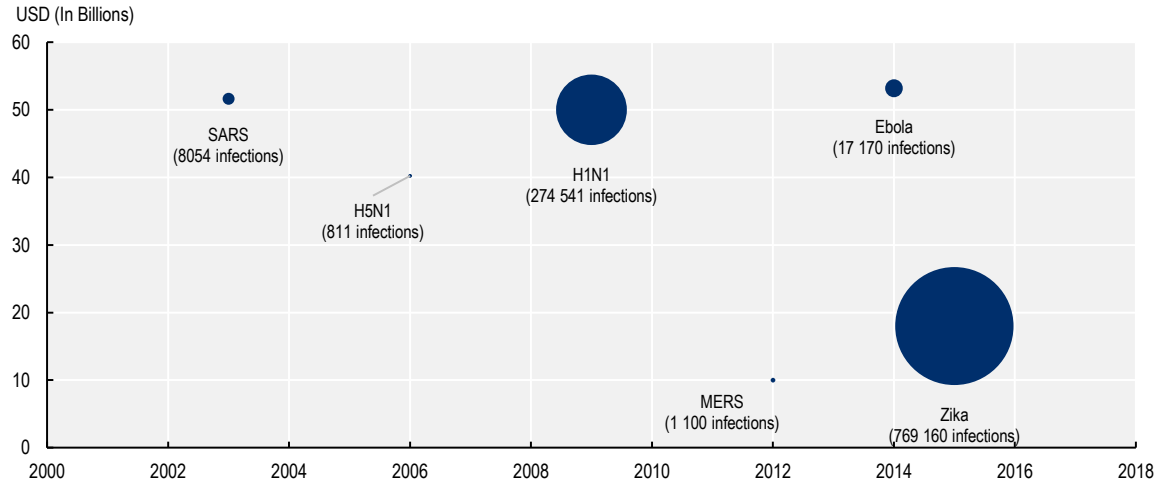
3.2. Over the last two decades, the global community experienced several large-scale pandemics with profound health and economic consequences

Several major disease outbreaks had a significant impact on population health and the economy. The COVID-19 pandemic was the most devastating of recent outbreaks, resulting in more than 762 million infections worldwide by April 2023 (WHO, 2023[10]) and costing USD 13.8 trillion to the global economy between 2020-2024 (IMF, 2022[11]). Initially detected in China in December 2019, the COVID-19 pandemic was declared a Public Health Emergency of International Concern by the WHO's International Health Regulation Emergency Committee in January 2020, which was lifted in May 2023 (WHO, 2023[12]).

Even before the COVID-19 pandemic, several pandemics had considerable implications for population health. The 2002-2003 SARS outbreak gave early warning signs of major disruptions that could be caused by novel coronaviruses. The SARS outbreak spread across 26 countries on five continents (Wilder-Smith, 2021[13]; Peiris et al., 2003[14]), with estimated infections exceeding 8 000 cases (WHO, 2015[15]). Two years after the SARS outbreak, in 2005, another pandemic outbreak, this time caused by a highly pathogenic avian influenza (HPAI) H5N1 started spreading, first in countries such as China, Indonesia, Thailand and Viet Nam and eventually reaching Europe. The 2009 outbreak caused by the H1N1 influenza virus had a much broader reach, infecting nearly 275 000 people (WHO/GIP, 2024[16]) across 75 countries and territories (WHO, 2025[17]). Coronaviruses continued to threaten population health after the 2002-2003 SARS outbreak. In 2012, a new outbreak caused by another coronavirus referred to as Middle East respiratory syndrome coronavirus (MERS-CoV) was first detected in Saudi Arabia, eventually spreading across 27 countries (WHO, 2026[18]). The global community experienced more localised disease outbreaks that were contained within certain geographic regions. For example, the 2014 EVD outbreak was primarily experienced in three West African countries, Guinea, Sierra Leone and Liberia, whereas the Zika outbreak primarily hit countries in the Latin American and Caribbean region. More recently, reports of rising human infections with another highly pathogenic avian influenza virus raise concerns about the risk of another large-scale outbreak (Rolfes et al., 2025[2]).

The OECD analysis suggests that the economic cost of recent disease outbreaks has been substantial (Figure 3.2). The estimated economic impact of the H1N1 outbreak is similar to the cost caused by the 2002-2003 SARS outbreak at around USD 50 billion, even though H1N1 infected almost 34 times more people than SARS. The H5N1 outbreak affected far fewer people compared to the SARS pandemic, but its economic cost was estimated to reach around USD 40 billion. The overall costs of MERS-CoV remained limited to USD 10 billion (Breban, Riou and Fontanet, 2013[19]). The 2014 EVD outbreak turned out to be more costly per infection compared to Zika. The estimated cost of the Zika outbreak for Latin American and Caribbean countries was approximately USD 17 billion, compared with USD 52 billion for EVD.

Figure 3.2. Health and economic cost of major epidemic outbreaks prior to the COVID-19 pandemic



Notes: The size of the bubbles reflects the number of reported infections in each outbreak. The estimated economic cost of each outbreak is quantified based on a comprehensive review of the literature, although it may not include all associated costs.
Source: The number of infections for SARS, H5N1, H1N1, MERS, Ebola and Zika are extracted from (WHO/GIP, 2024[16]; da Costa et al., 2020[20]; Noh et al., 2020[21]; PAHO, 2025[22]). The economic cost of SARS was calculated as the sum of costs reported for China, Canada, Hong Kong, Chinese Taipei, Singapore, Viet Nam and the United States in (Chen, 2008[23]; Cherry and Krogstad, 2004[24]; Hai et al., 2004[25]; Ostwald, 2014[26]; Steinmueller, 2005[27]; Knobler, Institute of Medicine (U.S.). Forum on Microbial Threats. and Institute of Medicine (U.S.). Board on Global Health., 2004[28]). The economic cost of H5N1 was calculated as the sum of costs for China, South-East Asian economies, and Egypt based on (World Bank, 2017[29]; Elci, 2006[30]; Hassouneh et al., n.d.[31]). The economic cost for H1N1 was extracted from (The World Bank, 2018[32]) for a global analysis. The global economic cost of MERS was extracted from (GPMB, 2019[33]). The economic cost of Zika was extracted from (UNDP, 2017[34]) for the Latin American and Caribbean region. The economic cost for Ebola, which was calculated as the sum of costs for three countries, including Guinea, Sierra Leone, and Liberia, was extracted from (Huber, Finelli and Stevens, 2018[35]).

Large differences in the economic impact of outbreaks often reflect factors beyond the number of infections alone, including sectoral exposure and geographic concentration. The economic impact of the 2002-2003 SARS outbreak was felt most in travel and consumer spending. The 2009 H1N1 pandemic mainly impacted tourism and the pork industry. For example, one study found that in Mexico, travel restrictions during the H1N1 outbreak led to USD 2.8 billion losses in tourism and a pork deficit of USD 27 million (Rassy and Smith, 2013[36]). The 2015 MERS-CoV outbreak led to widespread economic losses. In Korea, tourism revenue alone dropped by an estimated USD 2.6 billion (Joo et al., 2019[37]). The accommodation sector lost around USD 542 million, whereas the food and beverage industry lost around USD 359 million (Ibid). The losses in the transportation sector were estimated to be around USD 106 million (Ibid). The Zika outbreak also caused widespread losses in international tourism, with an estimated lost income between USD 6.5 billion and USD 9 billion (UNDP, 2017[34]).

3.3. Why only certain pathogens have pandemic potential?

Disease outbreaks can vary in size, ranging from small and localised events to global (Box 3.2). While all disease outbreaks are concerning for public health, only certain pathogens with certain epidemiological traits have the potential to spread widely and cause global concern.

Box 3.2. Characteristics of disease outbreaks

A disease outbreak is defined as the occurrence of cases of disease in excess of what would normally be expected in a defined community, geographical area or season. Often maintained by infectious agents that spread directly from person to person, via an insect or animal vector or from exposure to an animal reservoir or other environmental source, disease outbreaks can broadly be classified as endemic, epidemic and pandemic (Ibid). Understanding the characteristics of disease outbreaks (e.g. its size, type, susceptibility of population exposed, time and place of occurrence) is essential for investigating and mitigating the spread of infectious diseases. Specifically:

- An **endemic** refers to the constant presence or usual prevalence of a disease or infectious agent in a population within a geographic area (Center for Disease Control and Prevention, 2006[38]). A disease outbreak is endemic when it is consistently present but limited to a particular region (Columbia Mailman School of Public Health, 2021[39]).
- An **epidemic** refers to the increase, often sudden, in the number of cases of a disease, specific health-related behaviour, or other health-related event above what is normally expected in that population in that area (Center for Disease Control and Prevention, 2006[38]). When describing an epidemic, the time period, geographical region and characteristics of the population in which the unexpected rise of cases has occurred must be specified (Bonita et al., 2006[40]). It is important to note that while epidemics can be large, they do not necessarily have to be contagious and are generally contained or expected in their spread.
- A **pandemic** is an epidemic that has spread over several countries or continents, usually affecting large numbers of people (Center for Disease Control and Prevention, 2006[38]). Importantly, the difference between an epidemic and a pandemic outbreak is determined by the degree to which the disease is spread rather than the disease severity. As such, WHO declares a pandemic when a disease's growth is exponential. The wide geographical reach is what makes pandemics lead to large-scale social disruptions and economic loss and general hardships (Columbia Mailman School of Public Health, 2021[39]).

Source: Center for Disease Control and Prevention (2006[38]), *Principles of Epidemiology in Public Health Practice; An Introduction to Applied Epidemiology and Biostatistics. 3RD ed,* https://stacks.cdc.gov/view/cdc/6914/cdc_6914_DS1.pdf; Colombia Mailman School of Public Health (2021[39]) *Epidemic, Endemic, Pandemic: What Are The Differences?,3RD ed,* https://stacks.cdc.gov/view/cdc/6914/cdc_6914_DS1.pdf; Bonita et al. (2006[40]), *Basic Epidemiology,* https://apps.who.int/iris/handle/10665/43541.

As shown in Table 3.1, the extent to which pathogens can disrupt society depends broadly on two factors:

- **Epidemic trajectory** refers to the rate at which the number of active cases occur at any given time in the population (Thomas et al., 2020[41]; Chiossi, Tsolova and Ciotti, 2021[42]). Assessing the epidemic trajectory of a pathogen requires understanding the type of agent (e.g. virus, bacteria or fungi) causing the outbreak and the efficiency with which a disease is circulating in the population, as measured by the basic reproduction number ($\boldsymbol{R_o}$).
- **Course of infection** refers to the disease process from exposure to infection and the resolution of the case. Examining the course of infections necessitates understanding a range of factors such as the mode of transmission (e.g. direct contact, droplets), time elapsed between the onset of infection to onset of contagiousness (i.e. incubation period), the share of infected patients who exhibit symptoms and the proportion of cases that result in mortality.

Each of these factors and their interactions influence the potential of a pathogen to cause pandemics. The remainder of this section explores these key epidemiological characteristics, with examples of outbreaks caused by pathogens of pandemic potential in the past.

Table 3.1. Key determinants of epidemic trajectory and course of infection

Dimension	Factors	Definition	Pandemic potential
Epidemic trajectory	**Agent type**	Intrinsic characteristics of pathogen agents, such as being a virus, bacteria or fungi, have an impact on their capacity to replicate, mutate and infect hosts	Varies by agent type
	Basic reproduction number (R_o)	A measure to determine the efficiency with which a disease is transmitted. It represents the estimated number of secondary cases due to exposure to a single infector	↑ Higher R_o increases pandemic potential
Course of infection	**Modes of transmission**	Mode of transmission of a pathogen agent from infector to infectee (e.g. direct contact, droplet spread, airborne, vector-borne)	Varies by mode of transmission
	Latent period	Time elapsed from onset of infection to onset of disease symptoms (within the same person)	↓ In general, longer latency period decreases pandemic potential
	Incubation period	Time elapsed between onset of infection and onset of contagiousness (within the same person)	↓ In general, longer incubation period reduces pandemic potential
	Infectious period	Time during which a person can transmit the disease to another person	↑ Longer infectious period increases pandemic potential
	Asymptomatic proportion	The share of infectees that does not develop symptoms. An asymptomatic infector can still infect others and be unaware of own infectiousness	Higher proportion of asymptomatic infections increase pandemic potential ↑
	Case fatality rate (CFR)	Proportion of cases that result in death	On its own, CFR does not signal information on pandemic potential
	Immunogenicity	Development of immune protection against re-infection with the same/similar organisms following the initial infection	Immunologically naïve populations have a greater risk of potential outbreaks ↑

Note: This table is not intended to be exhaustive; it presents selected determinants of epidemic trajectory and infection course, with a particular focus on those commonly used in modelling exercises.
Source: Porta (2016[43]), *A Dictionary of Epidemiology*; Nelson and Williams (2014[44]), Infectious Disease Epidemiology: Theory and Practice; Adalja et al. (2018[45]), *The Characteristics of Pandemic Pathogens: Improving Pandemic Preparedness by Identifying the Attributes of MIcroorganisms Most LIkely to Cause a Global Catastrophic Biological Event*, https://www.centerforhealthsecurity.org/our-work/pubs_archive/pubs-pdfs/2018/180510-pandemic-pathogens-report.pdf; Mizumoto et al. (2020[46]), Estimating the asymptomatic proportion of coronavirus disease 2019 (COVID-19) cases on board the Diamond Princess cruise ship, Yokohama, Japan, 2020; Fraser et al. (2004[47]), *Proceedings of the National Academy of Sciences of the United States of America*; Center for Disease Control and Prevention (2006[38]), *Principles of epidemiology in public health practice: An introduction to applied epidemiology and biostatistics. 3rd ed*, https://stacks.cdc.gov/view/cdc/6914.

The remainder of the section presents the key epidemiological characteristics of pathogens of pandemic potential as follows (Annex 3.A provides more details):

- **Different classes of microbes** vary substantially in their potential to generate global catastrophic biological risks. Viruses, especially rapidly evolving RNA viruses such as highly pathogenic avian influenza (HPAI) (Box 3.3) pose the greatest concern, while bacteria represent a growing threat due to rising antimicrobial resistance. In contrast, fungi, prions and protozoans currently have more limited pandemic potential given biological constraints, restrictive transmission routes and the availability of effective prevention or control strategies (Adalja et al., 2018[45]).

Box 3.3. HPAI is a looming public health threat

Animal influenza viruses, similar to those causing seasonal influenza in humans, continue to evolve. These viruses have the potential to adapt and spread efficiently among humans, posing a pandemic threat (CDC, 2023[48]). The highly pathogenic avian influenza A(H5N1) virus is of particular concern due to its ability to infect humans. Estimates of transmissibility of HPAI A(H5N1) in humans remain limited and transmission rates depend heavily on the outbreak setting and the type of infected animal (Kirkeby and Ward, 2022[49]). Humans who are infected with H5N1 face a very high risk of requiring ICU care, with around 63% of hospitalised patients requiring advanced organ support (Gruber, Gomersall and Joynt, 2006[50]). Infected patients also have a high risk of mortality (Lai et al., 2016[51]).

The increasing number of reported human infections with HPAI A(H5N1) in recent years has been raising concerns about the risk of another large-scale outbreak. In total, there were 91 reported human cases of H5N1 worldwide from 2024 to 2025 (Institut Pasteur, 2025[52]). Most of the detected cases were reported in four countries: Bangladesh, Cambodia, China and India (ECDC, 2025[53]). While transmission between humans has not been observed, infections following exposure to infected animals continue to occur (CDC, 2023[48]).

Source: CDC (2023[48]), *Technical Report: Highly Pathogenic Avian Influenza A(H5N1) Viruses,* https://www.cdc.gov/flu/avianflu/spotlights/2022-2023/h5n1-technical-report.htm; Kirkeby and Ward (2022[49]), "*A Review of Estimated Transmission Parameters for the Spread of Avian Influenza Viruses*", https://doi.org/10.1111/tbed.14675; Gruber, Gomersall and Joynt (2006[50]), "*Avian Influenza (H5N1): Implications for Intensive Care*", https://doi.org/10.1007%2Fs00134-006-0148-z; Lai et al. (2016[51]), "*Global Epidemiology of Avian Influenza A H5N1 Virus Infection in Humans, 1997–2015: A Systematic Review of Individual Case Data*", https://doi.org/10.1016/s1473-3099(16)00153-5; Institute Pasteur (2025[52]), *"Avian Influenza: A Global Epidemic Under Surveillance"*, https://www.pasteur.fr/en/research-journal/news/avian-influenza-global-epidemic-under-surveillance; ECDC (2025[53]), *"Avian influenza overview June–September 2025"*, https://www.ecdc.europa.eu/en/publications-data/avian-influenza-overview-june-september-2025.

- **The basic reproduction number** (R_o) is one of the most important factors that helps assess the epidemic trajectory of a disease. It describes how many secondary infections one case generates in a fully susceptible population and is a key indicator of an outbreak's potential trajectory (Delamater et al., 2019[54]). Outbreaks grow when R_o is at or above 1 and decline when it falls below 1, but estimating its exact value is challenging because R_o varies by context, pathogen and stage of the epidemic (Box 3.4). Historical and recent outbreaks, including the 1918 influenza pandemic and successive coronavirus epidemics, demonstrate how R_o can shift over time as conditions change (Biggerstaff et al., 2014[55]).

Box 3.4. Transmission rates associated with various coronaviruses vary, underscoring the complex interplay of viral characteristics, environmental factors and human behaviours

Severe acute respiratory syndrome (SARS-CoV), MERS-CoV and SARS-CoV-2 are all coronaviruses that have caused disease outbreaks over the last two decades, each with distinct transmission dynamics. SARS-CoV-2 exhibited the highest transmissibility, driving its rapid global spread. SARS-CoV had a lower but still significant transmission rate, resulting in the 2002-2003 outbreak. MERS-CoV demonstrated more limited human-to-human transmission. More specifically:

- **MERS-CoV** is considered to have relatively low pandemic potential (Breban, Riou and Fontanet, 2013[19]). MERS-CoV transmission rates were observed to be higher in healthcare settings largely due to the close contact between infected patients and healthcare workers, especially in the absence of proper infection prevention and control measures. Community transmission is estimated to be less frequent, because in most cases, the infection was traced back to direct or indirect physical contact with infected camels, which are the known reservoir of the virus.
- **SARS-CoV** primarily spreads through respiratory droplets and aerosol particles (Yu et al., 2004[56]) and its symptoms range from mild flu-like symptoms to severe pneumonia, with some cases leading to acute respiratory distress syndrome. The 2003 SARS outbreak highlighted the potential for zoonotic diseases to cause widespread health crises. SARS-CoV remains an important point of reference in understanding the epidemiology and control of novel coronaviruses.
- **SARS-CoV-2**, the coronavirus that caused the COVID-19 pandemic, evolved throughout the pandemic. The first variant of concern for SARS-CoV-2, referred to as the Alpha variant, was initially detected in the United Kingdom in late 2020. Another variant named Delta was detected in India in late 2020. By the end of 2021, the Omicron variant was detected in South Africa (CDC, 2023[57]). Each variant had substantially different properties from the ancestral strain of SARS-CoV-2. The Delta variant had an estimated R_o value of 5.08 (Liu et al., 2020[58]) whereas the Omicron variant had an R_o reaching 9.5 (Liu and Rocklöv, 2022[59]). Both of these R_o values are substantially higher than the $R_o$of the ancestral strain of around 2.79 (Liu et al., 2020[58]).

Source: Breban, Riou and Fontanet (2013[19]), *"Interhuman Transmissibility of Middle East Respiratory Syndrome Coronavirus: Estimation of Pandemic Risk"*, https://doi.org/10.1016/s0140-6736(13)61492-0; Yu et al. (2004[56]), *"Evidence of Airborne Transmission of the Severe Acute Respiratory Syndrome Virus"*, https://doi.org/10.1056/NEJMoa032867; CDC (2023[57]), *SARS-CoV-2 Variant Classifications and Definitions*, https://www.cdc.gov/coronavirus/2019-ncov/variants/variant-classifications.html; Liu et al. (2020[58]), *"The Reproductive Number of COVID-19 is Higher Compared to SARS Coronavirus"*, https://doi.org/10.1093/jtm/taaa021; Liu and Rocklöv (2022[59]), *"The Effective Reproductive Number of the Omicron Variant of SARS-CoV-2 is Several Times Relative to Delta"*, https://doi.org/10.1093/jtm/taac037.

- **The mode of transmission** refers to the variety of ways through which an infectious agent may be transmitted to a susceptible host from its natural reservoir (Adalja et al., 2018[45]). Identification of the mode of transmission in the early stages of an outbreak is key to support the mitigation efforts and to ensure that the response is effective. Modes of transmission shape the scale and severity of infectious disease outbreaks, with respiratory and faecal – oral pathogens (e.g. Hepatitis A and *Vibrio cholerae*) posing particularly high risks because their spread is harder to interrupt and can be amplified by weaknesses in public health or sanitation systems (Mavhunga, 2023[60]). In contrast, pathogens transmitted through direct contact may be more easily interruptible through strengthened infection prevention and control measures. Vector- and tick-borne diseases remain geographically constrained but are becoming a growing concern as vector ranges expand (Chapter 4).
- **Timing of disease transmission** strongly influences outbreak dynamics. Diseases such as EVD and smallpox are contagious primarily when symptoms appear (Wilder-Smith, 2021[13]), whereas human immunodeficiency virus (HIV) can be infectious for years after the initial infection (Nelson and Williams, 2014[44]). Other pathogens (e.g. influenza viruses) can spread during the incubation period and even before symptoms appear, creating more opportunities for infected individuals to transmit the disease while conducting their daily activities without any major interruptions (Box 3.5).

Box 3.5. Pandemic influenza

Influenza is a common acute respiratory infection responsible for 3-5 million severe illnesses every year (WHO, 2023[61]). Each year, seasonal influenza causes up to 650 000 deaths globally, including an estimated 72 000 in the WHO European region (WHO, 2024[62]). Of the four known influenza virus types (i.e. types A, B, C and D), pandemics occur when a novel influenza virus emerges in the population with little or no pre-existing immunity (CDC, 2023[63]). Past influenza A pandemics include the 1918-1919 H1N1 outbreak, the 1957-1958 H2N2 outbreak and the 2009 H1N1 outbreak (CDC, 2019[64]; ECDC, 2023[65]).

Transmission and severity vary across influenza strains. The basic reproduction number of the 2009 H1N1 pandemic was estimated at around 1.46, with higher values reported in higher-density settings such as schools (Biggerstaff et al., 2014[55]). CFR for influenza pandemics is generally low compared to other diseases such as EVD, ranging from 0.26% in the 2009 H1N1 outbreak in England (Donaldson et al., 2009[66]) to less than 0.2% in the 1957-1958 H2N2 (ECDC, 2023[65]). Mortality risk also differs across population groups (CDC, 2019[64]).

Source: WHO (2023[61]),*Influenza (Seasonal),* https://www.who.int/news-room/fact-sheets/detail/influenza-(seasonal); WHO (2024[62]),*"Pandemic Influenza: A Threat That All Countries Need to Prepare For"* https://www.who.int/europe/emergencies/emergency-cycle/prepare/pandemic-influenza; CDC (2023[63]), *Types of Influenza Viruses,* https://www.cdc.gov/flu/about/viruses/types.htm; CDC (2019[64]), *2009 H1N1 Pandemic (H1N1pdm09 virus),* https://www.cdc.gov/flu/pandemic-resources/2009-h1n1-pandemic.html; ECDC (2023[65]),*Questions and Answers on influenza pandemics,* https://www.ecdc.europa.eu/en/seasonal-influenza; Biggerstaff et al. (2014[55]), *"Estimates of the reproduction number for seasonal, pandemic, and zoonotic influenza: a systematic review of the literature",* http://doi.org/10.1186/1471-2334-14-480; Donaldson et al. (2009[66]), *"Mortality from pandemic A/H1N1 2009 influenza in England: public health surveillance study"*, http://doi.org/10.1136/bmj.b5213; ECDC (2023[65]),*Questions and Answers on influenza pandemics,* https://www.ecdc.europa.eu/en/seasonal-influenza.

- **Non-symptomatic infections**, those that occur without observable symptoms, can substantially shape outbreak dynamics by allowing transmission to go undetected. *Asymptomatic infections* occur when an infected individual never develops symptoms, whereas *pre-symptomatic infections* refer to cases detected before symptoms eventually appear. Evidence from dengue, Ebola and COVID-19 shows that a meaningful share of infected individuals falls into these categories, with estimates for COVID-19 suggesting that 8.4% to 39% of cases may remain asymptomatic (Gao et al., 2021[67]). The relative infectiousness of non-symptomatic infections compared to symptomatic ones is difficult to quantify due to variations in testing capacity and follow-up (Gao et al., 2021[67]; CDC, 2021[68]).
- **Disease severity**, often summarised through case fatality rate (CFR), is a critical determinant of a pathogen's impact on population health and the economy. CFR refers to the proportion of infected individuals who lose their lives from a particular condition, and its value reflects both the epidemiology of the pathogens and the current standard of healthcare, as well as the availability of new therapeutics or vaccines. High mortality is not a prerequisite for major social disruption, as shown in the 1918 influenza pandemic, which caused approximately 50-100 million deaths worldwide (Beach, Clay and Saavedra, 2022[69]) even though it has a relatively low CFR of around 1-2% (Schoch-Spana et al., 2017[70]). Conversely, although Ebola has a much higher CFR (Box 3.6), its pandemic potential remains more limited if public health measures are effectively implemented with high proportion of the population adhering to guidelines (ECDC, 2022[71]).

Box 3.6. The risk of EVD outbreaks in most OECD countries remains low but possible

The risk of EVD outbreaks in most OECD countries remains low

EVD is a rare but severe infectious disease transmitted through direct contact with the blood, organs and bodily fluids of the infected people/animals, as well as through unsafe handling of human remains. Asymptomatic infection is uncommon, even in high-exposure situations (Glynn et al., 2017[72]). The risk of large-scale outbreaks can be reduced when effective infection prevention and control measures are in place (ECDC, 2022[71]).

EVD is characterised by relatively low transmissibility but extremely high lethality. One systematic assessment of the major EVD outbreaks between 2013 and 2016 in several West African countries suggested that the median basic reproduction number ranged from around 1.51 (95%CI: 1.50-1.52) in Guinea to 1.59 (95% CI: 1.57-1.60) in Liberia (Wong et al., 2017[73]). Depending on the context, the estimated CFR has been shown to range from 25-90% (Malvy et al., 2019[74]).

The latest EVD outbreak, caused by the Bundibugyo species of Ebola, was declared in the Democratic Republic of the Congo and Uganda in May 2026, with the WHO designating it a Public Health Emergency of International Concern on 17 May 2026. As of 29 July 2026, the Democratic Republic of the Congo reported 3 442 confirmed cases and 1 521 deaths, whereas the last confirmed case in Uganda was reported on 21 June 2026 (ECDC, 2026[75]).Response efforts are complicated by the absence of any approved vaccine or treatment for Bundibugyo virus, alongside armed conflict, weak health infrastructure, low contact-tracing coverage and a substantial funding gap. At the time of writing of this chapter, the risk of an EVD outbreak in most OECD countries is considered very low (ECDC, 2026[75]).

Source: Glynn et al. (2017[72]), *"Asymptomatic Infection and Unrecognised Ebola Virus Disease in Ebola-affected Households in Sierra Leone: A Cross-sectional Study Using a New Non-invasive Assay for Antibodies to Ebola Virus"*, https://doi.org/10.1016/s1473-3099(17)30111-1; ECDC (2022[71]), *Factsheet about Ebola Disease,* https://www.ecdc.europa.eu/en/infectious-disease-topics/z-disease-list/ebola-virus-disease/facts/factsheet-about-ebola-disease; Malvy et al. (2019[74]), "*Ebola Virus Disease"*, http://doi.org/10.1016/s0140-6736(18)33132-5; Wong et al. (2017[73])*"A Systematic Review of Early Modelling Studies of Ebola Virus Disease in West Africa"*, http://doi.org/10.1017/s0950268817000164; ECDC (2026[75]), " *Ebola disease outbreak in the Democratic Republic of the Congo and Uganda*",https://www.ecdc.europa.eu/en/ebola-outbreak-democratic-republic-congo-and-uganda.

- **Populations with little or no pre-existing immunity** are more vulnerable to pandemic outbreaks because a larger share of individuals is susceptible to infection. Immunity acquired through prior infection or vaccination can slow transmission and reduce the severity of disease (Box 3.7), easing pressure on health systems even if its effect on the basic reproduction number is limited. When a novel pathogen emerges, however, the entire population is essentially susceptible, as seen with COVID-19, allowing the disease to spread rapidly and cause substantial health impacts.

Box 3.7. Measles remains a leading cause of vaccine-preventable deaths globally

Measles is a highly contagious airborne disease and remains one of the leading causes of vaccine-preventable deaths worldwide. With a basic reproductive number estimated at 12 to 18, measles spreads rapidly, particularly among children under five years of age (Do and Mulholland, 2025[76]). The virus causes a systemic infection affecting the skin, eyes, respiratory tract and gastrointestinal system. Common symptoms include fever, cough, rash and conjunctivitis (NHS, 2024[77]). Vulnerable populations, including malnourished children, immunocompromised individuals and pregnant people, face significantly higher risks of severe disease and mortality.

Since 2024, all WHO regions have reported rising measles incidence, with 395 521 confirmed cases in 2024 and over 16 000 cases recorded in the first two months of 2025 (Ibid). In 2023, measles caused an estimated 107 500 deaths globally, despite the widespread availability of a safe and cost-effective vaccine (WHO, 2026[78]).

Source: Do and Mulholland (2025[76]), *"Measles 2025"*, https://doi.org/10.1056/nejmra2504516; NHS (2024[77]), *"Measles"*, https://www.nhs.uk/conditions/measles/; WHO (2026[78]), *"Measles"*, https://www.who.int/news-room/fact-sheets/detail/measles.

3.4. The OECD SPHeP-PPR model is used to assess the potential health and economic impacts of five pandemic scenarios

The OECD SPHeP-PPR model is a microsimulation model that simulates the spread of five pandemics by replicating the epidemiological characteristics of pathogens of pandemic potential and healthcare resources in 51 OECD, EU/EEA and G20 countries (Box 3.8). Broadly, the OECD model aims to:

- Build five unmitigated pandemic scenarios to quantify the potential health and economic impact of pandemics, assuming that no measure is implemented to curb the spread of infections during the first nine months of the outbreak.
- Assess the effectiveness of the selected NPIs aiming to stem the spread of infections in each pandemic scenario assuming that there are no reliable medical treatments and vaccines available to treat infections.

Box 3.8. The OECD SPHeP-PPR Model

The COVID-19 pandemic led to a proliferation in the use of mathematical models that consider both epidemiological and economic factors for guiding policymakers

Epidemiological-economic models have become essential tools for assessing the potential consequences of pandemics and for informing policy decisions before, during and after an outbreak (OECD/WHO/The World Bank, 2024[79]). They bring together two components: an epidemiological one that simulates how a pathogen spreads through a population and the resulting burden on health system capacity, morbidity and mortality and an economic one that translates these health impacts into broader economic outcomes. By linking the two, such models allow policymakers to weigh the costs of an outbreak against the costs and benefits of measures to contain it.

Epidemiological-economic models differ in how the two components are connected (Bonnet et al., 2024[80]). In linked models, epidemiological outcomes are estimated first and then used to drive economic impacts, with no feedback from economic conditions to disease transmission. Fully integrated models instead capture the two-way interaction between the epidemic and the economy, allowing economic conditions and individual behaviour to feed back into disease transmission. They can also differ in scope. Some apply a common framework across many countries to enable cross-country comparison (Haw et al., 2022[81]), while others provide more detailed analyses of individual countries (Romijn, Stadhouders and Polder, 2025[82]).

The OECD SPHeP-PPR Model

It is a country-specific, age-stratified compartmental model that incorporates spatial population density mapped in 5x5 km grids. Using discrete time steps of one day, the model predicts disease outcomes by generating a synthetic cohort of individuals that fully replicates the historical profile of a given population in terms of demographic characteristics, risk of infections for selected pathogens, the likelihood of requiring hospital care (i.e. care received in inpatient or intensive care) and mortality, as well as the epidemiology of the disease. The analysis focusses on the first nine months of the outbreak under the assumption that there is no reliable pharmaceutical treatment or vaccine to stem the spread of the outbreak. It does not account for the potential long-term health impacts of pandemics (e.g. on non-communicable disease burden, mental health, long COVID etc.).

As with all models, the OECD SPHeP-PPR Model is a simplification of reality and its results are, therefore, subject to uncertainty. Actual impacts may be more variable than estimated. Nevertheless, by integrating detailed epidemiological, demographic, health system and economic information, the model provides a comprehensive framework for assessing the potential consequences of pandemic outbreaks and response measures.

The OECD model uses social contact matrices to take into account person-to-person contact patterns unique to each country

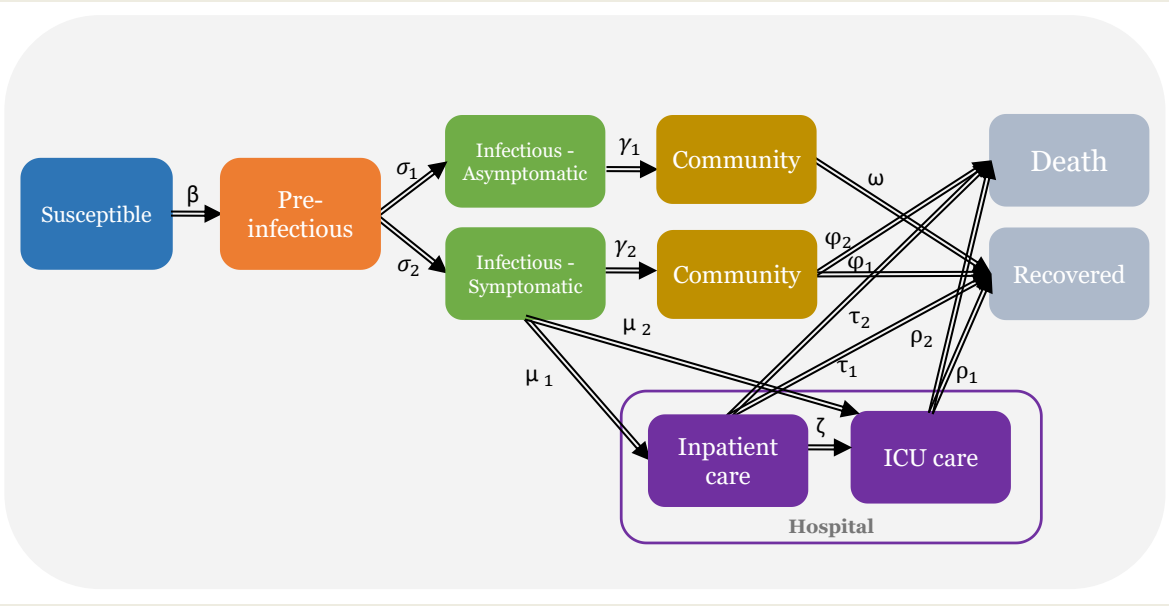
The risk of disease transmission of communicable diseases depends heavily on who interacts with whom. In settings where the average number of daily contacts is higher, infectious diseases may spread more rapidly and extensively, assuming that all other factors remain the same and no public health measures are put in place to control the spread of the outbreak. Contact patterns can vary considerably by age and by setting (e.g. households, workplaces and schools), within a country and across countries.

The OECD SPHeP-PPR Model accounts for social contact patterns by integrating country-, age- and setting-specific synthetic contact matrices developed by Prem and colleagues (Centre for the Mathematical Modelling of Infectious Diseases COVID-19 Working Group, 2021[83]). Contact matrices refer to a systematic approach to depict the patterns and frequency with which individuals from various demographic profiles come into contact with one another in various settings. Integrating contact matrices into the modelling framework can offer important advantages for accurately modelling the disease transmission within the community and identifying the likely containment impact of a range of NPIs.

The OECD model extends the traditional Susceptible-Infected-Recovered framework

The model categorises individuals into 10 mutually exclusive groups representing their health status (Figure 3.3). At the outset, the model assumes that some or all individuals in a closed population are susceptible to infections, depending on the pathogen. As individuals advance through various compartments reflecting their health status, they are first infected but cannot spread the pathogen (i.e. pre-infectious). Next, individuals become infectious. Symptomatic patients can be admitted to hospital to receive inpatient or ICU care. The model has two absorbing states: 1) recovery and 2) death.

Figure 3.3. Structure of the OECD SPHeP-PPR model



Note: Greek letters summarise transition probabilities between health states as follows: β = From susceptible to pre-infectious, σ_1 = From pre-infectious to infectious (asymptomatic), σ_2 = infectious (symptomatic), γ_1 = From infectious (asymptomatic) to community, ω = From Community to Recovery (for infectious [asymptomatic]), φ_1 = From Community to Recovery (for infectious [symptomatic]), φ_2 = From Community to Death (for infectious [symptomatic]), γ_2 = From infectious (symptomatic) to community, μ_1 = From infectious (symptomatic) to inpatient care, μ_2 = From infectious (symptomatic) to ICU care, τ_1 = From inpatient care to Recovery, τ_2 = From inpatient care to Death, ζ = From inpatient care to intensive care unit (ICU), ρ_1 = From ICU to Death, ρ_2 = From ICU to Recovery. ICU = intensive care unit.
Source: OECD SPHeP-PPR model.

The probability of death increases as an infected individual proceeds from the community setting to ICU. Transitions across compartments occur depending on (1) effective contact rate and (2) rate of recovery (or death). The effective contact rate determines the transition probability from susceptible to infected whereas the rate of recovery alters the transition probability from the infected to recovered.

The model represents hospital care using two compartments: inpatient care and ICU care. Individuals can enter these compartments through several pathways. Those who require hospital or ICU care can be admitted directly if beds are available on that day of the simulation. Depending on how their symptoms evolve, patients may progress from inpatient care to the ICU. When ICU beds are unavailable, patients who need ICU may instead be admitted to regular hospital wards if inpatient beds are available. Survival probabilities in the model depend on both disease severity and access to care: patients who cannot access hospital or ICU care when needed face a higher risk of death.

The OECD model employs a maximum capacity approach to ascertain healthcare needs

The OECD SPHeP-PPR model employs a maximum capacity approach to simulate the strain on hospital services during outbreaks. To accurately predict the number of days required to reach maximum hospital and ICU capacity in each country, the model makes the following assumptions:

- The maximum number of patients that can be hospitalised at a given moment of the simulation coincides with data from national statistics on the number of hospital and ICU beds per capita in the country, as retrieved from Eurostat and World Bank data. This rate is extrapolated for countries with missing data (Özçelik et al., 2024[84]).
- At the beginning of the simulation, pre-pandemic hospital and ICU occupancy rates are used as the baseline. As an outbreak progresses, hospital occupancy rates rise. Even before

reaching full capacity, an increasing number of individuals are assumed to be denied hospital and ICU admission. This assumption reflects real-life situations that some hospitals fill faster than others, resulting in some patients lacking access to alternative healthcare facilities. This approach allows the model to simulate the uneven geographical distribution of hospitals within a country.

- As the pandemic in the simulation progresses, the pre-pandemic hospital and ICU occupancy rates within a country are adjusted by a certain percentage to account for non-urgent patients.
- During the simulation, ICU bed capacity can be expanded over time as the pandemic scenario progresses. The rate of expansion and the time that it takes to achieve this is country-specific and based on a comprehensive review of the existing literature.

Estimating the economic impact of pandemic outbreaks

Outputs from the OECD SPHeP-PPR model are used as inputs for the economic model developed by the French Observatory of Economic Conjunctures at Sciences Po (Dauvin and Sampognaro, 2021[85]). This is a modified version of a Leontief model, which uses the national input-output tables produced by the OECD for the 51 OECD, EU/EEA and G20 countries included in the analysis and 19 sectors of the economy as defined by the International Standard Industrial Classification of All Economic Activities, Revision 4. The model is designed to capture the simultaneous shocks to both supply and demand, going beyond traditional models, facilitating an in-depth exploration of disruptions in economic activity due to outbreaks as follows:

- **On the supply side**, the model considers factors such as workforce availability and supply chain interruptions, which hindered production capabilities.
- **On the demand side**, the model accounts for changes in consumer behaviour, including reduced spending and shifts in consumption patterns due to social distancing measures or changes in human capital.

By integrating dual shocks, the model provides a nuanced view of the economic impact of the unmitigated outbreak scenarios as well as during the implementation of the various NPIs based on their level of stringency. It highlights the interconnectedness of various sectors and the cascading effects of disruptions across the economy. This holistic perspective is crucial for policymakers to design effective responses and recovery strategies, ensuring that both supply and demand factors are addressed to stabilise and stimulate economic activity.

Economic impacts should be interpreted in the context of each country's economic structure. In some cases, headline macroeconomic indicators may be influenced by sectoral concentration, export activity or the presence of multinational enterprises. As a result, estimated economic effects may not fully capture changes in domestic economic welfare, although they provide a consistent basis for cross-country comparison. The economic estimates captured by the model do not include the long-run loss of future output associated with premature mortality and should be considered as a conservative measure of the total economic cost.

Source: OECD/WHO/The World Bank (2024[79]), "*Strengthening Pandemic Preparedness and Response Through Integrated Modelling*", http://doi.org/10.1787/5f046115-en; Bonnet et al. (2024[80]), "*A Scoping Review and Taxonomy of Epidemiological-Macroeconomic Models of COVID-19*", http://doi.org/10.1016/j.jval.2023.10.008; Haw et al. (2022[81]), *"Optimizing social and economic activity while containing SARS-CoV-2 transmission using DAEDALUS*", http://doi.org/10.1038/s43588-022-00233-0; Romijn (2025[82]), "*Application of an Epi-Econ-Model to Analyze COVID-19 Lockdown Policies in the Netherlands: Lessons and Limitations*", http://doi.org/10.1017/bca.2025.10; Centre for the Mathematical Modelling of Infectious Diseases COVID-19 Working Group (2021[83]), *"Projecting contact matrices in 177 geographical regions: An update and comparison with empirical data for the COVID-19 era*", https://doi/org/10.1371/journal.pcbi.1009098; Özçelik et al. (2024[84]), *"Estimating the return on investment of selected infection prevention and control interventions in healthcare settings for preparing against novel respiratory viruses: modelling the experience from SARS-CoV-2 among health workers*", http://doi.org/10.1016/j.eclinm.2023.102388; Dauvin and Sampograno (2021[85]), *"Dan les coulisses du confinement: modelisation de chocs simultanes d'offre et de demande. Une application au confinement du mois d'avril 2020 en France",* https://www.ofce.sciences-po.fr/pdf/dtravail/OFCEWP2021-05.pdf.

The remainder of the chapter focusses on the first objective, whereas methodologies and results related to the second objective are presented in Chapter 7. An unmitigated pandemic outbreak is unlikely in real-world settings given that, for example, population mortality would rise rapidly and, even in the event of no governmental action, individuals would be likely to start readopting behaviours learned during the COVID-19 pandemic. This expectation is consistent with emerging evidence that people adapted their behaviours beyond legally mandated restrictions during the pandemic, with voluntary avoidance strongly correlating with local COVID-19-related deaths (Goolsbee and Syverson, 2021[86]). Nonetheless, these simulations are important for at least three reasons:

- Outputs help confirm the internal validity of the model by ensuring consistency across various dimensions (e.g. predicted number of deaths over time should align with the progression of the outbreak in terms of the number of infections) and by comparing against empirical evidence from other studies;
- Outputs can serve as a stress test to evaluate the resilience of healthcare services in the face of an emerging pandemic. Similar to stress tests conducted in other sectors, such as banking, this analysis involves a hypothetical extreme shock that exceeds what is likely to occur, which helps identify potential vulnerabilities and prepare for worst-case scenarios; and
- Results from the unmitigated spread of infections provide a common baseline for comparing other analyses that entail the scale up of various NPIs modelled in Chapter 7, which, in turn, facilitates understanding the potential of NPIs and underlining the importance of timely and effective action.

The five pandemic scenarios modelled in this chapter broadly reflect the epidemiological characteristics of pathogens of pandemic potential as follows (Table 3.2):

- **Ebola-like outbreak** represents a pathogen with lower transmission but extremely high severity, testing healthcare systems' ability to manage critical cases.
- **Avian influenza-like outbreak** models a new animal-to-human influenza strain with high levels of hospitalisation and case fatality.
- **Influenza A-like outbreak** simulates a highly transmissible but less severe flu virus, representing a classic fast-spreading pandemic.
- **Coronavirus-like outbreak** is a simulation of a novel coronavirus, characterised by asymptomatic spread and age-dependent severity.
- **Measles-like outbreak** is the most extreme scenario, featuring a hyper-infectious agent in a non-immune population.

While each scenario draws on the epidemiological profile of a specific pathogen, the parameters used in the OECD model are not intended to replicate the exact dynamics of those diseases. Rather, they are designed to represent a range of plausible outbreak archetypes that differ in transmissibility, severity and the pressure they can put on health systems. The OECD model does not distinguish between modes of transmission, even though the five pathogens span different real-world routes from direct contact with bodily fluids in Ebola virus disease to airborne spread in measles. The model uses the same underlying logic and structure to simulate each pandemic scenario (e.g. the same population size, healthcare capacity limits etc.) to ensure that differences in outcomes reflect the epidemiological assumptions and country characteristics and not unrelated modelling quirks.

Table 3.2. Key modelling parameters used in the OECD analysis to model five pandemic scenarios

	Ebola-like outbreak	Avian influenza-like outbreak	Influenza A-like outbreak	Coronavirus-like outbreak	Measles-like outbreak
Estimated (R_o)	1.71 (WHO Ebola Response Team, 2014[87])	1.59 (Kim and Cho, 2021[88])	2.00 (Petersen et al., 2020[89])	4.22 (Linka, Peirlinck and Kuhl, 2020[90])	12.5 (Guerra et al., 2017[91])
Incubation period	11.4 days (WHO Ebola Response Team, 2014[87])	5 days (Huai, 2008[92])	7 days (Andronico et al., 2019[93])	6.7 days (Cowling et al., 2015[94])	11 days (CDC, 2021[95])
Latency period	11.75 days (Velásquez et al., 2015[96])	3.1 days (Tuite et al., 2010[97])	1.3 days (Canini and Carrat, 2011[98])	5.5 days (Xin et al., 2022[99])	12 days (Griffin, Lin and Pan, 2012[100])
Infectious period	15.3 days (WHO Ebola Response Team, 2014[87])	9.3 days (95% CI 2.6-24.2 days) (Tuite et al., 2010[97])	8-12 days (CDC, 2023[101])	9.7 days (95% CI 8.3-11.2), (Sender et al., 2022[102])	8 days (CDC, 2025[103])
From onset to admission to hospital (days)	9.4 days (WHO Ebola Response Team, 2014[87])	6 days (Kandun et al., 2008[104]; Fiebig et al., 2011[105])	4.5 days (Hui, 2008[106])	4 days (Vijayanand, Wilkins and Woodhead, 2004[107])	4 days (Fragkou et al., 2020[108])
Asymptomatic proportion	27.1% (95%CI: 14.5-39.6%) (Dean et al., 2016[109])	19.1% (95%CI: 5.2%–35.5%) (Furuya-Kanamori et al., 2016[110])	21% (95%CI:4.2-41.0) (Furuya-Kanamori et al., 2016[110])	0-18 years: 46.7% 19-59 years: 32.1% 60+ years:19.7% (Sah et al., 2021[111])	None
Hospitalisation rate	95% Assumption based on (Hartley et al., 2017[112])	80% Assumption based on (Petersen et al., 2024[113])	0-4 years: 20% 5-24 years: 8% 25-49 years: 16% 50-64 years: 30% 65+ years: 44% (CDC, 2009[114])	0-9 years: 0.01% 10-19 years: 0.02% 20-29 years: 0.11% 30-39 years: 0.44% 40-49 years: 1.24% 50-59 years: 4.56% 60-69 years: 11.81% 70-79 years: 22.73% 80+ years: 37.8% (Souris and Gonzalez, 2020[115])	29.6% (Probert et al., 2021[116]; Winkler et al., 2022[117])
Mean duration of hospitalisation	8 vs. 6.1 days (survivors vs. non-survivors) (Bah et al., 2015[118]; Van Kerkhove et al., 2015[119])	6.5 days (Pormohammad et al., 2020[120])	5 days (Lai et al., 2016[51])	0-19 years:3 days 20-59 years: days 60+ years: 9 days (Belgian Collaborative Group on COVID-19 Hospital Surveillance, 2020[121])	7.3 days (Maltezou et al., 2020[122])

	Ebola-like outbreak	Avian influenza-like outbreak	Influenza A-like outbreak	Coronavirus-like outbreak	Measles-like outbreak
Share of hospitalised needing ICU (%)	50% (Kiiza et al., 2020[123])	54% (Wang et al., 2014[124])	17% (Wang et al., 2014[124])	8.9% (Leboucher et al., 2023[125])	9.68% (Maltezou et al., 2020[122])
Duration of stay in ICU	13.5 and 4.3 days (survivors vs. non-survivors (EC, 2016[126])	5.5 and 7.6 days (survivors vs. non-survivors) (Kumar et al., 2012[127])	12 days (Kumar et al., n.d.[128])	0-19 years:3.8 days 20-59 years:6.4 days 60+ years: 7.6 days (Belgian Collaborative Group on COVID-19 Hospital Surveillance, 2020[121])	4 days (Stahl et al., 2013[129])
CFR in ICUs	80% (Assumption)	75% (Assumption based on (Petersen et al., 2024[113])	21%21% (Hadler et al., 2010[130])	29.3% (Guillon et al., 2021[131])	22.2% (Wong et al., 1993[132])
CFR in hospitalised but not in ICUs	0-4 years: 79.1% 5-9 years: 59.7% 10-14 years: 40.3% 15-19 years:20.8 20-24 years: 27.2% 25-29 years: 33.5% 30-34 years: 39.8% 25-39 years:46.1% 40-44 years: 52.4% 45-49 years: 58.7% 50-54 years: 65.1% 55-59 years: 71.3% 60-64 years: 77.7% 65-69 years: 84% 70-74 years: 90.3% 75+ years: 96.6% (Garske et al., 2017[133])	52% (Secretariat's assumption based on (Petersen et al., 2024[113])	0-19 years: 0.8% 20-64 years: 5.4% 65+ years: 10.7% (Wong et al., 2015[134])	0-9 years: 0.32% 10-19 years:0.65% 20-29 years: 0.84% 30-39 years: 1.66% 40-49 years: 2.90% 50-59 years: 6.16% 60-69 years: 12.00% 70-79 years: 19.79% 80-89 years: 28.63% (Souris and Gonzalez, 2020[115])	10.8% (Portnoy et al., 2019[135])
Baseline immunity	Immunologically naïve population where no individual has any prior immunity to the pathogen	10% of the population above the age of 20 are assumed to have prior immunity to the pathogen	10% of the population above the age of 20 are assumed to have prior immunity to the pathogen	10% of the population above the age of 20 are assumed to have prior immunity to the pathogen	Immunologically naïve population where no individual has any prior immunity to the pathogen
Immunity after recovery	Recovered individuals are assumed to acquire immunity for the rest of the simulation	Recovered individuals are assumed to acquire immunity for the rest of the simulation	Recovered individuals are assumed to acquire immunity for the rest of the simulation	Immunity is assumed to wane over time	Recovered individuals are assumed to acquire immunity for the rest of the simulation

Notes: CFR = case fatality rate, ICU = Intensive care unit, R_o = Basic reproduction number.
Source: OECD review of the existing evidence base.

3.5. Results

3.5.1. Health impacts

Figure 3.4 illustrates the pandemic curves that depict how the share of population infected evolves over time, expressed in days, under five unmitigated outbreak scenarios. The figure presents the average across the 51 countries included in the analysis, with shaded areas indicating cross-country variability. For instance, the measles-like outbreak shows a smaller shaded area, indicating less cross-country variability compared to the other scenarios and, similarly, slightly different cross-country variability patterns can also be discerned between, for example, avian influenza-like outbreak and influenza A-like outbreak. This suggests that:

- **Pathogen-specific factors** are crucial in shaping the progression of the disease. For example, in an outbreak driven by a measles-like agent with such high infectivity, other factors tend to become secondary in influencing the evolution of the outbreak.
- **Country-specific factors** such as demographics and social contact patterns are pivotal in the progression of epidemics when the infectivity of the pathogen is lower. This is particularly evident in the influenza A-like outbreak, where two epidemic peaks can be observed, approximately 7-10 days apart, indicating that the agent spreads at varying speeds across different populations. Country-specific outputs (not shown) also show that epidemic peaks can occur across a range of days, anywhere from 74-264 days after the onset depending on the country.

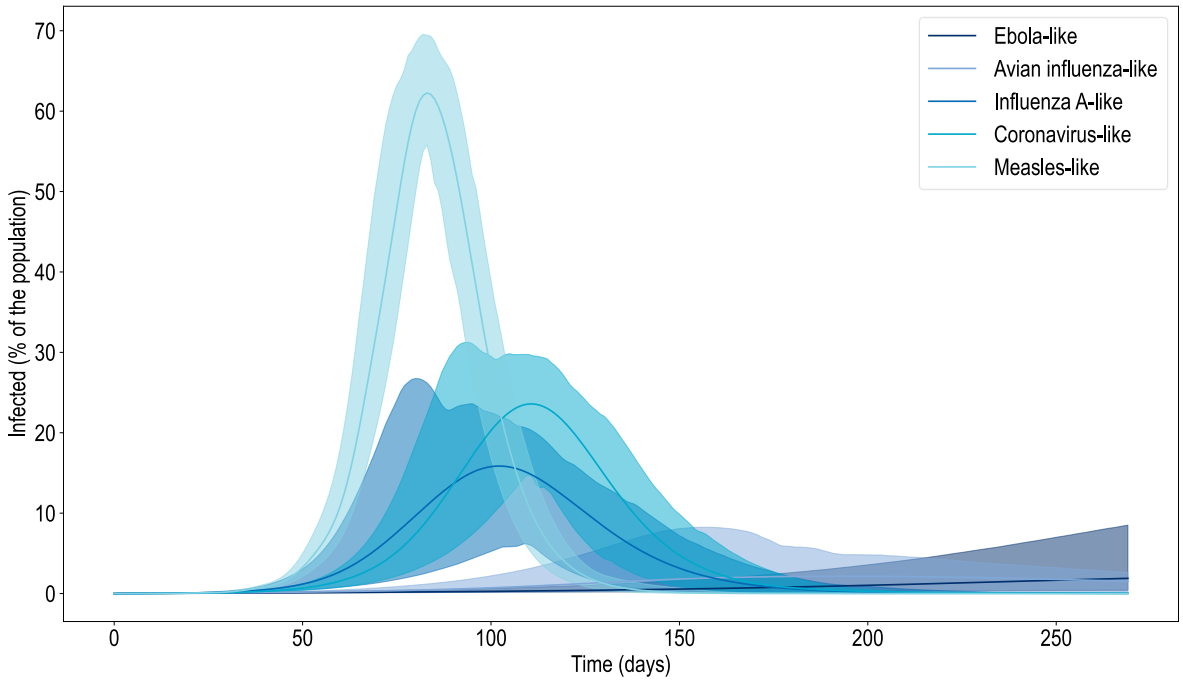
Figure 3.4 shows that all five scenarios modelled in the analysis could lead to large scale outbreaks. The most severe outbreak would be caused by a measles-like agent, with infections quickly rising to around 62.3% of the population (min: 55.8%, max: 69.5%) in 83 days before tapering off. This scenario depicts a rapid outbreak with a steep peak that can burden the healthcare system in a relatively short period.

By contrast, an outbreak caused by an Ebola-like agent reflects a more gradual rise in infections. By the end of the 9-month simulation period, the outbreak would fall short of reaching a peak. This means that the outbreak would still be in its growth phase (i.e. R_o remains >1) by the end of the simulation whereby the susceptible population would have been depleted for transmissions to start declining. In this outbreak scenario, infections would spread over a longer period, limiting the immediate strain on healthcare resources but prolonging the duration of the pressure on the healthcare systems.

The remaining scenarios would fall between these two extremes. The outbreak caused by a coronavirus-like agent would peak on the 111th day with about 23.6% of the population (min: 14.5%, max: 29.6%) being infected, whereas an outbreak caused by an H5N1-like agent would lead to an extended outbreak with a lower peak on the 192nd day. These findings are aligned with emerging evidence. For example, one earlier modelling study showed that highly transmissible pathogens with higher R_o would lead to rapid surges in the number of infections and steep epidemic peaks, whereas less transmissible pathogens would create more prolonged epidemic curves (Vallée, Faranda and Arutkin, 2023[136]).

Figure 3.4. How a pandemic unfolds depends on the pathogen and population characteristics

Share of the population infected over time, unmitigated outbreaks, by scenario

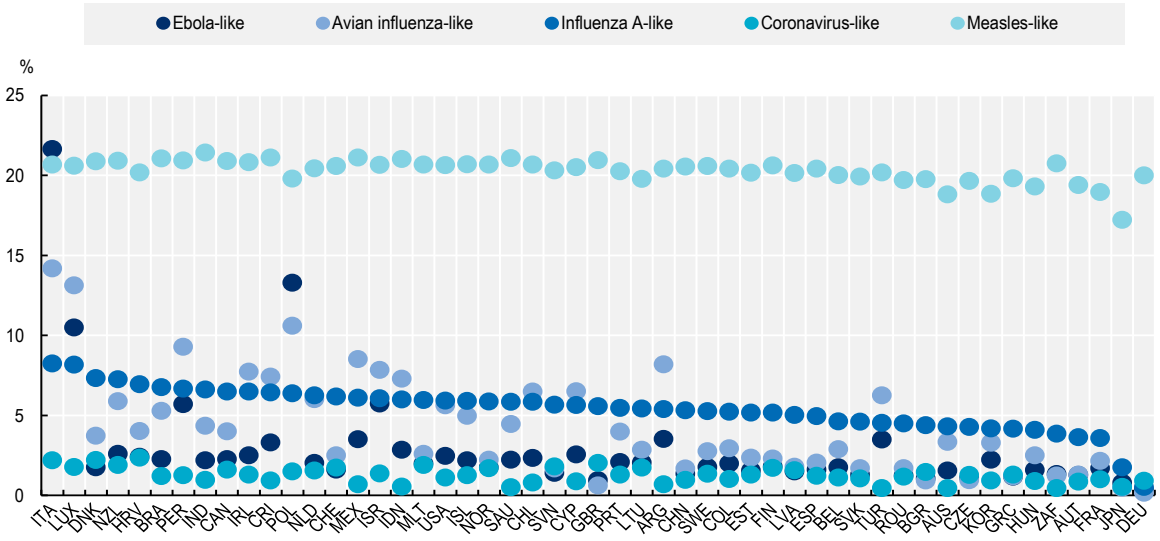


Note: The figure presents the cross-country average across the 51 OECD, EU/EEA and G20 countries included in the analysis, with the shaded areas indicating cross-country variability. Evolution of the pandemic is expressed in days. Each outbreak is simulated to last for 9 months.
Source: Analysis based on the SPHeP-PPR model.

Figure 3.5 illustrates the proportion of the population that would succumb to the outbreak by the end of each simulation. As previously mentioned, mortality depends not only on how widely the infection spreads but also how deadly the pathogen is. A highly infectious agent such as the one in the measles-like outbreak could spread rapidly, infecting a huge number of the population. The sheer number of infections would drive the high death toll, even though the CFR of the measles-like agent is lower than the CFR of an extremely lethal agent such as the one in the Ebola-like outbreak. This is the case for the mortality toll of the modelled scenarios. The measles-like outbreak would be the most severe, with 20.3% of the population losing their lives, on average, across the 51 countries included in the analysis. The lowest level of mortality would be observed in Japan (17.2%) whereas the highest fatality would be in India (21.4%). Pandemics caused by influenza A-like and avian influenza could also have substantial impacts, with mortality averaging at 5.4% and 4.3% of the population respectively. Both scenarios show large cross-country variations. In both scenarios, Italy would face the most severe mortality burden, potentially reaching as high as 14.2% in an avian influenza outbreak and 8.3% in an outbreak caused by influenza A-like pathogen. In comparison, Germany would face the least severe mortality burden with an estimated loss of 0.2% and 0.5% of its population respectively.

Figure 3.5. Unmitigated pandemics would have devastating consequences for population health

Share of population losing their lives by the end of the simulation, unmitigated outbreaks, by country and scenario



Note: Countries are sorted from left to right from lowest to highest percentage of population losing their lives under the Ebola-like outbreak (e.g. a value of 23.9 in the Ebola-like outbreak scenario in Italy means 23.9% of the Italian population is estimated to lose their lives due to an Ebola-like pathogen by the end of the 9-month simulation period). Averages for different country groupings are unweighted.
Source: Analysis based on the SPHeP-PPR model.

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3.5.2. Impact on healthcare system resilience

When outbreaks spread without mitigation, they can rapidly overwhelm healthcare systems. Figure 3.6 reports how quickly ICU beds are exhausted under different scenarios for the 51 countries included in the analysis. In nearly all scenarios, existing capacity falls far short of the surge in demand. Depending on the scenario, ICU capacity across the 51 countries included in the analysis would be exhausted within 9 to 139 days.

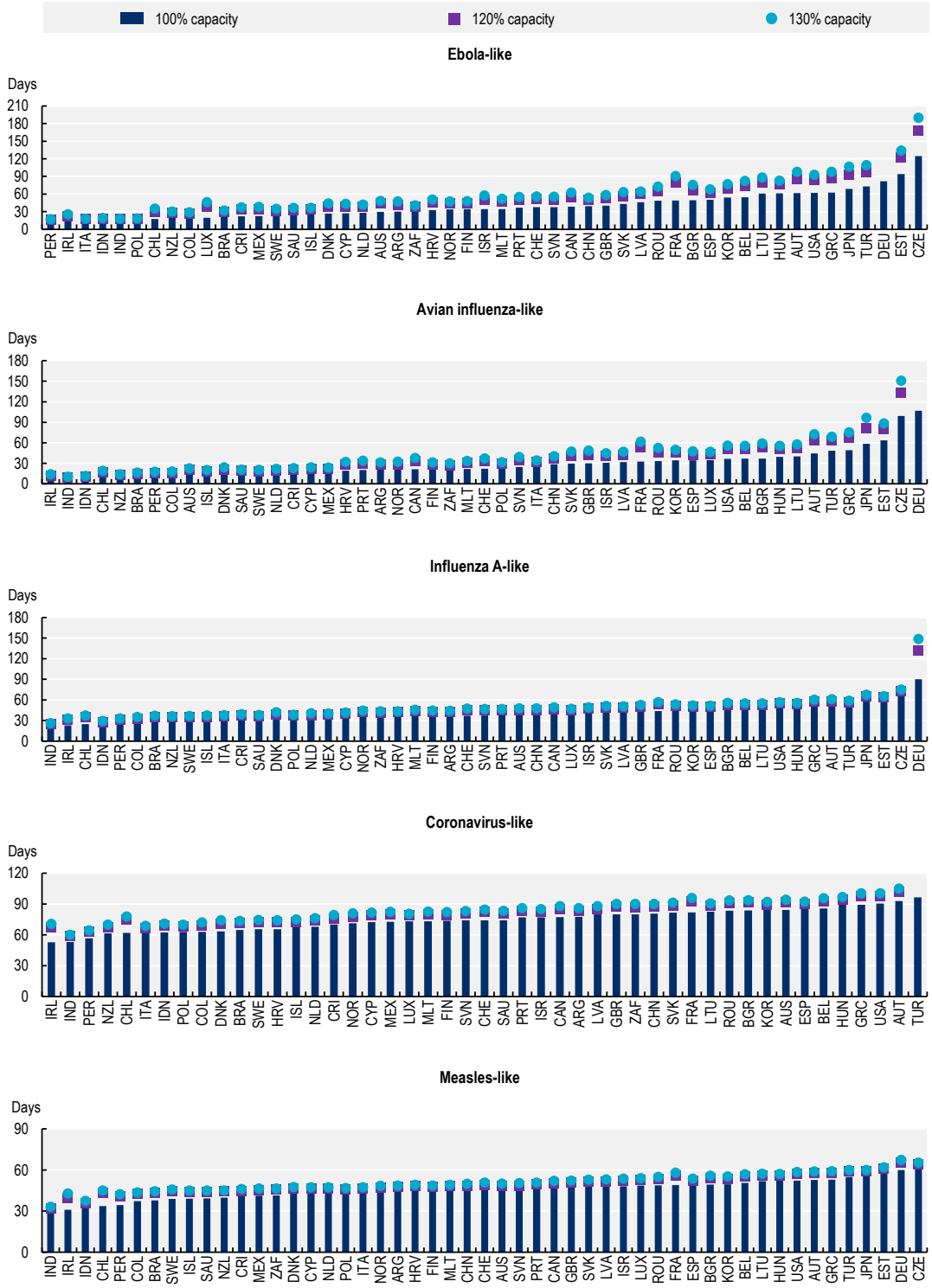
Across the 51 countries, outbreaks caused by avian influenza and influenza A-like agents would be the most alarming, with ICUs reaching full capacity, on average, within 28.6 days (min: 8.8 days, max: 107 days) and 39.8 days (min: 21.7 days, max: 90.1 days) respectively. In the avian influenza outbreak, in countries such as Ireland and Indonesia, ICU capacity could be saturated within 8.8 and 9.1 days respectively, leaving little time for health systems to meet the rapid rise in demand.

A measles-like outbreak also poses major risks for health systems, though the timeline of the saturation is longer at an average of 45.6 days (min: 29.9 days, max: 61.4 days), leaving slightly more room for response. In an outbreak caused by a coronavirus-like agent, ICUs remain under far less pressure where full ICU capacity is reached in 77.3 days (min: 52.6 days, max: 139 days).

Surge capacity would provide only temporary relief but cannot compensate for the rapid spread of outbreaks. Even expanding ICU capacity to 130% of non-emergency levels, similar to measures taken early in the COVID-19 pandemic, would only slightly extend the healthcare systems' ability to manage the outbreaks, by approximately an additional 5.4 to 18.6 days, depending on the outbreak. This finding suggests that mitigation of the spread is the only viable strategy to avoid the collapse of healthcare systems.

Figure 3.6. Unmitigated pandemics could place immense pressure on healthcare systems

Number of days it takes to reach or exceed ICU capacity, unmitigated outbreaks, by country and scenario



Note: Countries are sorted from left to right from lowest to highest number of days to reach 100% ICU capacity in each pandemic scenario (e.g. a value of 58.6 in the avian influenza-like outbreak scenario in Japan means it would take 58.6 days to reach 100% ICU capacity during an avian influenza like outbreak). Each outbreak is simulated to last for 9 months.

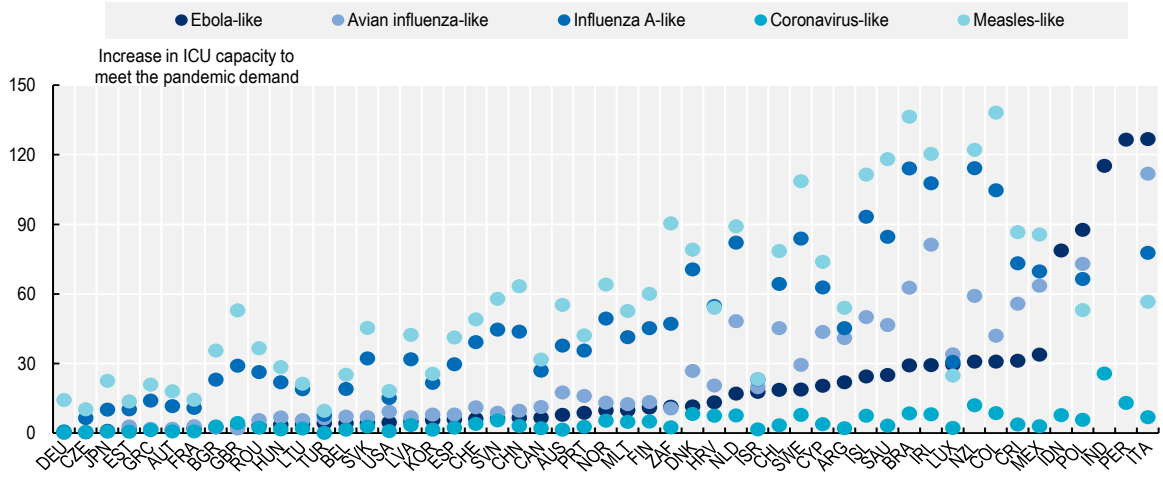
Source: Analysis based on the OECD SPHeP-PPR model.

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As a complementary step, the model also estimated how much ICU capacity would need to expand to meet the excess demand during an unmitigated outbreak (Figure 3.7). It is important to stress that this exercise is purely theoretical, as scaling up ICU beds to the required levels would not be feasible in practice. The measles-like outbreak scenario would be the most extreme, with the 51 countries included in the analysis needing, on average, 72.3-fold increase in ICU beds to meet the excess demand due to the outbreak. The influenza A-like outbreak would also lead to substantial upscaling, requiring, on average, 58.1-fold expansion of current capacity, while an outbreak caused by a coronavirus would call for a more modest expansion of the order of 4.5 times, on average, though some countries such as India would still need to increase their ICU capacity by 25.7-fold. Combined, these results suggest that solely relying on surge capacity remains insufficient to meet the surge demand in most outbreak scenarios.

Figure 3.7. Required increase in ICU bed capacity to meet demand, unmitigated outbreaks, by country and scenario

Increase in ICU capacity to meet the pandemic demand



Note: Countries are sorted from left to right from lowest to highest increase in ICU bed capacity to meet the demand for ICU beds in an Ebola-like outbreak. A value of 6.6 in the influenza A-like outbreak in the Czech Republic (hereafter 'Czechia') means the ICU bed capacity would need to be scaled up 6.6 times to meet the demand during an influenza A-like outbreak. Each outbreak is simulated to last for 9 months.
Source: Analysis based on the OECD SPHeP-PPR model.

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Beyond ICU capacity, a surge in infections during outbreaks could stretch other essential components of the healthcare systems. Experiences from the COVID-19 pandemic demonstrated that meeting the surge in demand goes far beyond adding more hospital or ICU beds (Grasselli, Pesenti and Cecconi, 2020[137]). Critical care equipment (e.g. ventilators), consumables and pharmaceuticals might need to be rapidly scaled up to meet patient needs (Phua et al., 2020[138]) but these resources can become scarce during large outbreaks, if the global supply chains cannot keep up with the simultaneous surge in demand across countries. Equally important is the human factor. Expanding capacity would depend on mobilising a much larger pool of healthcare professionals (e.g. ICU nurses), but the health workforce cannot be increased substantially in a short period of time (Vera San Juan et al., 2022[139]). The prolonged pressure on existing health personnel could also lead to fatigue, absenteeism and burnout (Aymerich et al., 2022[140]; Morgantini et al., 2020[141]), further compromising the system's ability to deliver care. Other parts of the health infrastructure (e.g. laboratory capacity) could also face unprecedented pressure (Phua et al., 2020[138]).

3.5.3. Economic impacts

Figure 3.8 shows that during the initial nine months of the unmitigated outbreak, GDP is projected to decline, on average, by 2.7% to 16.2% across 50 countries included in the analysis, depending on the scenario. A measles-like outbreak could result in the highest levels of collapse, with almost every sector contracting by around 16% or more. A coronavirus-like outbreak could shrink the economy, on average, by around 2.7%, reflecting a milder but still disruptive shock. The economic impact of the other outbreaks would fall within these two scenarios, from 3.4% in an Ebola-like outbreak to 5.5% in an influenza A-like outbreak. In reality, countries would likely intervene to attenuate the economic consequences of the outbreak, as they did during the COVID-19 pandemic through policies such as job retention programmes and monetary easing. The unmitigated outbreak scenarios presented in Figure 3.8 do not account for such policy responses.

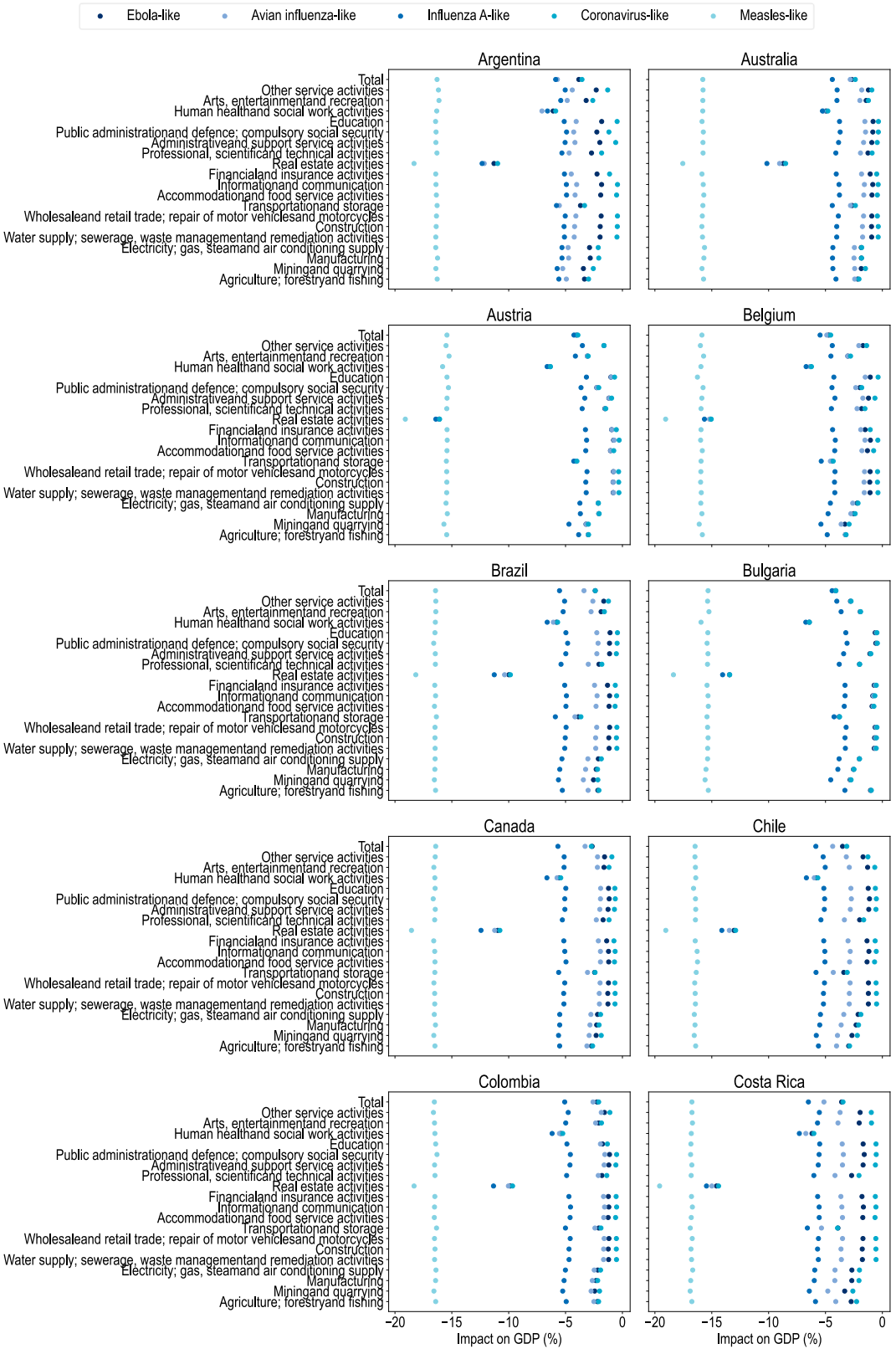
Some sectors are consistently more exposed to shocks than others. The transportation and storage, manufacturing, administrative and support services activities and professional, scientific and technical activities would show distinct but consistently severe patterns of contraction. The transportation and storage sector could experience by far the steepest losses, contracting, on average, between 13.4% and 18.9% in outbreaks caused by a coronavirus-like and by a measles-like agent respectively. Manufacturing would follow a similar trajectory but at a lower magnitude, with the average declines ranging from 5.9% to 16.2% depending on the scenario. Both the administrative and support services, and professional, scientific and technical activities sectors could experience contractions of the order of 4.2% to 5.5% in four scenarios, while collapsing by, on average, 16.1% in the measles-like outbreak.

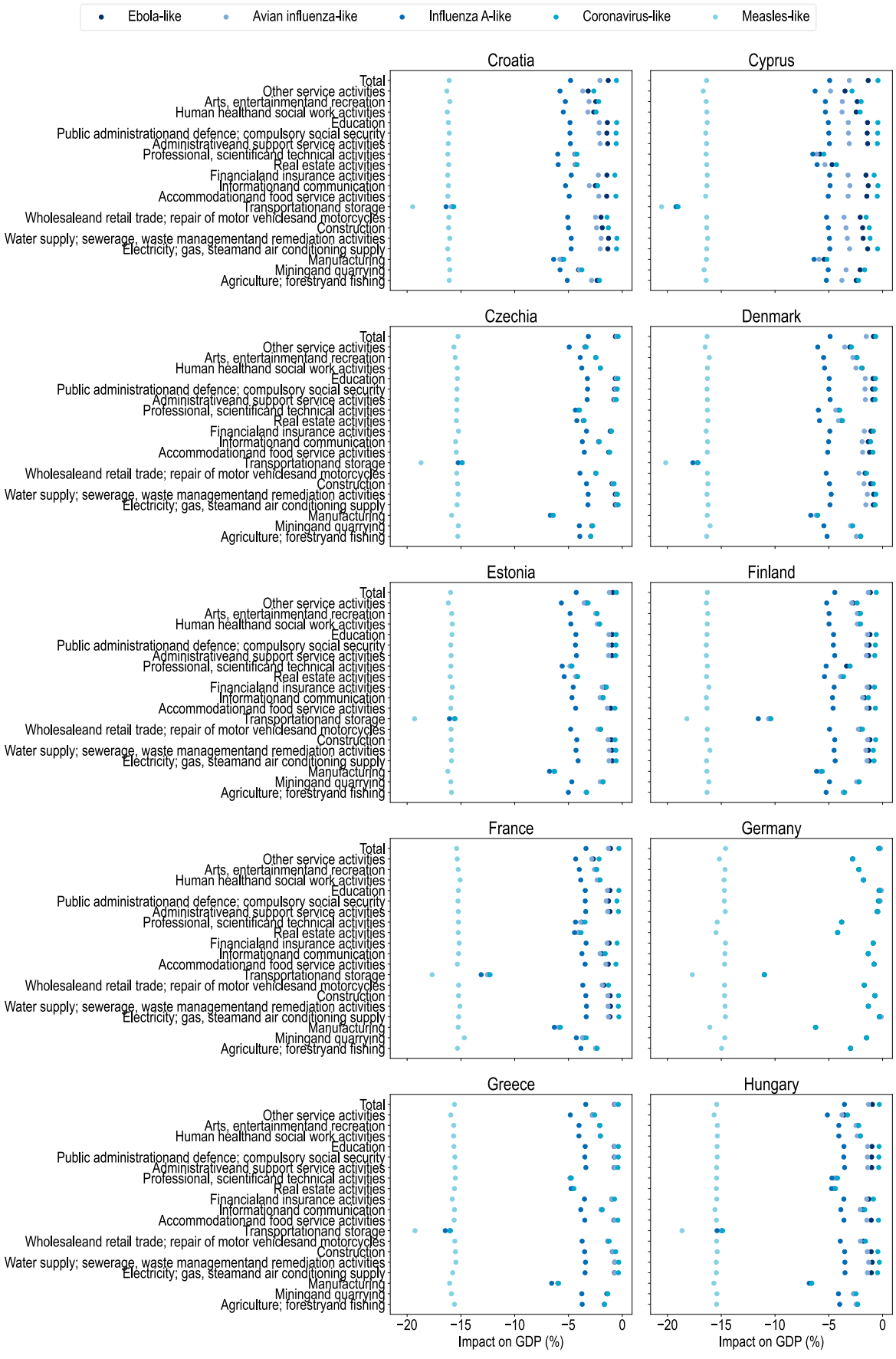
Service-based sectors such as education, human health and social work activities, public administration and defence, compulsory social security, and information and communication sectors would experience the lowest levels of contraction, reflecting their relative insulation from immediate demand shocks. In the first four outbreak scenarios, the education and human health and social work sectors are projected to contract from 0.5% to 4.5%. Similarly, public administration and defence, compulsory social security and information and communication sectors would also experience relatively modest declines between 1.5% and 4.4%. These sectors would not be insulated in the case of an outbreak caused by a measles-like agent, with average losses of around 16%.

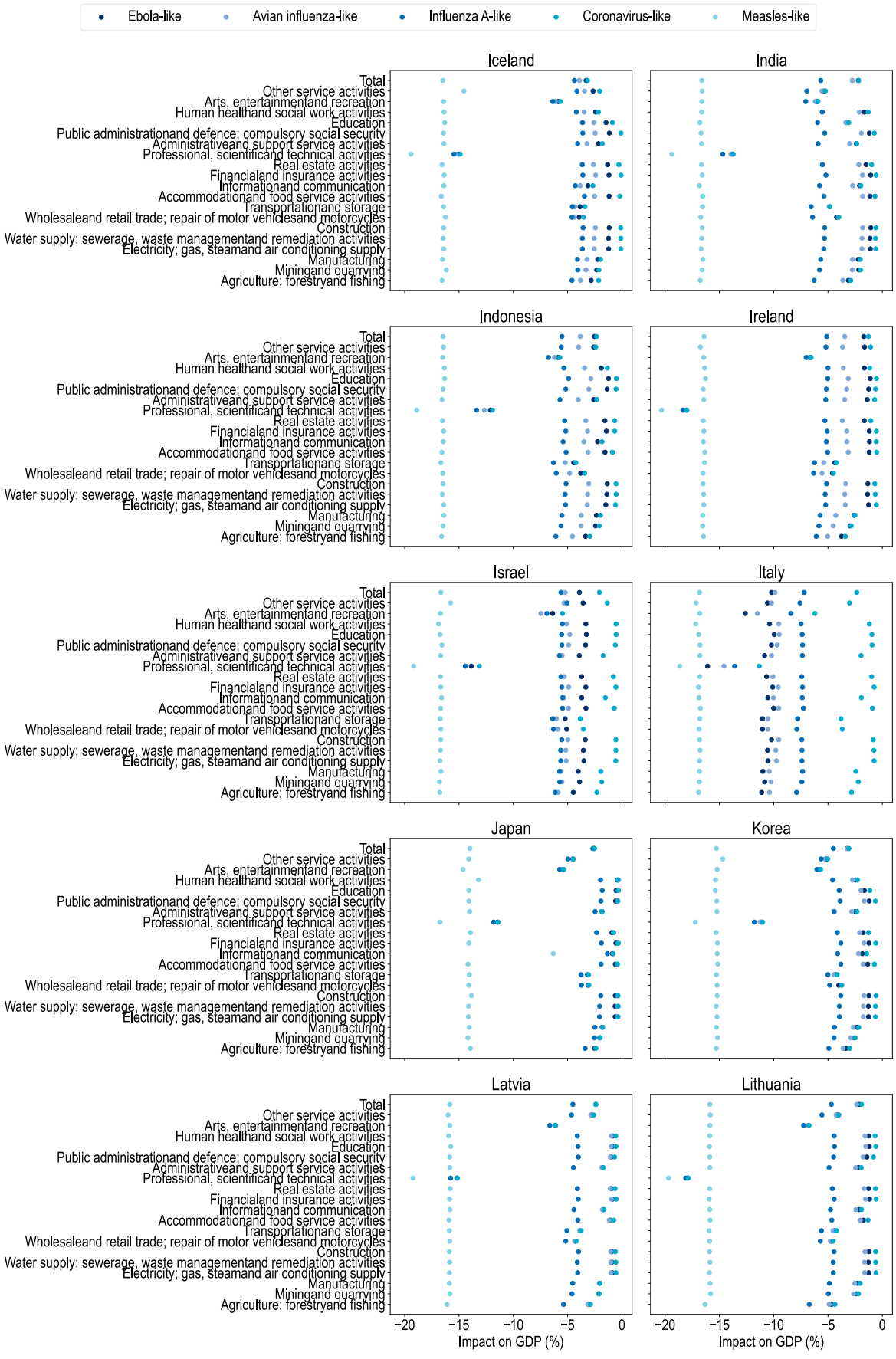
The differences in GDP contraction across sectors are explained by several factors. On the demand side, sectors that rely heavily on face-to-face interactions or discretionary spending (e.g. transportation) would experience sharp declines. By contrast, sectors such as health and education could face relatively stable or even increased demand, as they are often classified as essential services and therefore remain fully or partially operational during outbreaks (European Commission, 2021[142]). On the supply side, disruptions depend on the ability of firms to maintain operations amid workforce and input shortages and restrictions on mobility. Transport and storage and manufacturing sectors would be particularly vulnerable, whereas service-based sectors, especially those that can operate remotely (e.g. information and communication sector) face fewer physical bottlenecks. However, in severe outbreaks, both demand and supply channels would deteriorate simultaneously.

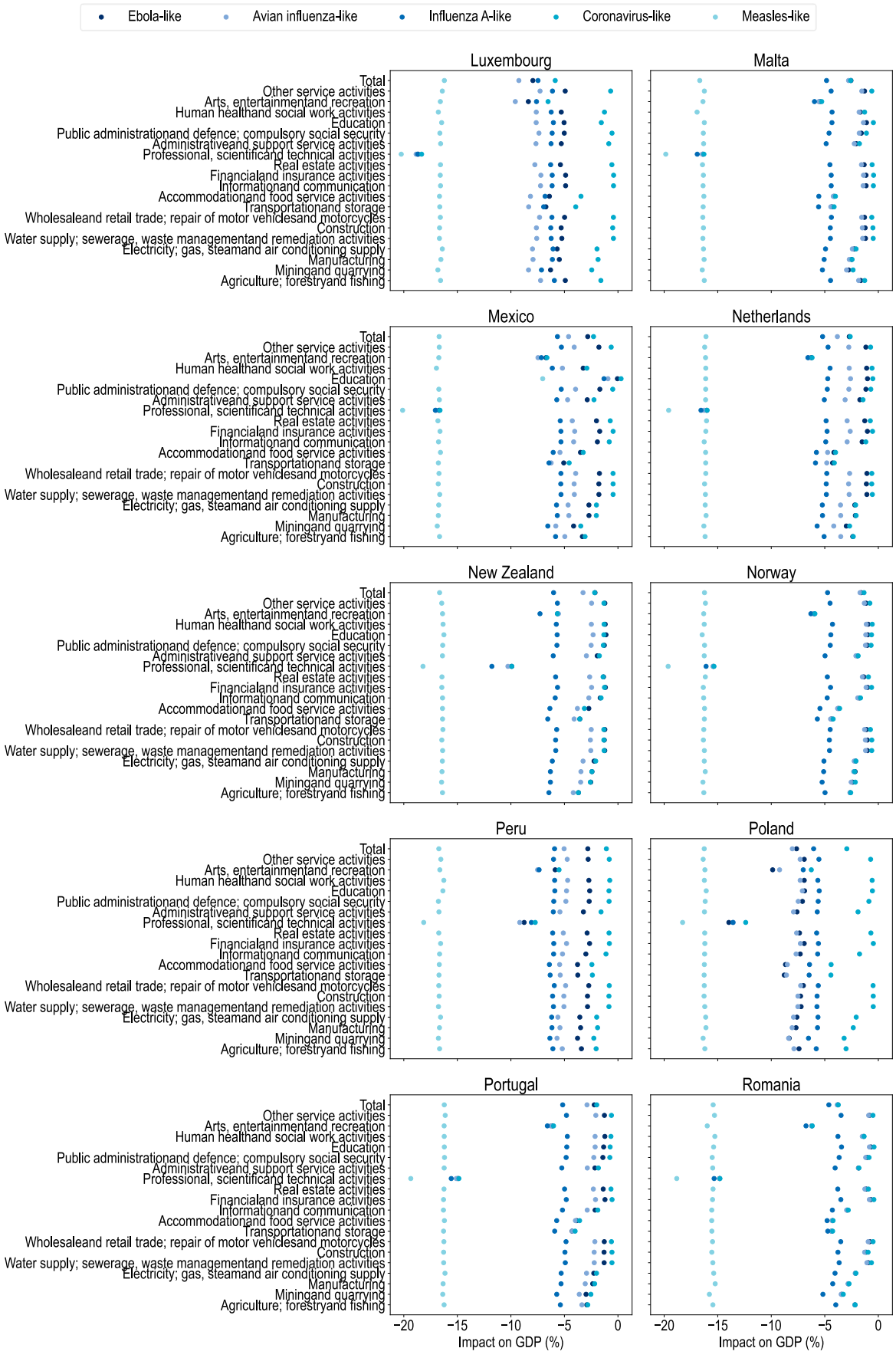
Figure 3.8. If no action is taken during a pandemic, the economy takes a major hit

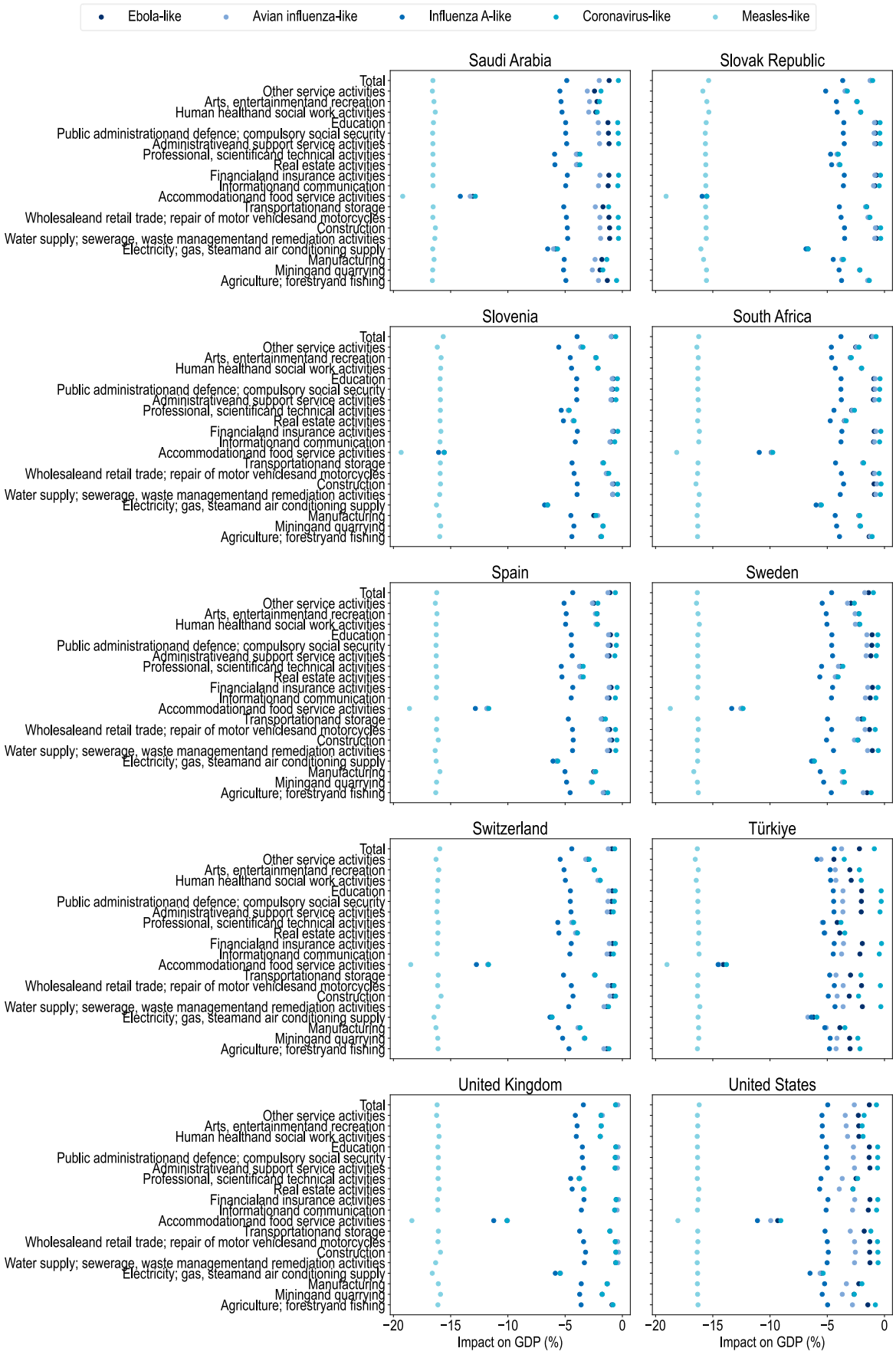
Percentage of GDP contracted during the first nine months of unmitigated outbreaks by sector




Ebola-like
Avian influenza-like
Influenza A-like
Coronavirus-like
Measles-like
Croatia
Cyprus
Czechia
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Total
Other service activities
Arts, entertainmentand recreation
Human healthand social work activities
Education
Public administrationand defence; compulsory social security
Administrativeand support service activities
Professional, scientificand technical activities
Real estate activities
Financialand insurance activities
Informationand communication
Accommodationand food service activities
Transportationand storage
Wholesaleand retail trade; repair of motor vehiclesand motorcycles
Construction
Water supply; sewerage, waste managementand remediation activities
Electricity; gas, steamand air conditioning supply
Manufacturing
Miningand quarrying
Agriculture; forestryand fishing
−20
−15
−10
−5
0
Impact on GDP (%)


Ebola-like
Avian influenza-like
Influenza A-like
Coronavirus-like
Measles-like
Iceland
India
Indonesia
Ireland
Israel
Italy
Japan
Korea
Latvia
Lithuania
Total
Other service activities
Arts, entertainmentand recreation
Human healthand social work activities
Education
Public administrationand defence; compulsory social security
Administrativeand support service activities
Professional, scientificand technical activities
Real estate activities
Financialand insurance activities
Informationand communication
Accommodationand food service activities
Transportationand storage
Wholesaleand retail trade; repair of motor vehiclesand motorcycles
Construction
Water supply; sewerage, waste managementand remediation activities
Electricity; gas, steamand air conditioning supply
Manufacturing
Miningand quarrying
Agriculture; forestryand fishing
−20
−15
−10
−5
0
Impact on GDP (%)


Ebola-like
Avian influenza-like
Influenza A-like
Coronavirus-like
Measles-like
Luxembourg
Malta
Mexico
Netherlands
New Zealand
Norway
Peru
Poland
Portugal
Romania
Total
Other service activities
Arts, entertainmentand recreation
Human healthand social work activities
Education
Public administrationand defence; compulsory social security
Administrativeand support service activities
Professional, scientificand technical activities
Real estate activities
Financialand insurance activities
Informationand communication
Accommodationand food service activities
Transportationand storage
Wholesaleand retail trade; repair of motor vehiclesand motorcycles
Construction
Water supply; sewerage, waste managementand remediation activities
Electricity; gas, steamand air conditioning supply
Manufacturing
Miningand quarrying
Agriculture; forestryand fishing
−20
−15
−10
−5
0
Impact on GDP (%)


Ebola-like
Avian influenza-like
Influenza A-like
Coronavirus-like
Measles-like
Saudi Arabia
Slovak Republic
Slovenia
South Africa
Spain
Sweden
Switzerland
Türkiye
United Kingdom
United States
Total
Other service activities
Arts, entertainmentand recreation
Human healthand social work activities
Education
Public administrationand defence; compulsory social security
Administrativeand support service activities
Professional, scientificand technical activities
Real estate activities
Financialand insurance activities
Informationand communication
Accommodationand food service activities
Transportationand storage
Wholesaleand retail trade; repair of motor vehiclesand motorcycles
Construction
Water supply; sewerage, waste managementand remediation activities
Electricity; gas, steamand air conditioning supply
Manufacturing
Miningand quarrying
Agriculture; forestryand fishing
−20
−15
−10
−5
0
Impact on GDP (%)

Note: Sectors of the economy include: Agriculture, forestry and fishing; mining and quarrying; manufacturing; electricity, gas, steam and air conditioning supply; water supply, sewerage, waste management and remediation activities; construction; wholesale and retail trade, repair of motor vehicles and motorcycles; transportation and storage, accommodation and food service activities; information and communication; financial and insurance activities; real estate activities; professional, scientific and technical activities; administrative and support service activities; public administration and defence, compulsory social security; education; human health and social work activities; arts, entertainment and recreation; and other service activities.
Source: Analysis based on the OECD SPHeP-PPR and the FOEC models.

StatLink https://stat.link/ov4hsc

3.6. Conclusions

This chapter assessed the potential health and economic consequences of pandemic outbreaks across five illustrative scenarios reflecting pathogens of pandemic potential. The results indicate that unmitigated outbreaks could cause severe health impacts and place substantial strain on healthcare systems, with outcomes varying widely across countries depending on both pathogen characteristics and national contexts.

The analysis also highlights the significant economic disruption that pandemics can generate. Across 51 countries, GDP could contract by 2.7% to 16.2%, depending on the scenario, with the transport, manufacturing and professional services sectors among the most affected. These estimates are likely conservative, as the model does not account for the long-term health and economic repercussions of future pandemics. The findings of the chapter underscore the need for sustained investment in PPR capacities. Building on lessons from COVID-19, subsequent chapters examine the health and economic impact of scaling up NPIs to mitigate pandemic impacts (Chapter 7) and estimate the cost of investing in the strengthening of PPR capacity (Chapter 8).

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Annex 3.A. Epidemiological factors that contribute to the pandemic potential of pathogens

Agent type

Different classes of microbes have a differentiated potential to become a global catastrophic biological risk:

- **Viruses** are of higher concern given their rate of replication, the lack of broad spectrum anti-viral agents and the genomic characteristics of RNA viruses. In particular, concerns are rising in recent years about the risk of highly pathogenic avian influenza (HPAI) caused by the H5N1 virus
- Infections caused by **bacteria** are another rising concern, considering the serious threat of antimicrobial resistance.
- In comparison, **fungal infections** have a more limited pandemic potential given that, in general, fungi show a more limited ability to reproduce efficiently in mammalian hosts with higher body temperatures (Adalja et al., 2018[45]).
- **Prions** (i.e. transmissible infective proteins) also have more limited pandemic potential because their transmission routes are restrictive.
- Finally, infections caused by **protozoans** are often vector-borne, thus their pandemic potential is currently considered to be limited given the availability of anti-malarian compounds and vector avoidance strategies have proved successful when employed appropriately (Adalja et al., 2018[45]).

Basic reproduction number (R_o)

The basic reproduction number is one of the most important factors that help assess the epidemic trajectory of a disease. It refers to the average number of secondary cases that can occur after one infectious individual is introduced in a susceptible population (Delamater et al., 2019[54]). The basic reproduction number is typically reported as a single numeric value or a range with high and low values. The magnitude of $\mathrm{R_o}$ is considered to shed light on to the potential size of an outbreak. It is generally accepted that if the average number of secondary cases:

- exceeds 1 or equal to 1 (i.e. $\mathrm{R_o} \geq 1$), a disease is outbreak is likely to occur or persist.
- stays below 1 (i.e. $\mathrm{R_o} < 1$), then the outbreak would be expected to end.

Quantifying the precise magnitude of $\mathrm{R_o}$can be difficult, because it depends on a wide range of factors such as the location of the outbreak, population density, seasonality and the stage of the outbreak. The $\mathrm{R_o}$value can also be different for the same disease across the different stages of the outbreak. This has been shown to be the case during the 1918 influenza outbreak when the median $\mathrm{R_o}$value around 1.81 in the first wave of the outbreak, 1.73 in the 2nd wave and 1.70 in the third wave (Biggerstaff et al., 2014[55]). Similarly, there has been considerable variation in the estimated $\mathrm{R_o}$ of recent outbreaks caused by coronaviruses.

Mode of transmission

The mode of transmission refers to the variety of ways through which an infectious agent may be transmitted to a susceptible host from its natural reservoir. Certain transmission types can pose a greater threat to population health (Adalja et al., 2018[45]). For example, disease pathogens that spread through the respiratory route (e.g. influenza) are considered to pose great risks for large outbreaks, because public health interventions that aim to interrupt the spread of an airborne pathogens/ droplets are substantially more difficult to implement (e.g. mask wearing). Similarly, pathogens such as Hepatitis A and *Vibrio cholera* that spread though faecal/oral exposure can cause large outbreaks if water and sanitation infrastructures are undermined (Mavhunga, 2023[60]). In contrast, the spread of a pathogen agent that is transmitted through direct contact may be more easily interrupted by scaling up infection prevention and control measures in the community and healthcare settings (e.g. increasing the use of personal protective equipment). The spread of vector- and tick-borne diseases are generally circumscribed by the geographic distribution of disease vectors, though these diseases are becoming increasingly worrisome threat to population health across OECD, EU/EEA and G20 countries.

Timing of transmission

Several factors that relate to the timing of disease transmission play a crucial role in determining the scale of disease outbreaks. Certain infectious diseases such as EVD are contagious during the later stages of an infection while the infected person shows symptoms. This limits the opportunities for spreading the infection (Wilder-Smith, 2021[13]). This was also the case for smallpox – the only human infectious disease eradicated from the planet – which was not contagious during its incubation period (Adalja et al., 2018[45]). In comparison, a person infected with the human immunodeficiency virus (HIV) can potentially infect other persons years after the initial infection, even though the estimated probability of disease transmission per exposure without treatment remains low (Nelson and Williams, 2014[44]). Other pathogen agents such as influenza viruses are contagious during their incubation period and even before the infected person develops any symptoms. In other words, there may be more opportunities for these types of pathogen agents to spread because the infected individuals can transmit the disease while conducting their daily activities without any major interruptions.

Non-symptomatic disease transmission

The share of non-symptomatic infections is another factor that plays a crucial role in determining the course of an infection as well as the course of an outbreak. Non-symptomatic infections can occur in two ways:

- **Asymptomatic infection**: An asymptomatic infection refers to a situation where an infected person does not develop any symptoms over the course of the disease (Gao et al., 2021[67]).
- **Pre-symptomatic infection**: Whereas pre-symptomatic infection occurs when the infection is detected before the infected individual eventually develops symptoms.

Previous evidence documented that the transmission of dengue and EVD can occur in the absence of any symptoms (Duong et al., 2015[143]). In the case of COVID-19, the evidence on emerging data collated through systematic reviews and meta-analysis suggested that the share of people who tested positive for COVID-19 and never developed any symptoms range from around 8.4% to 39% (Gao et al., 2021[67]).

The relative infectiousness of asymptomatic cases in comparison to symptomatic cases remains highly uncertain. This uncertainty is a reflection of the differences across study settings in terms of what is considered an asymptomatic case, the testing capacity and the accuracy of tests used, the duration of the follow-up period and difficulties around measuring and quantifying disease transmission (Gao et al.,

2021[67]; CDC, 2021[68]). Considering this uncertainty and based on available evidence, the CDC suggests that COVID-19 can consider that asymptomatic patients are around 25% as infectious as symptomatic individuals (CDC, 2021[68]).

Non-symptomatic infections can complicate the public health response to halt the spread of an outbreak. Non-symptomatic infections can be addressed by scaling up early and effective testing capacity. However, as shown by previous evidence from the COVID-19 pandemic, the identification of non-symptomatic infections can become more difficult during the peak moments of large outbreaks because the pressure on the testing capacity exacerbates as the infection rates rise (Gao et al., 2021[67]; Oran and Topol, 2020[144]).

Disease severity

The severity of a disease is another key factor that affects the extent to which a pathogen can cause harm to population health and disrupt economic activity. CFR is one summary measure that help assess the severity of disease. It refers to the proportion of population who lose their lives due to a particular condition. CFR reflects not only the epidemiology of the pathogen agent, but also the current standard of healthcare and it could be influenced by the emergence of new therapeutics or vaccines.

A pathogen of pandemic potential does not need to have an extremely high CFR value to cause significant disruption to the society. For example, the 1918 influenza pandemic had a devastating impact on population health (Beach, Clay and Saavedra, 2022[69]), causing approximately 50-100 million deaths worldwide. Yet, compared to other diseases such as EVD, the disease severity of the 1918 pandemic is considered to be low, with an estimated CFR of around 1-2% (Schoch-Spana et al., 2017[70]). In contrast, the EVD is considered to have a very high risk of mortality, with an estimated CFR rate of around 60% (Kawuki, Musa and Yu, 2021[145]). Despite this, the risk of a global EVD pandemic is considered to be relatively low (Box 3.6), partly because the spread of the disease is expected to be curbed relatively fast if a high proportion of the population adheres with public health guidelines (ECDC, 2022[71]).

Relying solely on a pre-defined CFR threshold to inform policy decisions around the use of non-pharmaceutical interventions (NPIs) could hinder the public health response during the pandemics. For example, during a disease outbreak caused by a pathogen with low risk of mortality, relying only on CFR may prevent policymakers from taking policy action. Yet, an uncontrolled outbreak may still result in substantial detrimental impacts to the society, because CFR does not account for other effects of pandemics such as absenteeism from work due to ill health and excess demand for healthcare services (Reed et al., 2013[146]). Conversely, a disease agent with a high level of CFR may prompt policymakers to impose a wide range of NPIs (e.g. stay-at-home orders). However, the benefits of NPIs do not always outweigh their costs considering that certain diseases such as common cold are self-limiting such that they will resolve on their own without medical intervention or treatment. Importantly, a single summary measure of CFR cannot fully capture the detrimental impacts of outbreaks on the health of vulnerable populations (e.g. older adults and people with immunodeficiencies) who might bear a heavier attributable mortality burden (Dadras et al., 2022[147]).

Level of baseline immunity in the population

Broadly, having an immunologically naïve population may increase the risk of pandemic outbreaks because a larger share of the population is susceptible to infections. When the individuals in a population have already been exposed to a disease agent through previous infection (i.e. natural immunity) or vaccination (i.e. vaccine-induced immunity), they may develop immunity. In turn, the pre-existing immunity in the community can help slow the spread of the disease agent and reduce the number of new infections, decreasing the risk of a pandemic outbreak. In addition, pre-existing immunity in the community may also

decrease the health burden and the burden on the health system, even when the impact on the basic reproduction number is limited, for example by limiting the development of more serious forms of the disease. Conversely, when a novel disease agent emerges, all individuals in the community are considered to be susceptible to infection because no individual would have pre-existing immunity. This could mean that the disease could spread in the population at a faster pace, potentially resulting in a pandemic outbreak. This was the case with the COVID-19 pandemic that emerged in an immunologically naïve population, causing millions of infections and deaths.

4 Extreme weather events are reshaping the landscape of communicable diseases

This special focus chapter reviews the existing evidence on the extent to which extreme weather events can influence the burden of communicable diseases. The analysis adopts a One Health lens, which makes a strong case for collaboration and co-ordination across human and animal health sectors, agri-food systems and the environment to address threats to population health.

In Brief

Key messages

Extreme weather events are becoming more frequent and intense

- Extreme weather events such as heatwaves, heavy precipitation, droughts and associated wildfires and coastal flooding are becoming more frequent and intense across every geographic region, including the OECD and EU/EEA countries.
- The rise in the frequency and intensity of extreme weather events helps create a more favourable environment for many diseases to flourish and expand their reach. Extreme weather events have been shown to aggravate 58% of all known communicable diseases that impact human health.

The rise in the frequency and intensity of extreme weather events influences changes in the landscape of communicable diseases

- The health consequences of extreme weather events are already substantial and mounting. Beyond their immediate impact through heat-related illnesses, extreme weather events are reshaping the landscape of communicable diseases by
  - directly impacting the emergence, distribution and resurgence of many communicable diseases through their influence on the pathogens, vectors, hosts and the environment within which diseases are transmitted.
  - indirectly by exacerbating the increased risk of opportunistic infections and co-morbidities and malnutrition and limiting access to public health services and medicines, exacerbating food insecurities, altering migration patterns and increasing the likelihood of engaging in risky behaviours.
- Mirroring global trends, there has been a sustained expansion of environmental suitability in the EU/EEA countries for major arboviruses over the last three decades, including dengue transmission by *Aedes aegypti* and by *Aedes albopictus*, chikungunya transmission by *Aedes albopictus* and Zika virus transmission by *Aedes aegypti*.
- The risk of water-borne diseases rises with floods, heavy rainfall, hurricanes and heatwaves. Heavy precipitation, particularly following dry periods, has been shown to trigger outbreaks of cryptosporidiosis, giardiasis and other gastrointestinal illnesses, while major flooding events have caused large, well-documented outbreaks in Europe and North America. Increases in sea surface temperature and sea level are also expanding the environmental suitability for *Vibrio* species, heightening risks in coastal regions.
- Heatwaves and heavy rainfall are increasingly recognised as important drivers of food-borne diseases. Rising water temperatures in freshwater and marine systems have mixed effects on food-borne pathogens, with some bacteria proliferating in warmer conditions and others showing higher survival at lower temperatures. Heavy rainfall also elevates contamination of surface waters and aquaculture systems, increasing risks from *Campylobacter*, *Listeria* and *Escherichia coli (E. coli)*.
- Key antimicrobial resistance (AMR)-causing organisms, including *Campylobacter*, *E. Coli*, *Klebsiella pneumoniae* and *Staphylococcus aureus*, have shown sensitivity to rising

temperatures. As these pathogens already account for most AMR-related deaths in the OECD and EU/EEA countries, extreme weather events could intensify the future AMR burden.

Disease surveillance systems can be bolstered to counter risks associated with extreme weather events

- The existing disease surveillance systems can be strengthened to consider the rising risks of extreme weather events by
  - Integrating data from multiple sources, including information on pathogens, hosts, vectors, human populations as well as meteorological and environmental conditions;
  - Risk mapping the environmental suitability for disease vectors;
  - Providing tools for early warning and targeted public health action;
  - Using predictive models that couple disease dynamics with meteorological and environmental data and
  - Strengthening early warning systems to integrate the high risk of extreme weather events.

4.1. Extreme weather events are rising across the globe

Extreme weather events such as heatwaves, heavy precipitation, drought and associated wildfires and coastal flooding are becoming more frequent and intense across every geographic region, including the OECD and EU/EEA countries (ECDC, 2010[1]; IPCC, 2023[2]). For example, in 2024, Europe's warmest year on record, persistent and stable drought conditions gripped Southern and Central and Eastern Europe, while heatwaves continued to become longer, more frequent and more intense (C3S and WMO, 2025[3]). Exceptional heat and drought have been exacerbating wildfire risk across Europe, North America and beyond. Heavier downpours have been triggering catastrophic flooding in many areas (C3S and WMO, 2025[3]).

The health consequences of extreme weather events and climate-related events are already substantial and mounting. The European Environment Agency estimated that between 1980 and 2020, around 85 000 to 145 000 people lost their lives due to weather events across the EU/EEA countries, with more than 85% of these deaths occurring due to heatwaves (European Environment Agency, 2022[4]). More recent events have shown that the attributable risks remain high. In 2024 alone, storms and floods affected an estimated 413 000 people and resulted in at least 335 deaths across Europe (C3S and WMO, 2025[3]).

Beyond these immediate impacts, extreme weather events are reshaping the broader communicable disease landscape. A growing body of evidence shows that extreme weather events have already led to worrisome increases in the incidence and severity of weather-related vector-borne, water-borne and food-borne diseases; precipitated the emergence of infectious diseases with non-human animal origin (WHO, 2021[5]); contributed to the emergence and resurgence of diseases such as dengue, hantavirus and cholera (Wu et al., 2016[6]); led to shifts in the geographic distribution and seasonal patterns of diseases (McIntyre et al., 2017[7]) and contributed to the emergence of clustered disease outbreaks and outbreaks in non-traditional geographic areas and in unexpected times (Wu et al., 2016[6]).

Considering that extreme weather events are becoming more frequent, it is crucial to assess their links with communicable diseases. This chapter aims to examine the extent to which extreme weather events may exacerbate future pandemic risks by influencing communicable disease patterns. The existing evidence on extreme weather events and communicable diseases is reviewed, using methods grounded in the One Health approach. (Box 4.1). While the chapter attempts to be as comprehensive as possible in its scope, the drivers of changes in communicable disease patterns other than extreme weather events (e.g. domestic and international travel, urbanisation, socio-economic development) are excluded. A review

of the links between extreme weather events and their impact on population health other than communicable diseases is also outside the scope of the chapter. The chapter also does not assess how robust the systems for implementing non-pharmaceutical interventions are or the extent to which the general public complies with them in countries at higher risk of extreme weather events. The chapter concludes by discussing the ways in which disease surveillance systems can be enhanced to take into account the rising risks of extreme weather events.

Box 4.1. The role of the environment in the One Health framework

The importance of One Health is widely acknowledged in tackling threats to population health

One Health is a multi-disciplinary and multi-sectoral approach to improving population health. It acknowledges that human health is closely interlinked with the health of animals, agri-food systems and the environment. It promotes adopting a collaborative framework that addresses the complex drivers of communicable diseases across multiple sectors while designing and implementing programmes, policies, legislation and research (WHO, 2022[8]).

Over the last two decades, the centrality of One Health has been increasingly recognised as a vital step to improve population health. For example, building on previous efforts, the WHO, the Food and Agriculture Organization of the United Nations and the World Organisation for Animal Health formed the Tripartite Alliance in 2010 to help operationalise the One Health approach (FAO, OIE and WHO, 2017[9]). More recently, the COVID-19 pandemic, once again, spotlighted the importance of One Health. In 2021, many countries, including G20 countries, committed to strengthening the implementation of One Health in the Rome Declaration (Global Health Summit, 2021[10]). In 2022, the United Nations Environment Programme formally joined the Alliance on One Health.

The role of the environment within the One Health framework is often overlooked

To date, much of the effort to strengthen the implementation of One Health focussed on the intersection between human and animal health. In this light, WHO recently highlighted that the environment can broadly impact human health through three pathways:

- Acting as a **reservoir** through which nutrients, living organisms (e.g. animals, plants, microorganisms), pathogens and chemicals are accumulated and transported
- Serving as **a focal point** for ecological and chemical processes essential to human health
- Acting as a **health mediator** through which disease agents in the environment are transferred to human and animal hosts either directly from the soil, air or through feeding or contact with infected organisms.

The WHO underscored the importance of exploring all three of these pathways to better understand the linkages at the human, animal and environment interface and underlined that it is crucial to assess how changes in the environment affect all these three mechanisms.

Source: WHO (2022[8]),*Global Tuberculosis Report*, https://www.who.int/teams/global-tuberculosis-programme/tb-reports/global-tuberculosis-report-2022; FAO, OIE, WHO (2017[9]), *The Tripartite's Commitment Providing multi-sectoral, collaborative leadership in addressing health challenges,* www.oie.int/2010tripartitenote; European Commission and G20 (2021[10]), *Global Health Summit – The Rome Declaration,* https://www.g20.utoronto.ca/2021/Global_Health_Summit_Rome_Declaration.pdf.

4.2. Extreme weather events create new pathways for communicable diseases to emerge, spread and thrive

Extreme weather patterns are already driving profound changes in communicable disease patterns. One recent systematic assessment found that 58% (218/375) of known communicable diseases that affect human health have been shown to be aggravated by changes in weather patterns and rising temperatures (Mora et al., 2022[11]).Another assessment found that in Europe, around 63% of human and domestic animal pathogens are sensitive to extreme weather events and other meteorological changes (McIntyre et al., 2017[7]). Table 4.1 provides examples of communicable diseases that have been shown to be sensitive to extreme weather events.

Table 4.1. Extreme weather events impact the patterns of many communicable diseases

Communicable diseases	Precipitation / Moisture	Warming	Drought	Storms/ Rainfall	Floods	Natural cover change	Ocean temperature rise / acidificaition / circulation	Fires	Heat waves	Sea level
Ascariasis	√	√								
Hepatitis A	√		√	√	√					
Hepatitis B				√						
Hepatitis E	√	√	√	√	√					
Chagas disease	√	√		√			√	√		
Chlamydial infections			√							
Cystic echinococcosis	√	√				√				
Dengue	√	√	√	√	√	√	√	√	√	√
Diarrheal disease	√	√	√	√	√	√	√	√	√	√
Ebola	√	√	√		√	√			√	
Encephalitis					√					
Gonococcal infections				√						
Guinea worm disease	√					√				
HIV/AIDS			√			√				
Hookworm disease	√	√			√	√				
Invasive Non-typhoidal Salmonella (iNTS)	√	√	√	√	√				√	
Leishmaniasis	√	√	√		√	√	√	√		
Leprosy	√	√								
Respiratory infections*	√	√	√	√	√			√	√	√
Malaria	√	√	√	√	√	√	√	√	√	√
Measles			√	√	√					
Meningitis	√	√	√	√			√			
Rabies		√	√			√				
Schistosomiasis	√	√				√				
Tetanus				√	√					
Trichuriasis	√	√								
Tuberculosis				√				√		
Typhoid	√	√	√	√	√			√	√	
Paratyphoid fever	√	√			√					

Communicable diseases	Precipitation / Moisture	Warming	Drought	Storms/ Rainfall	Floods	Natural cover change	Ocean temperature rise / acidificaition / circulation	Fires	Heat waves	Sea level
Whooping cough (Pertussis)					√					
Yellow fever	√	√	√		√	√		√		
Zika Virus	√	√	√	√		√	√			

Source: OECD review based on (Mora et al., 2022[11]).

The remainder of this section provides an overview of the pathways through which changes in the environment and extreme weather events alter communicable disease patterns, with a focus on three disease categories: i) vector-borne diseases, ii) water-borne diseases and iii) food-borne diseases. An overview of the definitions used in the chapter is provided in Box 4.2.

Box 4.2. Exploring the links between extreme weather events and communicable diseases: Definitions

Extreme weather conditions can influence the emergence, distribution and resurgence of many communicable diseases by influencing the pathogens, vectors, hosts and the environment within which diseases are transmitted. Definitions of some of the technical terms used in this chapter include the following:

- *Agent* refers to infectious organisms, pathogens and chemical contaminants. In general, the presence of an agent is necessary but not sufficient for a disease to occur. A number of factors such as an organism's ability to result in disease or dose of exposure influence whether the presence of an agent will cause disease
- *Pathogen* refers to organisms (e.g. bacteria, viruses, parasites and fungi) that can cause diseases in human and animal populations. A range of factors influence whether exposure to a pathogen will generate disease (e.g. the ability of the pathogen to cause disease)
- *Vector* refers to living organisms (e.g. ticks, fleas, mosquitoes) that act as an intermediary that carries a disease agent from a reservoir to a host that is susceptible to the disease
- *Host* refers to humans or other living organisms that are susceptible to infectious agents. A host's susceptibility and response to an agent is influenced by a number of factors including genetic composition, nutritional and immunologic status, anatomic structure, presence of disease or medications and psychological makeup
- *Environment* refers to a host of external factors that bring together hosts and agents. Environmental factors encompass physical factors (e.g. geology), biological factors (e.g. the presence of vectors like insects to transmit agents) and socio-economic factors (e.g. crowding, sanitation and accessibility of healthcare services)
- *Basic reproduction number* (R_o) refers to the average number of secondary cases that occur in a susceptible population after the introduction of one infectious individual. The value of R_o gives information about the potential magnitude of the outbreak. Broadly, if the value of R_o exceeds 1, an outbreak is likely to occur/persist. Conversely, if R_o is below 1, then the outbreak is likely to end
- *Incubation period* refers to the time elapsed between exposure to an infectious agent and the onset of disease

- *Vectorial capacity* is a summary measure that tracks the capacity of a vector to transmit disease based on vector abundance, survival, competence and feeding rate and the length of the extrinsic incubation period
- *Climate suitability (CS) for infectious disease transmission* is a measure that helps assess the extent to which shifts in temperature and precipitation can promote the transmission of infectious diseases. Specifically, rises in temperature and precipitation have been shown to increase the suitability of many vector- and tick-borne diseases. Changes in R_0 are often used in the literature to track trends in the CS of a number of pathogens such as dengue, chikungunya, Zika, malaria and Vibrio bacteria.

4.2.1. Extreme weather events are driving the spread of vector-borne diseases

Vector-borne diseases refer to illnesses caused by a wide range of parasites, viruses and bacteria that are transmitted via vectors (Table 4.2). In general, vector-borne diseases are considered to be limited to the geographic areas where their vectors are available. However, in recent years, rising temperatures and extreme weather events have been shown to precipitate an expansion in the distribution of many vectors in new geographic areas (Baylis, 2017[12]; El-Sayed and Kamel, 2020[13]).

Table 4.2. Example list of vector-borne diseases and pathogens

Vector	Disease caused	Pathogen type
Mosquito (*Aedes)*	Chikungunya	Virus.
	Dengue	Virus
	Lymphatic filariasis	Parasite
	Rift Valley fever	Virus
	Yellow fever	Virus
	Zika	Virus
Mosquito (*Anopheles)*	Lymphatic filariasis.	Parasite
	Malaria	Parasite
Mosquito (*Culex*)	Japanese encephalitis	Virus.
	Lymphatic filariasis	Parasite
	West Nile fever	Virus
Aquatic snails	Schistosomiasis (bilharziasis)	Parasite
Blackflies	Onchocerciasis (river blindness)	Parasite
Fleas	Plague (transmitted from rats to humans)	Bacteria
	Tungiasis	Ectoparasite
Lice	Typhus.	Bacteria
	Louse-borne relapsing fever	Bacteria
Sandflies	Leishmaniasis.	Parasite
	Sandfly fever (phlebotomus fever)	Virus
Ticks	Crimean-Congo haemorrhagic fever	Virus
	Lyme disease	Bacteria
	Relapsing fever (borreliosis)	Bacteria
	Rickettsial diseases (e.g. spotted fever and Q fever)	Bacteria
	Tick-borne encephalitis	Virus
	Tularaemia	Bacteria
Triatome bugs	Chagas disease (American trypanosomiasis)	Parasite
Tsetse flies	Sleeping sickness (African trypanosomiasis)	Parasite

Source: Adapted from (WHO, 2024[14]).

Extreme weather events can drive complex changes in the transmission dynamics of vector-borne diseases by altering environmental conditions, vector ecology and host behaviour. Heavy precipitation, for example, can create favourable breeding environments for mosquitoes, particularly when combined with warming temperatures and elevated humidity. Evidence from the United States shows that such conditions can measurably increase disease risk (Soverow et al., 2009[15]). Using more than 16 000 WNV cases reported between 2001-2005, one study found that cumulative weekly precipitation and the occurrence of at least one day of heavy rainfall in the preceding month were both associated with higher WNV incidence (Ibid). Shifts in precipitation patterns can also influence the movement and concentration of animal hosts, bringing them into closer proximity to vectors or human populations. For instance, rodent-borne hantavirus outbreaks have been linked to the displacement and aggregation of rodent populations following periods of intense rainfall or drought (Engelthaler et al., 1999[16]).

However, impacts of extreme weather events on vector ecology are not uniform such that some extreme conditions may have opposing or indirect effects. While drought can reduce the availability of natural mosquito habitats, it may simultaneously increase human-made breeding sites if households rely more heavily on stored water for domestic use (Rocklöv and Dubrow, 2020[17]). This dynamic has been documented in Northeastern Brazil, where increased household water storage during a prolonged drought created additional breeding habitats for *Aedes aegypti*, facilitating range expansion and elevating the risk of local dengue outbreaks (Pontes et al., 2000[18]).

Beyond vectors themselves, extreme weather events and changes in the environment are also reshaping the behaviour, distribution and interactions of hosts and broader ecosystems. Shifts in temperature and rainfall patterns have been linked to changes in the geographical range of reservoir species, enabling pathogens to emerge in areas previously unaffected. In Australia, for example, weather-related disturbances have contributed to the southward movement of black flying foxes (i.e. reservoirs for the Hendra virus) leading to spillover events in horses and subsequent human infections in new regions (Baker et al., 2021[19]).

Arboviruses

Arboviruses use vectors such as mosquitoes, ticks, midges and sandflies as their main transmission routes to cause infection and serious disease in humans (Table 4.3). For example, two types of mosquitoes (i.e. *Aedes aegypti* and *Aedes albopictus*) serve as vectors for diseases such as dengue, chikungunya and Zika virus. For certain arboviruses such as West Nile Virus (WNV), humans are considered to be a dead-end host such that the infected individuals do not contribute to onward transmission (Sigfrid et al., 2018[20]). For other arboviruses, such as dengue, chikungunya and Zika virus, humans are considered to be the main reservoir for infection, which poses a great risk of disease outbreaks without requiring an animal reservoir (ibid).

Table 4.3. Arboviruses that are considered to be clinically important in European countries

Family	Virus	Transmission type	European regions and risk	Occurrence
Flavivirus	West Nile Virus	Mosquito bites Blood transfusion Organ transplant Vertical (rare) Breastfeeding (rare)	Southern, Southeast and Central Europe (high risk)	Endemic
	Tick-borne encephalitis virus	Ticks Animal tissue Blood transfusion Breastfeeding	Northern, Central and Eastern Europe (high risk)	Endemic

Family	Virus	Transmission type	European regions and risk	Occurrence
	Dengue virus	Mosquito Anthroponotic Blood transfusion Transplant Breast milk	Madeira and Southern Europe (low risk)	Sporadic, localised outbreaks
Bunyaviridae Nairovirus	Crimean-Congo haemorrhagic fever	Tick Animal and human fluids Nosocomial	Southeast and Central and Eastern Europe (low risk)	Endemic
Bunyaviridae Phlebovirus	Toscana virus	Sandfly	Southern and Southeast Europe (high risk)	Endemic
Togaviridae Alphavirus	Chikungunya virus	Mosquito Anthroponotic	Southern Europe (low risk)	Sporadic, localised outbreaks
	Sindbis virus	Mosquito	Northern Europe	Endemic

Source: Modified from (Sigfrid et al., 2018[20]), Preparing clinicians for (re-)emerging arbovirus infectious diseases in Europe, https://doi.org/10.1016/j.cmi.2017.05.029.

Over the last three decades, there have been worrisome trends in the occurrence of disease outbreaks caused by arboviruses such as dengue and chikungunya across the OECD and EU/EEA countries as follows:

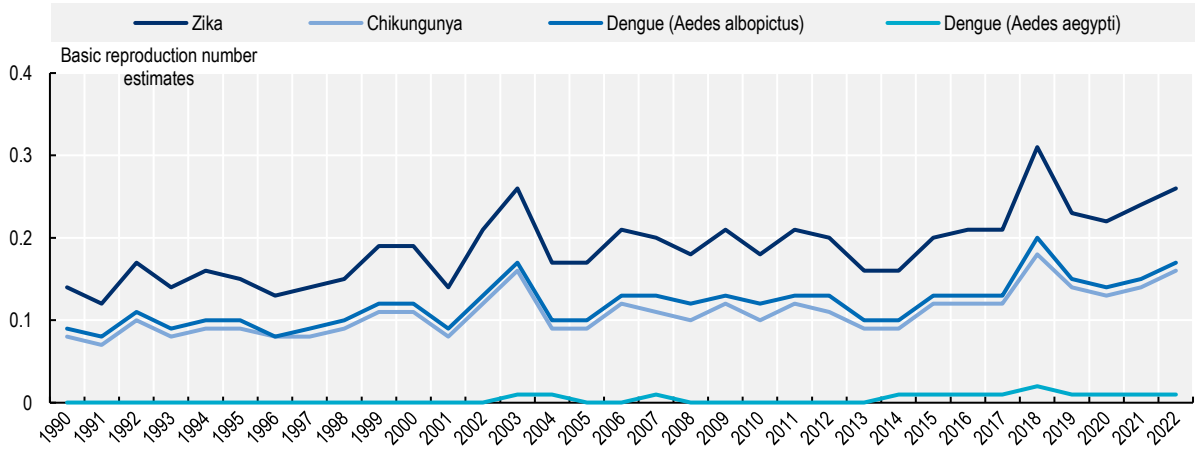
- Since the 1927/28 outbreak in Greece, countries in Europe were largely spared from locally transmitted cases of dengue (Lillepold et al., 2019[21]). This trend changed in 2010 when Croatia and France reported locally contracted cases of dengue. Over the last decades, sporadic dengue outbreaks occurred in France between 2013-2015 and in 2018 (ibid). More recently, Spain also reported locally transmitted dengue cases.
- Similarly, chikungunya was not present in European countries until recently. Italy was the first country that experienced large chikungunya outbreaks in 2007 and 2017, with more than 200 confirmed and probable cases occurring in each outbreak (Rezza et al., 2007[22]). Other locally transmitted chikungunya cases have also been reported in France in 2010, 2014 and 2017, though the scale of these outbreaks was substantially smaller compared to Italy (Lillepold et al., 2019[21]).
- The disease burden of the Zika virus remains low among OECD and EU/EEA countries (Rabe et al., 2025[23]). Costa Rica, Chile, Colombia, the United States of America and France are among OECD countries that have reported current or previous Zika virus transmission as of May 2024 (ibid). There were 22 reported cases of Zika in the EU/EEA in 2020, 7 in 2021 and 34 in 2022 (ECDC, 2023[24]; ECDC, 2024[25]). According to ECDC data, there were 79 travel-associated Zika cases in 2023 (Meredith, 2025[26]).

While the overall burden associated with these diseases remains low in the vast majority of OECD and EU/EEA countries, the rise in their burden is closely linked to increasing CS for the transmission of these diseases. Evidence from recent global analyses shows that climatic conditions have become progressively more favourable for the spread of arboviruses such as dengue, Zika and chikungunya over the past five decades (Romanello et al., 2022[27]). Using the basic reproduction number as a proxy for CS, one study estimated an increase of 11.5% in suitability for dengue transmission by *Aedes aegypti*, 12% for dengue by *Aedes albopictus*, 12% for chikungunya by *Aedes albopictus* and 12.4% for Zika virus transmission by *Aedes aegypti* between 1951-1960 and 2012-2021 (Ibid). Over the same period, the length of the transmission season for these arboviruses increased by approximately 6%, indicating both expanding geographical suitability and longer windows of potential transmission. Coupled with this, there has been a 6% increase in the length of transmission season for all arboviruses in this period (ibid).

Mirroring the global trends, there has been a steady long-term increase in the CS for the transmission of Zika, chikungunya and dengue over the last three decades in European countries (Figure 4.1). The

suitability of Zika, measured using its basic reproduction number, shows the largest relative growth, rising from 0.14 in 1990 to 0.26 by 2022. Chikungunya suitability also increased, rising from 0.08 to 0.16 in the same period. CS for dengue transmitted by *Aedes albopictus* also rose gradually and consistently from 0.09 in 1990 to approximately 0.17 by 2022, while the suitability for dengue transmitted by *Aedes aegypti* also increased in the same period.

Figure 4.1. Climate suitability of dengue, Zika and chikungunya increased across European countries over the last three decades



Note : Europe refers to the 38 member and co-operating countries of the European Environment Agency.
Source: (van Daalen et al., 2024[28]), The 2024 Europe report of the Lancet Countdown on health and climate change: unprecedented warming demands unprecedented action, https://doi.org/10.1016/s2468-2667(24)00055-0.

Evidence suggests substantial cross-country variation in the CS for the transmission of many arboviruses. Across the EU/EEA members, the CS for the transmission of chikungunya is estimated to be the highest in countries in Southern and Central Europe including in Croatia, Hungary, Romania and Bulgaria. In contrast, Norway, Sweden, Finland and Denmark have the lowest CS for the transmission of this disease (van Daalen et al., 2022[29]). Projections of the geographic distribution of *Aedes aegypti* and *Aedes albopictus* point towards expanded distributional potential across much of Western Europe, the Balkan region with particularly high risk around the Mediterranean and Adriatic coasts (Ibid). (Semenza and Paz, 2021[30]) report that areas of France, Spain, Germany and Italy may experience increases in climatic suitability for chikungunya, particularly along major river basins such as the Rhine and Rhone. The abundance of mosquitoes is also expected to increase in the next two decades, suggesting that more individuals will be at risk of malaria and dengue fever (Baharom et al., 2021[31]).

The geographic expansion of vectors and viruses is a crucial factor that exacerbates the CS of arboviruses. The most invasive mosquito, known as the Asian tiger mosquito (i.e. *Aedes albopictus*) is now considered to be endemic across countries in Southern Europe (Sigfrid et al., 2018[20]). This vector was shown to cause the first chikungunya outbreak in the province of Ravenna in Italy in July-August 2007 (Rezza et al., 2007[22]). Similarly, *Aedes albopictus* has been shown to expand its range. For example, in 2017, eggs and larvae of *Aedes albopictus* were found in separate locations in the United Kingdom (Public Health England, 2017[32]). The *Aedes aegypti* mosquito, introduced to the island of Madeira in Portugal in 2005, caused the first locally transmitted dengue outbreak in 2012 (Seixas et al., 2013[33]). This was considered to be the largest dengue outbreak in Europe in recent history, with the number of dengue cases exceeding 2 000 (Sigfrid et al., 2018[20]). Similar trends can be observed in North America. For example, one study

estimated that the average annual incidence of dengue in Mexico would increase around 12-18% by 2030, 22-31% by 2050 and 33-42% by 2080 (Colón-González et al., 2013[34]).

Several factors have been shown to explain the links between rising temperatures and vectorial capacity as follows:

- Rising temperatures can create a better environment for the development, survival and proliferation of many vectors. For example, higher temperatures have been associated with increases in the survival, abundance and feeding activity of the mosquitoes *Aedes aegypti* and *Aedes albopictus* (Reinhold, Lazzari and Lahondère, 2018[35]). Previous studies also showed that higher temperatures in several Northern European countries between 1950 and 2018 contributed to increased development rates for the tick *Ixodes ricinus*, the vector that causes Lyme disease, tick-borne encephalitis and Crimean – Congo haemorrhagic fever (Estrada-Peña and Fernández-Ruiz, 2020[36]).
- Higher temperatures can also alter the activity patterns of mosquitoes and ticks. For example, several studies have associated the rise in WNV infections in Europe to higher temperatures. This can partially be explained by the virus's ability to survive the winter in the mosquito vector, reduce the extrinsic incubation period and activate an earlier breeding season (Semenza and Paz, 2021[30]; Watts et al., 2021[37]; Young et al., 2021[38]; Chen et al., 2013[39]).
- Higher temperatures can also lead to a longer transmission season and expansions in the geographic range of vectors (El-Sayed and Kamel, 2020[13]). For example, studies show that from 1951-1960 to 2012-2021, the number of months suitable for malaria transmission has increased by 31.3% in highland areas of the WHO region of the Americas (Romanello et al., 2022[27]). The spatial distribution of malaria cases has also been shown to expand to higher altitudes in highland regions of Colombia and Ethiopia partly due to increases in temperature over time (Siraj et al., 2014[40]).

In addition to the factors mentioned above, air pollution and in particular exposure to fine particulate matter (PM2.5) has been suggested to significantly increase the risk of respiratory infections and illnesses. For example, a recent systematic review concluded that a 10 $\mu g/m^3$ increase in daily $PM_{2.5}$ levels was associated with a 1.5% rise in influenza risk (Orr et al., 2025[41]).

Tick-borne diseases

Extreme weather events and broader changes in the environment are also influencing the distribution and activity of non-mosquito vectors, including Ixodes ricinus ticks, which transmit Borrelia burgdorferi (i.e. the causative agent of Lyme disease) and tick-borne encephalitis virus. Evidence suggests that these vectors are expanding into wider geographic regions over time (The Lancet Microbe, 2021[42]; Couper, MacDonald and Mordecai, 2021[43]). In North America, rising temperatures have been associated with an earlier onset of the Lyme disease transmission season in the United States, as well as the northward movement of key reservoir hosts such as the white-footed mouse into previously unsuitable areas of Canada (Rocklöv and Dubrow, 2020[17]).

Similar patterns are observed in Europe. Multiple studies indicate that warmer temperatures have contributed to shifts in both the seasonal activity and geographic range of Ixodes ricinus, increasing the potential for Lyme disease transmission across Northern and Central European regions (Semenza and Paz, 2021[30]; Lindgren, Tälleklint and Polfeldt, 2000[44]; Estrada-Peña and Fernández-Ruiz, 2020[36]).

The distribution of other vector species such as sandflies, which transmit leishmaniasis, are also shifting (Rocklöv and Dubrow, 2020[17]). Warmer temperatures and shifting humidity patterns have already altered the geographic footprint of Phlebotomine sandflies, with evidence that future changes could support their expansion into central and Northern Europe, including Great Britain and Scandinavia (Semenza and Paz,

2021[30]). Such shifts imply that leishmaniasis, historically concentrated in Southern Europe, may emerge in regions previously considered low risk.

4.2.2. Extreme weather events alter the burden of water-borne diseases by impacting the quality, quantity and distribution of water resources

Water-borne diseases are closely linked with extreme weather events. Specifically, the forecasted increases in the frequency and intensity of floods and heavy rainfalls, driven primarily by the increases in the sea surface temperature, and more frequent hurricanes and El Niño events, are expected to increase the burden of water-borne diseases such as giardiasis, cryptosporidiosis, infections with pathogenic *Escherichia coli* (*E. coli)*, Shigella, cholera, viral hepatitis A and enteric/diarrhoeal diseases (El-Sayed and Kamel, 2020[13]). These extreme events can compromise drinking-water systems, facilitate the spread of pathogens through runoff and sewage overflows and increase human exposure to contaminated water sources.

Rising temperatures further compound these risks. A substantial body of evidence indicates that higher temperatures are associated with increased incidence of water-borne diseases (Levy et al., 2016[45]; Levy, Smith and Carlton, 2018[46]). A systematic review and meta-analysis examining the relationship between temperature and diarrhoeal disease found a positive association between increases in mean temperature and all-cause diarrhoea (incidence rate ratio [IRR] 1.06; 95% CI: 1.03-1.09), with a similarly elevated risk for bacterial diarrhoea (IRR 1.07; 95% CI: 1.04-1.10) (Carlton et al., 2015[47]). Evidence from OECD countries is consistent with these findings. In Australia, weeks with maximum temperatures above 31°C were associated with a 13.6 percentage points (p.p.) increase in the risk of cryptosporidiosis (Lal et al., 2013[48]). In Canada, analysis of 92 water-borne outbreaks between 1975 and 2001 found that outbreak risk increased during warmer weather (Thomas et al., 2006[49]).

Rising temperatures can also alter human exposure and susceptibility to infections by influencing their behaviour and engagement in activities but the existing evidence remains mixed (Committee on Emerging Microbial Threats to Health in the 21st Century, 2003[50]). For example, warmer weather can increase engagement in recreational water-related activities, which, in turn, increases the risk of water-borne diseases (Wu et al., 2016[6]). Extreme temperatures might also cause people to spend more time indoors, thereby promoting human-to-human transmission (Mora et al., 2022[11]).

Increases in the frequency and intensity of heavy rainfalls also precipitate a rise in water-borne disease outbreaks. For example, in the United States, one study that used data on 548 water-borne outbreaks between 1948-1994 found that more than half of outbreak events were preceded by heavy precipitation events within two months (Curriero et al., 2001[51]). Heavy precipitation events that follow a dry period have also been linked to increased risk of water-borne diseases. For example, one study used data collected from 2009 to 2014 from 4 cities whose water systems rely heavily on surface waters of the North American Great Lakes (e.g. Lake Ontario and Lake Michigan) (Graydon et al., 2022[52]). This study concluded that the risk of acute gastrointestinal illnesses caused by cryptosporidiosis and giardiasis increased after extreme precipitation events in 3 out of the 4 cities, with the relative risk estimates ranging roughly between 1.1 and 1.5 in 3-5 weeks after extreme precipitation weeks.

Flooding events can increase the risk of water-borne disease outbreaks by undermining the existing water supply systems and sanitation infrastructure. For example, one study from the city of Halle in Germany studied the potential impact of extreme river flooding after a heavy rain event in 2013. The study demonstrated that the extreme river flooding impacted the sewage system across the city and resulted in the contamination of the river water and water in recreational areas (Gertler et al., 2015[53]). In turn, the contamination of these water sources led to the largest cryptosporidiosis outbreak, a diarrhoeal disease caused by a parasite called Cryptosporidium, in Germany to date. The outbreak started about 6 weeks after the peak of the river flooding and led to the emergence of 167 cryptosporidium cases. Another study from the capital city of Copenhagen in Denmark studied the effects of an unusually heavy rainfall that

occurred in August 2010 the day before a triathlon competition, which led to severe flooding and overflow in the sewer system (Harder-Lauridsen et al., 2013[54]). This study found that this extreme weather event increased the risk of illnesses caused by *Campylobacter*, *Giardia lamblia* and *diarrhoeagenic E. coli* among swimmers that were exposed to the contaminated seawater during the triathlon compared to swimmers who were not. Other evidence from Austria, Bulgaria and France also highlight that floods are associated with increases in the incidence of leptospirosis, a re-emerging bacterial disease caused by exposure to contaminated water (Suk et al., 2020[55]).

Hurricanes and tsunamis can also trigger a rise in water-borne disease outbreaks. For example, in 2005 Hurricane Katrina, a category 4 storm, made landfall on the coast of Louisiana in the United States, particularly affecting the city of New Orleans. In the aftermath of the hurricane, an outbreak of acute gastroenteritis caused by norovirus occurred among more than 1 000 evacuees and relief workers in a temporary shelter at Reliant Park in Houston, Texas (Yee et al., 2007[56]). In India, the Indian Ocean tsunami that occurred in 2004 was followed by an outbreak of diarrhoeal illnesses caused by rotavirus in a temporary shelter (Liang and Messenger, 2018[57]).

Increased sea surface temperature can influence the life cycle of pathogens. One recent assessment showed that changes in sea surface temperature and surface salinity led to an expansion in the suitability for *Vibrio* bacteria (i.e. the disease agents that are found in marine waters and cause a wide range of infections in humans such as gastroenteritis, wound infections, sepsis and cholera). Specifically, one recent study suggested that around 86.3% of the Baltic coastlines have become suitable for infections caused by non-cholera *Vibrio* bacteria between 2014-2021 (Romanello et al., 2022[27]). This is a substantial rise from about 47.5% in 1982-1989 (ibid). In the United States between 2014-2021, about 57.1% of the Northeast coastlines became environmentally suitable for non-cholera *Vibrio* infections, a substantial rise compared to about 30% in 1982-1989 (ibid). The CS of infections caused by the non-cholera *Vibrio* bacteria also increased in the Pacific Northwest in the same period albeit at a smaller rate from 1.2% to 5.7% (ibid). This study further concluded that the proportion of global coastal waters suitable for *Vibrio cholera* has also expanded by 3.5% since 2003-2005 (Romanello et al., 2022[27]).

Rising sea levels have also been suggested to influence the burden of water-borne diseases by raising groundwater tables, damaging water and sanitation infrastructures, contaminating drinking water sources and facilitating the transfer of microbial pollutants from terrestrial sources (e.g. sewage) into marine environments used for food harvesting and recreational activities (National Collaborating Centre for Environmental Health, 2022[58]). Sea level rise can also create more suitable conditions for the proliferation of *Vibrio* by influencing the salinity of water (Jacobs et al., 2015[59]).

4.2.3. Extreme weather events are increasingly recognised as important drivers of food-borne diseases

Emerging evidence suggests that extreme weather events are an important driver of food-borne diseases, which can affect the entire food safety chain, from primary production and processing to storage and distribution.

Extreme heat exposure can lead to the proliferation of food-borne illnesses caused by bacteria such as *Salmonella.* One study from the United States extracted data from the Food-borne Diseases Active Surveillance Network between 2004-2014 and found that extreme heat exposure was associated with a 7% increase in the risk of Salmonella infections in Maryland and a 6% increase in Tennessee (Morgado et al., 2021[60]). This study also pointed to a worrisome rise in the risk of *Salmonella* serotype Javiana infections in Connecticut and Georgia that was associated with extreme precipitation events.

Similar findings have been reported in other OECD countries. One study used data from 1991 to 2001 from the National Notifiable Disease Surveillance System, including Perth, Adelaide, Melbourne, Sydney and Brisbane (D'Souza et al., 2004[61]). It showed that a 1-degree Celsius increase in temperature in the

previous month was associated with a 4.1% and 11% increase in the cases of *salmonellosis* in Perth and Brisbane respectively. One study from 10 European countries found that a 1-degree Celsius rise in weekly temperature was associated with a 5-10% increase in the number of *salmonellosis* cases (Kovats et al., 2004[62]), whereas another study projected that outbreaks in temperature-related incidences of Salmonella are expected to rise in Europe (Akil, Anwar Ahmad and Reddy, 2014[63]).

Rising surface water temperatures in fresh and marine water systems can have a mixed impact on the burden of food-borne illnesses. To date, some studies suggest a positive association between water temperature and the incidence of *Salmonella* and *Campylobacter* (Hellberg and Chu, 2015[64]) whereas others suggested an inverse relationship. For example, according to a recent study by (Semenza and Paz, 2021[30]), incidence of *Campylobacteriosis* is expected to increase by almost 200% across Scandinavian countries by the end of the century, which would translate to nearly 6 000 excess *campylobacter* cases per year (Ibid). Another study examined data collected from 21 sites in the coastal areas of Bahia de Todos Santos in Mexico between 2004 and 2006 (Simental and Martinez-Urtaza, 2008[65]). This study found that there was an inverse association between temperature and the detection of *Salmonella*. The authors indicated that this finding may be explained by the potential impact of sunlight and very high levels of solar radiation on the survival of the bacteria. Another study from Canada used data from the Grand River watershed in southern Ontario (Cheyne et al., 2009[66]) to show that two *Yersinia enterocolitica* virulence genes, a Gram-negative bacterium that causes a food-borne disease called yersiniosis, was more frequently detected in colder water temperatures. Another study from the United States also reported an inverse correlation between water temperature and detection frequency of *Campylobacter* in a rural mixed-use watershed over 2 years (2007-2009), though the study did not find a significant association between water temperature and detection frequency of *Salmonella* (Vereen et al., 2013[67]).

Heavy precipitation events are likely to increase the burden of food-borne illnesses by increasing the risk of water contamination. One study from Germany demonstrated that during and after heavy rainfall events, run-off from sewer overflow and non-point sources was associated with higher levels of *Campylobacter spp.* (Rechenburg and Kistemann, 2009[68]). Another study from Germany found that elevated levels of *C perfringens* and *E coli* in tributaries of multiple drinking water reservoirs were observed after extreme rainfall and runoff from surrounding agricultural and forest lands (Kistemann et al., 2002[69]). A subsequent study from Finland found that levels of *Listeria spp*. found in fish farms were elevated after periods of heavy rainfall (Miettinen and Wirtanen, 2006[70]). This study argued that this finding was most likely due to contaminated brooks and rivers, as well as other runoff waters in nearby areas.

Extreme weather events and rising temperatures can also impact pathogens directly by altering the habitats that pathogens and their competitors can survive in. For example, *Campylobacter spp*., Gram-negative bacteria that causes food-borne *Campylobacter* infections, has been shown to prosper in surface waters at low temperatures and during winter months (Jones, 2001[71]). The higher concentration of bacteria can partly be explained by the fact that warmer temperature can help promote the proliferation of bacteria that compete with *Campylobacter spp*.

4.2.4. Many pathogens that cause resistant infections are sensitive to extreme weather events

Antimicrobial resistance (AMR) remains a leading global health challenge that jeopardises the effectiveness of many medical and public health advances made in the 20th century. Patients with resistant infections have a greater risk of developing complications, a lower probability of recovery and a greater risk of death. Treating resistant infections tends to be costlier than treating susceptible infections because more intensive medical procedures and more aggressive antimicrobial therapies are generally used to treat these infections.

In 2023, the OECD produced a comprehensive assessment of the health and economic burden of AMR in 51 OECD, EU/EEA and G20 countries (OECD, 2023[72]). This publication demonstrated that in excess of

4.3 million resistant infections occurred annually across 34 countries included in the analysis. Approximately 65% of these infections were estimated to be acquired in community settings. The analysis also showed that up to 32.5 million extra days were spent in hospitals to treat resistant infections every year across the countries included in the OECD analysis. Considering this, the OECD and EU/EEA countries were estimated to spend up to USD 28.9 billion annually to treat resistant infections.

Findings from the latest OECD analysis suggested that extreme weather events are likely to exacerbate the AMR burden (OECD, 2023[72]). Many pathogens that cause significant AMR infections and deaths are sensitive to extreme weather events. For example, *Campylobacter,* a pathogen sensitive to climate, is responsible for more than 1.5 million infections that occur in community settings every year across 34 countries included in the OECD analysis, corresponding to around 36% of all resistant infections. Similarly, previous evidence showed that the incidence of superbugs such as *E. coli, Klebsiella pneumoniae and Staphylococcus aureus* have been shown to be sensitive to rising temperatures (Kaba, Kuhlmann and Scheithauer, 2020[73]). This poses a substantial threat to population health because the OECD analysis showed that these three superbugs are responsible for around three-quarters of all AMR-related deaths that occur annually across the 34 countries included in the analysis.

4.2.5. Extreme weather events can impact other diseases through indirect channels

An emerging strand of literature suggests that the effects of extreme weather events and rising temperatures can also impact communicable disease patterns indirectly. For certain diseases, such as tuberculosis (TB) and human immunodeficiency virus (HIV), the links between the changes in the environment and disease patterns may look less direct. For example:

- A growing body of evidence suggests that changes in temperature, precipitation, humidity and wind speed influenced the transmission of TB through the metabolic functions of *Mycobacterium tuberculosis* (i.e. the causative agent of TB) (Gelaw et al., 2019[74]; WHO, 2025[75]). For example, a study in Japan found that both extreme heat and cold temperature events were associated with a considerable rise in TB cases, with the estimated relative risks of 1.2 and 1.23 respectively (Onozuka and Hagihara, 2015[76]).
- Increases in temperature have also been linked with increased burden of HIV by increasing the risk of co-morbidities (Hewitt et al., 2006[77]; Guinto et al., 2022[78]) and HIV-associated opportunistic infections (Tong et al., 2017[79]), limiting access to public health services and antiretroviral medications (Lieber et al., 2021[80]), exacerbating food insecurities (Austin, Noble and Berndt, 2020[81]), altering migration patterns and increasing the likelihood of engaging in risky behaviours (e.g. substance use) (Baker, 2020[82]; Bellandi, 2022[83]; Vergunst et al., 2022[84]).

4.3. Disease surveillance systems can be adapted to consider the rising risks of extreme weather events

OECD, EU/EEA and G20 countries generally operate advanced infectious disease surveillance systems, comprising routine notification mechanisms, laboratory networks and emergency alert platforms such as the EU's Early Warning and Response System (EWRS). While effective for detecting many conventional outbreaks, these systems were not designed with accelerating meteorological extremes in mind, increasing the risk that communicable diseases that are sensitive to extreme weather events and changes in the climate go undetected or recognised only once they have already escalated.

Several limitations constrain the ability of current surveillance systems to detect and respond to health risks amplified by extreme weather:

- Routine health surveillance and weather information systems continue to operate largely in parallel. Only 23% of ministries of health (MOHs) globally report using meteorological data within their health surveillance systems, even though 74% of national meteorological and hydrological services provide relevant meteorological data (WMO, 2023[85]). Use is even lower for diseases sensitive to extreme weather events (ibid). Only 14% of MOHs incorporate meteorological information into vector-borne disease surveillance and only 12% do so for water-borne diseases and other water-related health outcomes (ibid).
- Current disease surveillance systems remain centred on human health, with hospital-based reporting serving as their primary foundation (Shen et al., 2025[86]). Because hospital-based systems detect cases only after individuals seek care, they could identify outbreaks with significant delays. For example, when COVID-19 struck, only a handful of countries (i.e. Denmark, Estonia and Latvia) had the infrastructure to have near real-time data on key areas such as hospital in-patients, emergency care, primary care, long-term care and prescription medicines (Oderkirk, 2021[87]).
- Surveillance networks tend to focus on a predefined list of notifiable pathogens, which may lead to under-detection of diseases that fall outside this list. Heatwaves, for example, may drive sporadic cases of uncommon infections (e.g. Vibrio wound infections in unusually warm waters or fungal respiratory infections after wildfires) that are outside the list of notifiable diseases. This was the case in Northern European countries with access to the Baltic Sea, where a substantial spike in vibriosis cases was observed after a heatwave during the summer of 2018 (Amato et al., 2022[88]).
- Surveillance capacity also varies widely across countries. While some countries maintain well-established surveillance infrastructure, others face persistent barriers ranging from limited financial resources and insufficient laboratory capacity to fragmented data-sharing arrangements (Shen et al., 2025[86]; Han et al., 2023[89]). In turn, these limitations delay timely detection. Disparities also exist within countries. Extreme weather events tend to disproportionately affect rural and remote communities (Dewi et al., 2024[90]) and socio-economically disadvantaged communities (Birkmann et al., 2022[91]). These populations often face longstanding barriers to healthcare access and rely on infrastructure and essential services that are more easily disrupted by extreme weather events such as floods, storms or heatwaves. As a result, in such settings, routine surveillance systems may not operate reliably, increasing the likelihood that outbreaks remain undetected or are captured only after significant delays.

4.3.2. Building infectious disease surveillance systems that consider the rising burden of extreme weather events requires comprehensive action

As extreme weather events increasingly influence communicable disease patterns, OECD, EU/EEA and G20 countries will need to modernise their surveillance systems to better anticipate and manage emerging risks. A central priority is the integration of multi-source data, including information on pathogens, hosts, vectors, human populations, meteorological and environmental conditions (Shen et al., 2025[86]).

Some OECD countries are already using multiple data sources to inform their disease surveillance efforts. For example, in the United States, the surveillance of WNV is based on two complementary approaches. Epidemiological surveillance focusses on human infections to measure the attributable health burden, detect early outbreak signals and inform timely action (CDC, 2024[92]). This includes analysing seasonal, geographic and demographic patterns in human mobility and mortality (ibid). Environmental surveillance, on the other hand, monitors local mosquito populations, viral activity in mosquito vectors and non-human hosts (e.g. birds) and other relevant environmental parameters (ibid). This surveillance helps predict human infection risk and enables preventive actions to avert outbreaks in people.

Another important step is the risk mapping of environmental suitability for disease vectors. Mapping current and projected meteorological conditions can highlight where vectors such as mosquitoes or ticks could

thrive, which in turn indicates where diseases might emerge or spread. In Canada, for instance, one project conducted model-based risk assessments to anticipate vector-borne disease emergence (WMO, 2023[85]). The first step was to identify which geographic regions were likely to be affected and when new risks were likely to appear. This was done by developing risk maps under current and future scenarios (ibid).

Providing tools for early warning and targeted public health action is equally important. For example, in Europe, the Lancet Countdown initiative included a risk assessment framework in its 2022 report (Alcayna, Rao and Lowe, 2025[93]). This effort included indicators to track the climatic suitability of several infectious diseases such as dengue, malaria, non-cholera Vibrio and West Nile virus.

The use of predictive models that couple disease dynamics with meteorological and environmental data can also help account for the impacts of extreme weather events. In Canada, for example, mathematical models of vector life cycles and disease transmission have been used to assess the climatic limits for various vectors and the diseases they carry (WMO, 2023[85]). These models shed light on how meteorological variables affected each stage of a vector's life and the pathogen's replication, while accounting for other ecological and socio-economic factors that influence disease occurrence. This approach yielded notable early warnings. For example, projections of the northward expansion of the blacklegged tick (i.e. the Lyme disease vector) under warming scenarios proved highly accurate and successfully predicted the emergence of Lyme disease in previously unaffected Canadian regions (ibid).

Beyond routine surveillance, countries can also strengthen EWRSs to better anticipate infectious disease outbreaks in the context of extreme weather events. Many of the infectious diseases detected by EWRSs are highly sensitive to extreme weather events. These systems can be further strengthened by incorporating meteorological information (WHO, 2021[94]). Several EWRSs in OECD, EU/EEA and G20 countries already integrate meteorological information (e.g. temperature, precipitation, extreme weather indicators) with epidemiological data to anticipate disease risks (Box 4.3). For example, in Mexico, one study showed that incorporating meteorological data into the national dengue and Zika surveillance accurately predicted outbreaks, with alarm signals predicting a dengue outbreak with 100% accuracy and a Zika outbreak with 97% accuracy (Cardenas et al., 2022[95]).

Box 4.3. The European Union's EWRS monitors extreme weather events that could amplify communicable disease risks

The European Union's EWRS, operational for more than two decades, serves as a central platform for monitoring communicable disease trends and identifying emerging health risks across EU members (European Commission, 2025[96]). It integrates information on approximately 50 communicable diseases, as well as other health issues such as AMR to enable public health authorities to rapidly assess threats and co-ordinate interventions that may require cross-border co-operation. Historically, the EWRS has supported responses to major events such as pandemic influenza A(H1N1), COVID-19 and, more recently, monkeypox (European Commission, 2025[96]).

The system is activated under four conditions:

- When a threat is unusual or unexpected for a given place and time;
- when it results in substantial morbidity or mortality;
- when it exceeds national response capacity; or
- when it affects multiple EU countries and may require co-ordinated action at the Union level.

Contingent on the responsiveness of Member States, alerts are issued within 24 hours of an EU country or the Commission becoming aware of a potential threat. For instance, the first notification of what

would later be identified as SARS-CoV-2 on 9 January 2020 was issued just days after China reported the emergence of an unidentified viral pneumonia (European Commission, 2025[96]).

Unlike specialised surveillance systems that track specific pathogens, the EWRS is designed to detect a broad range of hazards, including biological, chemical, environmental and unexplained events. This all-hazards mandate is increasingly important in the context of extreme weather events, because the EWRS also monitors extreme weather events and other environmental disruptions that may amplify infectious disease risks (European Commission, 2025[96]). For example, the system tracks severe floods, heatwaves, volcanic ash clouds, chemical spills and biological hazards such as biotoxins. Recently, the EWRS was activated for dengue outbreaks in the EU and overseas territories following a spike in cases across Italy, France and Spain in 2022 (European Commission, 2024[97]). As a result, disease surveillance at airports and ports was expanded to curb the spread of infections (ibid).

Source: European Commission (2025[96]); *"Surveillance and early warning"*, https://health.ec.europa.eu/health-security-and-infectious-diseases/surveillance-and-early-warning_en#the-early-warning-and-response-system-ewrs; European Commission (2024[97]), *"E-000791/2024 Answer given by Ms Kyriakides on behalf of the European Commission"*, https://www.europarl.europa.eu/doceo/document/E-9-2024-000791-ASW_EN.pdf.

4.4. Conclusions

Extreme weather events and rising temperatures are reshaping the epidemiology of communicable diseases. These shifts are already evident across OECD and EU/EEA countries, affecting vector-, water- and food-borne diseases and heightening the risk of antimicrobial resistance. The rising risks associated with extreme weather events underscore the need for strengthening disease surveillance platforms that integrate environmental, meteorological and epidemiological data to detect emerging threats earlier and safeguard population health.

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5 Community-based infection prevention and control measures are the first line of defence during outbreaks

Infection prevention and control (IPC) priorities implemented in community. settings are essential to prevent the spread of infections, including those caused by resistant organisms. This chapter reviews the existing evidence on the implementation of community-based IPC interventions, with an emphasis on 4 measures: 1) enhancing hand hygiene, 2) scaling up mask-wearing, 3) improving respiratory etiquette and 4) ensuring adequate ventilation and air filtration in indoor settings. The chapter starts by presenting findings from a new OECD survey on the landscape of community-based IPC policies implemented in 22 OECD Members and 2 accession countries. Next, the chapter presents and evaluates the existing evidence on the effectiveness of these interventions. After exploring the factors that influence the level of adherence with community-based IPC measures, the chapter concludes by exploring 9 policy options that can be used to motivate greater compliance. Throughout the chapter, best practice examples from OECD countries are provided.

In Brief

Key messages

Community-based infection prevention and control (IPC) measures provide the foundation for public health response to outbreaks in the absence of pharmaceutical interventions and vaccines

- Community-based infection prevention and control (IPC) measures refer to a set of interventions that mobilise individuals to actively participate in behaviours that can help interrupt the transmission of diseases in the community (e.g. hand hygiene, mask wearing, respiratory etiquette and indoor ventilation and air filtration).
- The COVID-19 pandemic put a spotlight on community-based IPC measures as a crucial strategy to curb the spread of outbreaks. Today, the importance of community-based IPC measures is widely recognised but there are crucial gaps in their timely implementation. The 2023-2024 OECD survey on Maintaining Infection Prevention and Control Measures in the Community showed that:
  - All 24 OECD Members and accession countries surveyed reported promoting community-based IPC measures during COVID-19, encouraging their use across settings such as childcare institutions, schools, workplaces and public or private buildings.
  - Among the 24 OECD Members and accession countries surveyed, most have prioritised hand hygiene and respiratory etiquette in their current pandemic preparedness and response plans (15 countries), while fewer prioritised mask-wearing (14 countries) and indoor ventilation (10 countries).
  - Interventions promoting hand hygiene are markedly more common than those focussed on mask use, respiratory etiquette or indoor ventilation and air filtration. Countries report stronger activity in educational initiatives and behavioural interventions in public spaces (e.g. visual cues). Many also involve local communities, technical experts and other stakeholders to ensure that programmes are evidence-based and effectively implemented. By contrast, far fewer countries report distributing IPC supplies or running large-scale awareness campaigns.
  - Only 6 of the 24 OECD Members and accession countries surveyed reported having a dedicated budget to support community-based hand hygiene and respiratory etiquette initiatives. Funding gaps are even more pronounced for mask wearing and indoor ventilation activities, with just 5 and 3 countries reporting dedicated resources respectively.

High levels of community compliance key to ensure community-based IPC measures are effective

- Emerging evidence shows that community-based IPC measures are an effective means to fight viral and bacterial infections, including resistant infections. But the magnitude of their impact depends heavily on community compliance.
- Globally, the level of compliance with community-based IPC measures remains low. The determinants of compliance are complex, reflecting situational factors (e.g. during/aftermath of outbreaks), sociodemographic characteristics, knowledge and understanding about disease transmission and the effectiveness of community-based IPC measures, spread of misinformation, risk perceptions and personal beliefs, societal norms and beliefs.

- The OECD analysis identified nine policy options that countries can consider sustaining high levels of compliance over time:
  - Provide clear regulations, guidelines and policy advice to promote best practices
  - Ensure adequate access to IPC supplies and materials (e.g. handwashing stations, masks)
  - Introduce financial incentives (e.g. financial rewards and/or penalties)
  - Design, implement and fine-tune community-based IPC programmes that are fit to address the unique community needs
  - Improve public awareness and understanding around community-based IPC measures
  - Implement behavioural nudges to build and maintain healthy behaviours (e.g. visual reminders)
  - Ensure sustainable funding for community-based IPC programmes
  - Set up routine monitoring and evaluation mechanisms to track compliance
  - Foster trust in public institutions

5.1. A primer on community-based IPC measures: What are they and why they are important?

Community-based infection prevention and control (IPC) measures refer to a range of non-pharmaceutical interventions implemented at the community level, with the aim of preventing and controlling the spread of infections. These measures typically involve mobilising community members to actively participate in behaviours that promote health and interrupt the chain of disease transmission. The vast majority of evidence demonstrates that community-based IPC measures can minimise the adverse health and economic consequences of viral and bacterial infections (Aiello et al., 2008[1]; Suess et al., 2012[2]), as well as antibiotic resistant infections (Maillard et al., 2020[3]). During epidemics and pandemics, these measures can play a pivotal role in emergency response, especially in the absence of effective medical treatments and vaccines (Müller, Razum and Jahn, 2021[4]). If compliance rates in the community are high, these measures can further yield considerable beneficial effects on the broader economy as they would limit the need for resorting to more stringent and restrictive policies.

The COVID-19 pandemic saw an unprecedented surge in the implementation of community-based IPC measures. Recent examples from OECD countries include hand hygiene campaigns in the United Kingdom (Department of Health and Social Care, 2020[5]); distribution of free-of-charge face coverings and masks in France (Service-Public, 2023[6]); raising awareness around the importance of respiratory etiquette in Canada (Infection Prevention and Control Canada, nd[7]); and improving natural and mechanical ventilation practices in Australia (Government of the State of Victoria, 2023[8]). The OECD countries differed considerably in terms of how they designed and implemented these measures in the context of COVID-19, with these differences creating a wide range in their overall effectiveness (Lison et al., 2023[9]; Persad and Pandya, 2022[10]).

Despite the benefits of community-based IPC measures, little is known in terms of: 1) the extent to which OECD countries rely on them to prevent and control various types of infections such as airborne diseases or antimicrobial resistance (AMR), 2) whether OECD countries integrate, or plan to integrate, them in their national pandemic preparedness plans, 3) the factors that influence the level of compliance with these measures in the community and 4) the policy levers that can be used to promote greater compliance in the general public. These knowledge gaps highlight the urgent need for generating high-quality evidence that can help OECD countries capitalise on the benefits of these measures.

Recognising these gaps, this chapter aims to review the existing evidence on the implementation of IPC practices in community settings.[1] The analysis focusses on four measures: 1) enhancing hand hygiene, 2) improving respiratory etiquette,[2] 3) scaling up mask-wearing and 4) ensuring adequate ventilation and air filtration in indoor settings. These interventions were selected because they are:

- Consistent with best-practice examples and international guidelines for limiting the spread of viral and bacterial infections and AMR rates
- Relevant to the policy priorities considered in the national pandemic preparedness plans across OECD and
- Shown effective for limiting the spread of infections based on high-quality evidence.

The chapter starts by examining the landscape of community-based IPC programmes implemented in OECD during the COVID-19 pandemic. The four measures examined in this chapter do not represent the full range of community-based IPC interventions. Others, such as environmental cleaning in community settings and waste management, also contribute to interrupting transmission (Dunn et al., 2024[11]) but fall outside the scope of this chapter. It, then, assesses the extent to which these measures have been integrated in national action plans to tackle disease outbreaks and future pandemics. Data presented in this section are gathered through the 2023-2024 OECD Survey on Community-based IPC Measures (Box 5.1). Next, the chapter shifts its focus and reviews the existing evidence on the effectiveness of the selected IPC measures. Most evidence presented in this section comes from the OECD and European Union/European Economic Area (EU/EEA) countries, though evidence from Group of 20 (G20) countries and OECD accession countries is also discussed. Next, the chapter explores the factors that impact the level of compliance with community-based IPC measures and presents nine policy options that can be used to motivate greater compliance in the long term.

Box 5.1. The 2023-2024 OECD survey on Maintaining Infection Prevention and Control Measures in the Community

The COVID-19 pandemic put a spotlight on community-based IPC measures as a crucial strategy to curb the spread of SARS-CoV-2. Despite this, comparable cross-country data on key aspects of implementing these measures have not been widely available. The 2023-2024 OECD survey on Maintaining Infection Prevention and Control Measures in the Community gathered information on 4 community-based IPC measures: i) hand hygiene, ii) respiratory etiquette, iii) mask wearing and iv) indoor ventilation.

The OECD survey had three focus areas:

i) The extent to which OECD Members and accession countries deployed community-based IPC measures during the COVID-19 pandemic,

ii) Whether community-based IPC measures are included as part of efforts to strengthen health system resilience and to prepare for future disease outbreaks and pandemics and

iii) The strategies that countries use to promote a greater level of compliance in the general public with these measures.

The questionnaire was sent to 43 countries in October 2023 and responses from OECD Members and accession countries were accepted until January 2024. A total of 24 countries, including 22 OECD Members and 2 accession countries, provided responses. More detailed information on the countries that participated in the survey is available in Annex Table 5.A.1.

5.2. Critical gaps undermine the implementation of community-based IPC measures

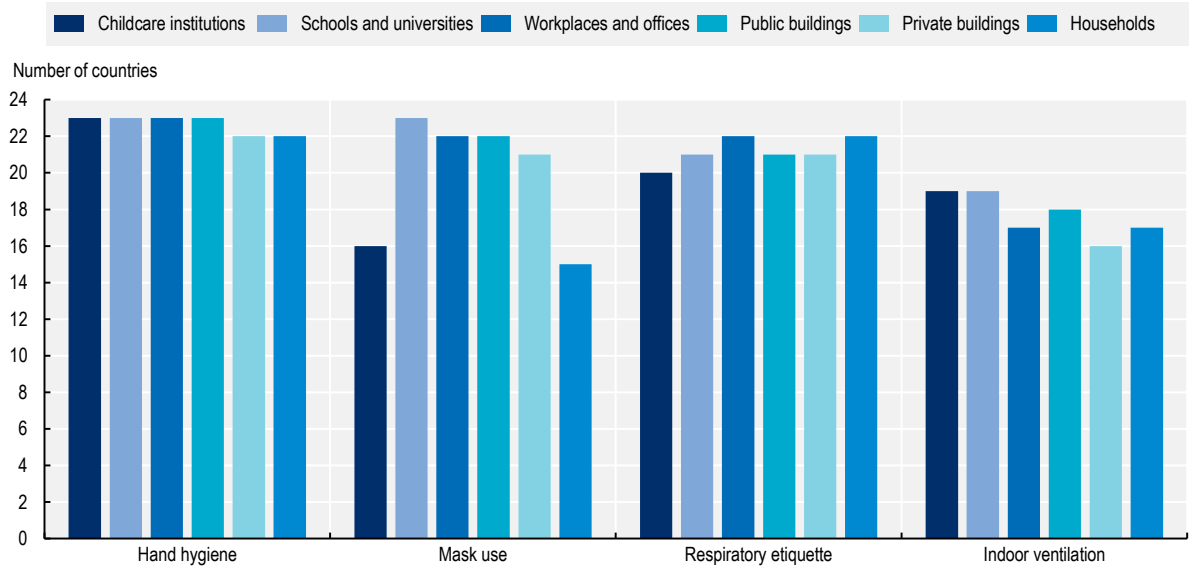
5.2.1. All OECD Members and accession countries deployed all 4 community-based IPC measures as part of their COVID-19 response

All 24 OECD Members and accession countries participated in the OECD survey indicated that they encouraged the use of all 4 of the community-based IPC measures as part of their COVID-19 response. These measures were implemented in the gamut of community settings from childcare institutions, schools and universities, workplaces and offices, to public and private buildings and households. Specifically, the OECD survey looked at the individual interventions and found that (Figure 5.1):

- **Hand hygiene**: Hand hygiene was promoted widely across many community settings, including in childcare institutions, schools and universities, workplaces and public buildings and to a lesser extent in private buildings and households.
- **Mask wearing**: 23 out of 24 OECD Members and accession countries that participated in the OECD survey reported that they promoted mask-wearing in schools and universities, making them the most popular setting for this intervention. In 22 countries, respondents reported promoting mask wearing in other settings such as workplaces and offices, public and private buildings. Mask-wearing was also promoted in childcare institutions and households albeit to a lesser extent.
- **Respiratory etiquette**: Respiratory etiquette was most frequently promoted in households, workplaces and offices, followed by other community settings such as schools and universities, public and private buildings.
- **Indoor ventilation:** Indoor ventilation was the least frequently promoted community-based IPC measure. Most OECD Members and accession countries chose to implement programmes targeting childcare institutions, schools and universities and public buildings. Workplaces and households were targeted to a smaller extent. Private buildings received the least attention.

Figure 5.1. Community-based IPC measures were implemented in a wide range of settings during the COVID-19 pandemic

Number of countries that reported implementing community-based IPC measures during the COVID-19 pandemic, by community setting



Note: This graph presents the number of countries that responded to the question "What were the main settings/population groups that the IPC interventions targeted during implementation during the COVID-19 pandemic?" The list of countries that participated in the survey is provided in Annex Table 5.A.1.
Source: Country self-assessment responding to the 2023-2024 OECD survey on Maintaining Infection Prevention and Control Measures in the Community.

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5.2.2. The centrality of community-based IPC measures is widely recognised but more needs to be done to fill the gaps in implementation

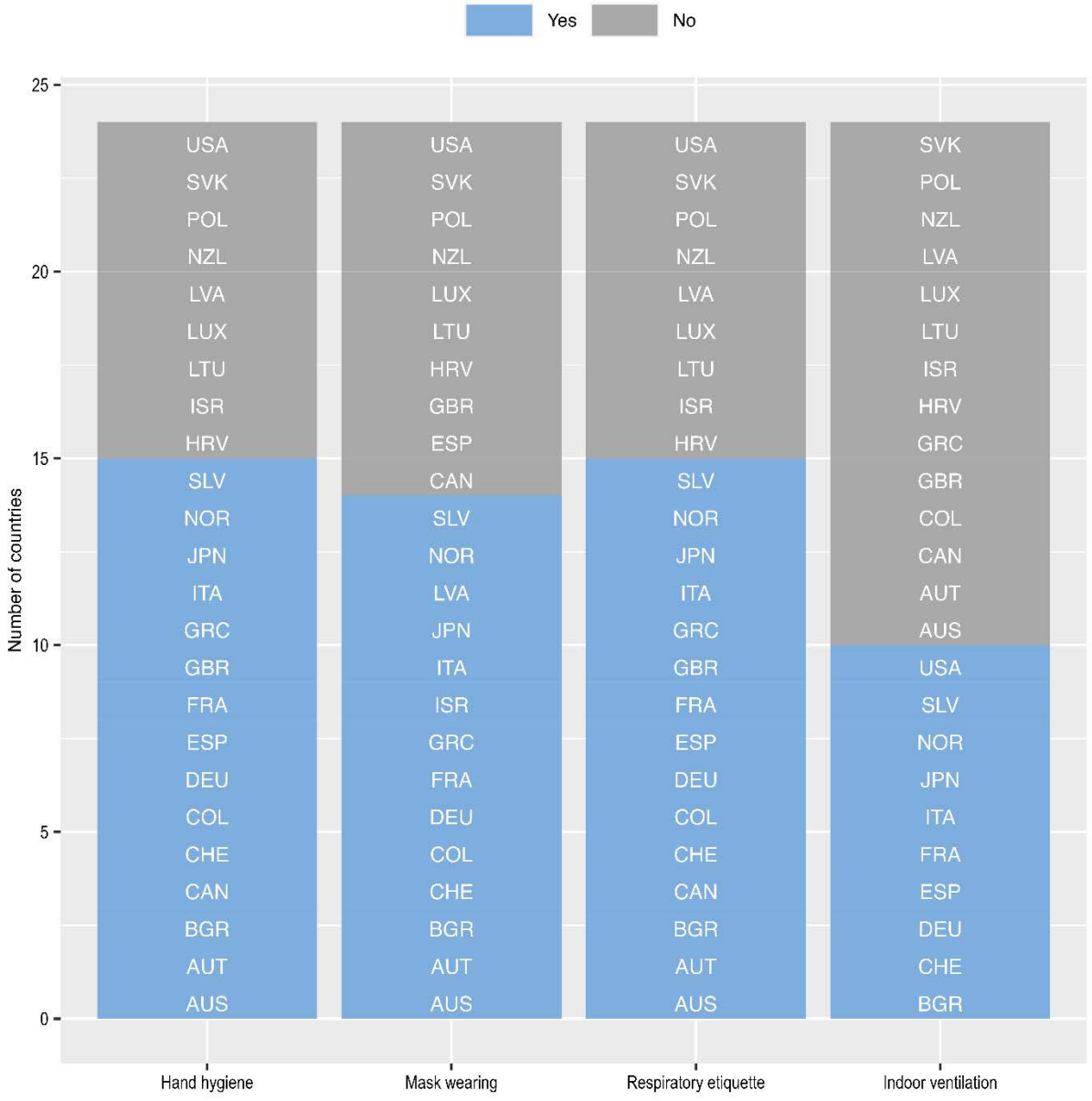
During the COVID-19 pandemic, the OECD Members and accession countries deployed a wide range of initiatives to promote greater compliance in the general public with community-based IPC interventions such as distributing free-of-charge hand hygiene materials (e.g. hand sanitisers and face masks); mass media campaigns and educational activities targeting community members; monetary/non-monetary fines for non-compliance and behavioural interventions (e.g. visual cues and reminders) (a more detailed discussion of these initiatives is provided throughout Section 5.3. These programmes often considered the benefits to high-risk groups such as young children, older people and people living with certain medical conditions.

Today, the importance of community-based IPC measures is widely recognised in the current national action plans on pandemic preparedness, pandemic influenza or other major infectious diseases with epidemic potential of most OECD Members and accession countries which participated in the OECD survey, but there are gaps (Figure 5.2).The survey shows that 15 out of 24 OECD Members and accession countries indicated that they have already incorporated improving hand hygiene and respiratory etiquette as a priority in their action plans and 14 countries included mask-wearing as a priority. In contrast,

improving indoor ventilation practices is not widely prioritised, with only 10 countries reporting that this intervention is incorporated in their national pandemic preparedness plans.

Figure 5.2. Community-based IPC measures highlighted in national pandemic preparedness plans, by intervention

Number of countries that reported having current national action plans on pandemic preparedness, pandemic influenza or other major infectious diseases that refer to community-based IPC measures



Note: This graph presents the number of countries that responded to the questions "Does your country's current national action plan(s) on pandemic preparedness, pandemic influenza or other major infectious diseases with epidemic potential refer specifically to hand hygiene/mask-wearing/respiratory etiquette/indoor ventilation?" The list of countries that participated in the survey is provided in Annex Table 5.A.1.
Source: Country self-assessment responding to the 2023-2024 OECD survey on Maintaining Infection Prevention and Control Measures in the Community.

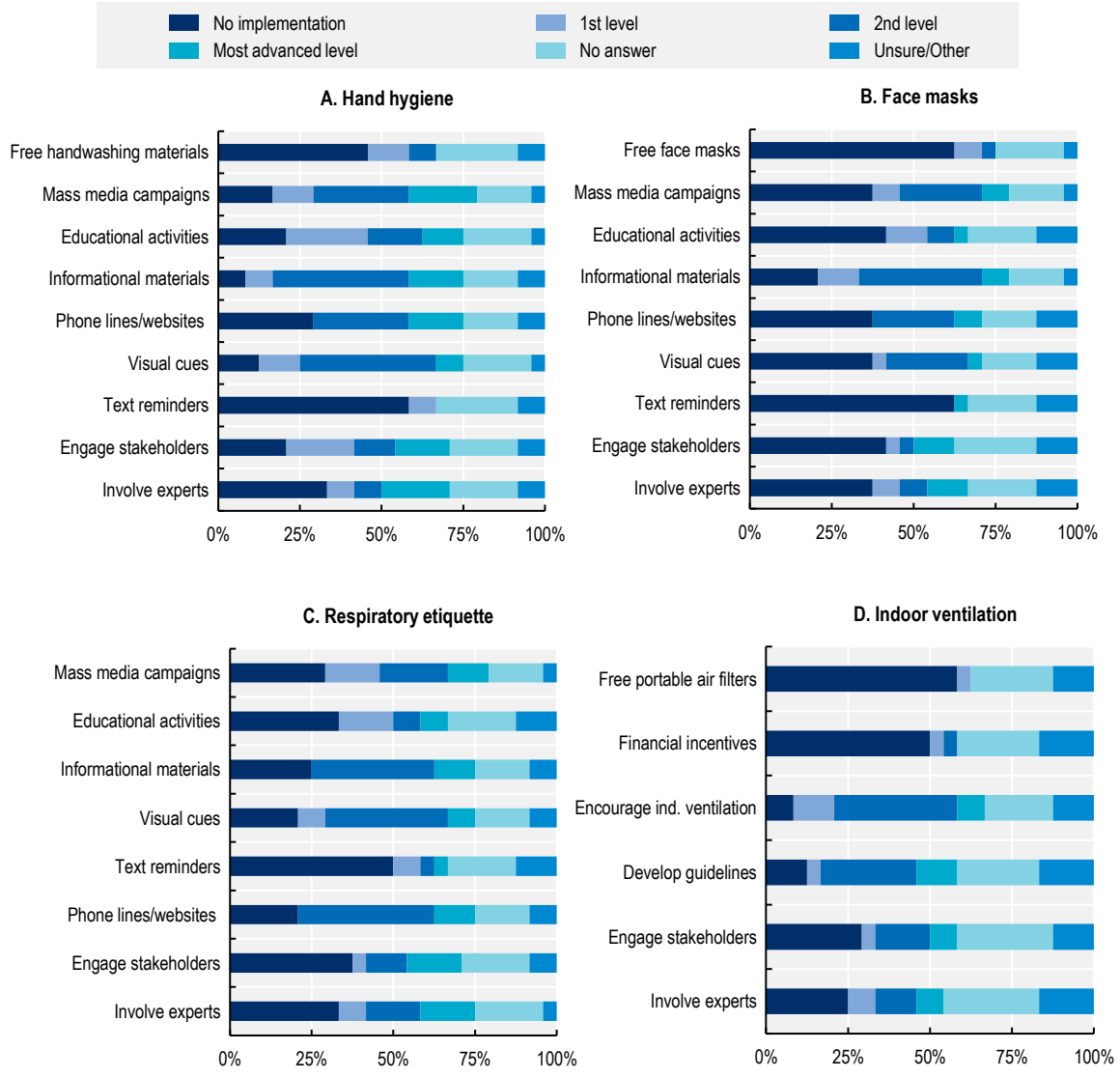
The majority of OECD Members and accession countries that already refer to community-based IPC measures in their current national action plans reported that they plan to continue to incorporate these measures in their future plans. In addition, 3 out of 4 OECD Members and accession countries that do not currently refer to at least one of the community-based IPC measures report that they plan to include at least one of these measures in their next national pandemic preparedness plans, suggesting that the importance of these measures to tackle infectious diseases is widely recognised. For example, in Luxembourg, this work is being co-ordinated by the Emergency Preparedness and Response Service for the development of the health preparedness and response plan.

Despite this, as shown in Figure 5.3, more needs to be done to fill crucial gaps in the implementation of these measures (Annex Table 5.B.1 provides a dashboard that provides more detailed information on the state of implementation of policies to promote community-based IPC practices). A closer look at the OECD survey shows that:

- **Distribution of IPC supplies**: Only 5 out of 24 OECD Members and accession countries reported that they have programmes that distribute free-of-charge hand hygiene materials (e.g. hand sanitisers) and 3 countries reported having arrangements for distributing free-of-charge facemasks. Only 1 country reported having programmes to improve the accessibility of air filters to improve indoor ventilation through the distribution of free-of-charge air filters.
- **Mass media campaigns:** Only 5 out of 24 countries participating in the OECD survey reported that mass media campaigns for hand hygiene promotion achieved the highest level of implementation, which entails having national-level activities/programmes that are fine-tuned/modified based on regular monitoring and evaluation activities. There are also gaps in the implementation of mass media campaigns promoting mask wearing and respiratory etiquette, with only 2 and 3 countries reporting to have mass media campaigns implemented at the most advanced for these interventions, respectively.
- **Strategies for increasing access to accurate information:** Information-based strategies are widely used by OECD Members and accession countries to increase awareness and understanding around community-based IPC practices. However, there are notable gaps. For example, 13 out of 24 countries reported that they have educational activities targeting community members to improve hand hygiene practices, but similar programmes only exist in 8 countries for promoting respiratory etiquette and in 6 countries for promoting mask wearing. There is also room for improving access to accurate information by offering free-of-charge phone lines and publicly available websites that offer high-quality public health information.
- **Behavioural interventions:** Many OECD Members and accession countries deploy visual cues in public areas and send text reminders to motivate greater compliance with community-based IPC practices but there are gaps. For example, 15 out of 24 countries that participated in the OECD survey indicated that they use visual cues in public areas as a reminder of best practices in hand hygiene and respiratory etiquette, whereas only 8 countries use visual cues for promoting mask wearing.
- **Engagement with relevant stakeholders and empowering local communities:** Engagement with relevant stakeholders and local communities can be improved. Of the 24 countries surveyed, 12 reported that they currently have advanced level arrangements for engaging relevant stakeholders and local communities in the design and implementation of programmes to improve hand hygiene and 8 countries have similar arrangements for respiratory etiquette. These figures are lower for other interventions.
- **Involving independent experts, scientists and credible public figures:** 10 out of 24 countries indicated that they currently have advanced level arrangements to involve independent experts, scientists and credible public figures to muster greater public compliance with respiratory etiquette and 9 countries have similar arrangements for hand hygiene. This strategy is also used to promote better respiratory etiquette and indoor ventilation but to a smaller extent.

Figure 5.3. OECD Members and accession countries can do more to promote community-based IPC programmes

Percentage of countries that reported having activities to promote greater compliance with community-based IPC measures, by level of policy implementation



Note: This graph presents the number of countries that responded to the questions "What type of policies does your country currently implement to address the factors that may hinder the general public's willingness to comply with hand hygiene/mask wearing/respiratory etiquette/indoor ventilation in the community?" Free handwashing materials: Distribution of free-of-charge handwashing materials (e.g. hand sanitisers); Mass media campaigns: Organising mass media campaigns (e.g. public announcements in TV/radio); Educational activities: Educational activities in the community such as peer-training, web-based training; Information materials: Distribution of free-of-charge informational materials; Visual cues: posters, stickers in highly visible areas; Phone lines/websites: Free-of-charge phone lines/websites to provide accurate public health information on best practices; Involve experts and others: Involve independent experts, scientists and credible public figures while communicating with the general public. Levels of implementation include: No implementation: No plans for implementation; 1st level = Activities/programmes were implemented at the regional/sub-national level; 2nd level: Activities/programmes were implemented at the national level; Most advanced level: Implementation of activities/programmes at national level were fine-tuned/modified based on monitoring and evaluation activities. The list of countries that participated in the survey is provided in Annex Table 5.A.1.

Source: Country self-assessment responding to the 2023-2024 OECD survey on Maintaining Infection Prevention and Control Measures in the Community.

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5.3. Community-based IPC measures are vital to safeguard population health

While there are many challenges to measuring the effectiveness of community-based IPC interventions (Box 5.2), understanding the impact of these interventions is integral to ensure that resources are allocated to the measures that offer the greatest health and economic benefits in various community settings.

Box 5.2. Estimating the precise impact of community-based IPC interventions is challenging

Many factors complicate estimating the precise effectiveness of community-based IPC measures (Ford et al., 2014[12]; Gozdzielewska et al., 2022[13]; Jefferson et al., 2023[14]):

- **Epidemiology of pathogens:** The effectiveness of an individual intervention depends on the epidemiological characteristics of pathogens (e.g. differences in transmissibility, mode of transmission) that the intervention aims to tackle.
- **Variation in the design and implementation of IPC programmes:** The design and implementation of community-based IPC programmes vary widely across countries and different community settings, making it challenging to pool and interpret the existing evidence.
- **Interactions with other interventions:** Community-based IPC programmes are often implemented in tandem with other public health initiatives, making it difficult to disentangle the specific impact of each intervention from the collective impact of the programmes implemented simultaneously.
- **Diagnostic capacity:** Diagnostic capacity reflects the ability to detect infections, including those caused by resistant organisms. The majority of evidence looking at the effectiveness of community-based IPC interventions does not consider the diagnostic capacity across/within each country, nor does it consider the changes in diagnostic capacity over time. The heterogeneity in diagnostic capacity can mean that an IPC intervention that appears effective in certain communities/areas with robust diagnostic capacity may not generate similar benefits in other communities/areas with limited diagnostic capacity, resulting in incorrect conclusions about the effectiveness of the intervention across various settings.
- **Measuring compliance with IPC measures**: The effectiveness of community-based IPC interventions depends largely on the extent to which community members comply with them in a consistent manner. But accurate measurement of compliance is difficult. Traditional methods (e.g. direct observation) can generate bias whereas self-reported data may not necessarily reflect the actual behaviours.

Source: Ford et al. (2014[12]), "*Increasing Hand Washing Compliance with a Simple Visual Cue*". https://doi.org/10.2105/ajph.2013.301477; Gozdzielewska et al. (2022[13]), "*The effectiveness of hand hygiene interventions for preventing community transmission or acquisition of novel coronavirus or influenza infections: a systematic review*", https://doi.org/10.1186/s12889-022-13667-y; Jefferson et al. (2023[14]), "*Physical interventions to interrupt or reduce the spread of respiratory viruses*", https://doi.org/10.1002/14651858.CD006207.pub6.

Section 5.3 reviews the existing evidence on the effectiveness of the selected interventions against various types of infections and Table 5.1 provides a summary of the findings for each intervention by type of infection. Most evidence suggests that community-based IPC measures are an effective tool to tackle various types of infections such as gastrointestinal and respiratory infections. As expected, the evidence on the precise magnitude of the effectiveness varies substantially, reflecting the differences in study settings and context, as well as the type of infection. The findings on hand hygiene illustrate this point. The existing evidence suggests that promoting hand hygiene in community settings is generally associated with greater reductions in gastrointestinal infections than in respiratory infections, suggesting that hand hygiene on its own is unlikely to control the spread of airborne pathogens. The interpretation of the

effectiveness estimates is further complicated by the fact that community-based IPC measures have frequently been used alongside other non-pharmaceutical interventions. This makes the contribution of any single measure difficult to isolate, which is reflected in the substantial heterogeneity of pooled estimates for individual interventions. The results also show that there are very few studies exploring the linkages between community-based IPC measures and resistant infections, highlighting the urgent need for high-quality research.

Table 5.1. Summary findings: Effectiveness of community-based IPC measures by infection type

	Gastrointestinal infections	Respiratory infections	Coronaviruses	Resistant infections
Improving hand hygiene	Vast majority of evidence concludes effectiveness, with pooled estimates in a recent meta-analysis showing an average 31% reduction in the incidence of infections ([1])	Majority of evidence points to effectiveness, with pooled point estimates from recent meta-analyses ranging from 16% to 21% reduction in the incidence of infections ([15]; [1])	Reductions were recorded in the incidence of SARS-CoV-1 and SARS-CoV-2 ([13]). The precise magnitude of effectiveness is highly context-dependent.	No studies identified
Enhancing mask wearing	-	Many studies point to effectiveness. The magnitude of protective effects varies by context. Pooled effectiveness estimates generated by two systematic reviews ranging from 11% to 56% depending on the quality of data included in the analysis quality ([16]; [17])	Evidence remains mixed. One Cochrane review of randomised controlled trials concluded little to no effect ([14]). Other systematic reviews including data from real-world experiences calculated a 44% reduction in the incidence of infections caused by SARS-CoV-2, MERS-CoV (RR = 0.56; 95% CI = 0.40, 0.79) ([18]) More recently, a 2024 state-of-the-science review concluded that masks are effective in reducing the transmission of respiratory diseases when worn correctly and consistently, with a dose-response effect such that the level of protection increases as adherence to masking increases ([19]). The same review argued that respirators (such as N95, FFP2, or FFP3) are significantly more effective than medical or cloth masks.	No studies identified
Respiratory etiquette	No studies identified	No studies identified	No studies identified	No studies identified
Indoor ventilation	-	No studies identified	Recent analyses point to effectiveness against SARS-CoV-1, MERS-CoV, SARS-CoV-2 ([20])	No studies identified

Note: 1) Gastrointestinal infections are typically caused by consuming contaminated water/food or by having direct contact with an infected individual/surface. Considering this mode of transmission, mask-wearing and indoor ventilation are not expected to reduce the burden of most gastrointestinal infections. In some cases, such as norovirus, which can be airborne for several hours after vomiting, promoting mask-wearing and indoor ventilation would be effective in reducing the burden of infection. 2) Respiratory infections category includes influenza-like illnesses such as infections caused coronaviruses. The table above presents coronaviruses as a separate category to take into account the mounting evidence focussing on illnesses caused by coronaviruses.
Source: OECD review.

5.3.1. Improve hand hygiene

Enhancing hand hygiene is a simple yet effective public health measure to curb the spread of viral and bacterial infections. Many infections are transferred through direct or indirect contact with contaminated objects and surfaces (e.g. handrails, doorknobs). Infectious agents can remain contagious on surfaces

depending on various factors such as the specific type of the infectious agent, environmental conditions and surface type, with estimates on the survival time ranging from several hours to more than 12 weeks (Wißmann et al., 2021[21]). Regular hand washing can help interrupt the chain of transmission at the individual level by limiting the transfer of pathogens from contaminated surfaces to hands and from hands to faces or other surfaces. This is particularly important in community settings where individuals often interact closely with one another. Improving hand hygiene is also a valuable tool to fight AMR because it can help reduce the need for using antimicrobials by preventing resistant infections from occurring in the first place.

While most evidence on the effectiveness and cost-effectiveness of hand hygiene comes from health facilities (Box 5.3), improving hand hygiene has also been shown effective in limiting the spread of infections in the community:

- **Gastrointestinal infections**: One systematic review showed that improving hand hygiene was effective against gastrointestinal infections, with the protective effects averaging at 31% (Relative risk [RR] = 0.69; 95% CI = 0.58, 0.81) compared to no intervention (Aiello et al., 2008[1]).
- **Respiratory infections**: Improved hand hygiene can also help reduce the risk of respiratory infections though the level of effectiveness has been shown to lower compared to gastrointestinal infections. An earlier systematic review reported that improved hand hygiene was associated with a 16% reduction in the risk of respiratory infections, with the effectiveness estimates ranging from 6% to 44% (Rabie and Curtis, 2006[15]). A subsequent review also concluded that hand hygiene was an effective means to tackling respiratory infections, though it estimated that this intervention was associated with a 21% reduction in the incidence of respiratory infections (RR = 0.79; 95% CI = 0.66, 0.95) (Aiello et al., 2008[1]). More recently, one systematic review evaluated the effectiveness of hand hygiene specifically on infections caused by coronaviruses (Gozdzielewska et al., 2022[13]). This review concluded that improving hand hygiene can help limit the spread of novel coronaviruses such as SARS-CoV-1 and SARS-CoV-2, though this review highlighted that the quality of the existing evidence was low.

Box 5.3. Improving hand hygiene in healthcare settings is highly effective and cost-effective

The latest OECD publication on AMR demonstrates that investing in improving hand hygiene practices in healthcare facilities generates significant health and economic returns

Building on its previous work, the OECD published in 2023 a new analysis – *Embracing a One Health Approach to Fight Antimicrobial Resistance* – which provided an update on the health and economic impact of antimicrobial resistance (OECD, 2023[22]). A key contribution of the OECD analysis was an evaluation of the effectiveness and cost-effectiveness of 11 interventions and 3 policy packages that, if implemented in desired levels, could limit the deleterious health and economic impacts of AMR in 34 OECD and EU/EEA countries.

The results from the OECD analysis demonstrate that improving hand hygiene is among the most effective and cost-effective healthcare-based interventions to tackle AMR. In 34 OECD and EU/EEA countries, investing USD PPP 0.48 per capita in hand hygiene can, on average, avoid more than 113 000 resistant and 392 000 susceptible infections every year, prevent more than 4 500 deaths due to resistant infections, help avert more than USD PPP 4 billion in health expenditure and save nearly USD PPP 5.3 billion by contributing to participation in the workforce and leading to gains in productivity.

The health and economic benefits of improving hand hygiene can be amplified if scaled up as part of a multi-sectoral policy package that also includes scaling up antimicrobial stewardship, delaying antimicrobial prescription, increasing mass media campaigns and enhancing food handling practices. Each year, investing in this policy package can, on average, avoid 1.6 million infections, prevent more

than 17 000 deaths, save more than USD PPP 9.4 billion in health expenditure and gain around USD PPP 13.8 billion through increased participation in the workforce and improved productivity at work.

Scaling up hand hygiene, either as a single intervention or as part of a policy package, is highly cost-effective. In all 34 OECD and EU/EEA countries included in the OECD analysis, the benefits that can be reaped by improving hand hygiene far exceed the implementation costs. The OECD analysis shows that every USD PPP invested in improving hand hygiene can return nearly USD PPP 25 gained through savings in health expenditure and gains in economic productivity. The return on investment of a policy package that includes hand hygiene is also high, with a return-on-investment equivalent to 5.

Source: OECD (2023[22]), *Embracing a One Health Framework to Fight Antimicrobial Resistance,* https://doi.org/10.1787/ce44c755-en.

A more detailed look into the existing evidence suggests considerable variation in the effectiveness of hand hygiene programmes depending on the community setting:

- **Day care centre- and school-based programmes:** Improving hand hygiene in schools is a widely deployed community-based IPC intervention that aims to foster good habits to support lifelong healthy behaviours. Generally, children and young people are considered to have an elevated risk of spreading and contracting infections due to their immature immune systems and behavioural factors (e.g. tendency to explore objects with hands and mouth). They have also been suggested to contribute to the transmission of influenza in households (Randle et al., 2013[23]; Viboud, 2004[24]). These factors make day care centres and schools hotspots for disease transmission.
  - **Gastrointestinal infections**: School-based programmes are effective in reducing the incidence of gastrointestinal infections. One recent Cochrane review that gathered evidence primarily from OECD countries (e.g. Australia, Canada, Denmark, the Netherlands) showed that school-based hand hygiene programmes were associated with an estimated 30% reduction in the incidence of diarrhoea episodes (Incidence Rate Ratio [IRR] = 0.70; 95% CI = 0.58, 0.85) (Ejemot-Nwadiaro et al., 2021[25]), confirming evidence from earlier Cochrane reviews (Ejemot-Nwadiaro et al., 2015[26]; Ejemot-Nwadiaro et al., 2008[27]).
  - **Respiratory infections:** These programmes can also limit the risk of respiratory infections albeit to a lesser extent compared to gastrointestinal infections. An earlier systematic review examining the effectiveness of hand hygiene interventions in schools and day care centres in Australia, Canada, Finland and the United States found that better hand hygiene was associated with a 16% reduction in the incidence of respiratory illness (RR = 0.84; 95% CI = 0.66, 1.07), with amplified impacts for younger children (RR = 0.80; 95% CI = 0.63, 1.01) (Aiello et al., 2008[1]). Findings from subsequent systematic reviews are aligned with these studies. One recent meta-analysis focussed on the impact of school-based interventions specifically on the laboratory-confirmed influenza cases. This study demonstrated that school-based hand hygiene interventions, excluding universities, led to reductions in the incidence of laboratory-confirmed influenza cases (Veys et al., 2021[28]). Another recent systematic review made similar conclusions about the relationship between improved hand hygiene and the incidence of influenza among students (Gozdzielewska et al., 2022[13]). However, given its relatively limited effect in childcare and school settings, hand hygiene is unlikely on its own to curb the spread of airborne pathogens.
  - School-based programmes can also reduce school absences. One earlier systematic review analysed the potential effectiveness of hand hygiene promotion programmes using data gathered primarily from studies conducted in OECD countries (Willmott et al., 2015[29]). This review concluded that the vast majority of evidence pointed to an inverse relationship between school-based hand hygiene programmes and absenteeism. Subsequently, one meta-analysis

also found that school-based hand hygiene programmes were associated with a reduction in absenteeism, with the magnitude of the estimated impact ranging from 29.5%- 57.1% (Wang et al., 2017[30]).

- **Workplace-based programmes**: Previous studies found high bacterial counts on elevator buttons, keyboards and vending machines and high viral counts on desks, office phones and computer mice and in common areas (e.g. break room sink faucet handles, microwave/refrigerator door handles) (Arbogast et al., 2016[31]), making workplaces a worrisome source of viral and bacterial infections. While teleworking was widespread in OECD countries during the COVID-19 pandemic (OECD, 2021[32]), a considerable proportion of employees continued to work at offices/shared workplaces (PRC, 2023[33]; EuroStat, 2022[34]) and certain jobs could not be done remotely. These factors make workplace programmes an important platform for community-based IPC measures as part of efforts to promote safer work environments.
- In OECD, workplace-based programmes are becoming an increasingly popular setting for promoting healthy behaviours (OECD, 2022[35]). Evidence on the effectiveness of workplace-based programmes to promote hand hygiene remains relatively limited, though generally points to promising results. For example, one recent systematic review that assessed the effectiveness of hand hygiene programmes in workplaces found that the available evidence comes primarily from a handful of studies conducted in OECD countries, including Finland, Germany and the United States (Zivich, Gancz and Aiello, 2018[36]). Findings from these studies suggest that workplace-based programmes can help improve hand hygiene practices and reduce the incidence of infections. In Finland, employees working in 21 district office units in the Helsinki region were given hand hygiene supplies (e.g. alcohol-based hand rub), coupled with guidance on hand hygiene practices and recommendations on how to limit the spread of infections (e.g. respiratory etiquette). This intervention was associated with around 26% (RR = 0.74; 95% CI = 0.51, 1.05) lower weekly prevalence of gastrointestinal infections compared to no intervention (Hovi, Ollgren and Savolainen-Kopra, 2017[37]). This study found that the risk of respiratory illness also reduced (RR= 0.68; 95% CI = 0.55, 0.82), though this protective effect was only observable when there was no prior exposure to a symptomatic individual.
- **Household-based programmes:** The evidence on the effectiveness of hand hygiene promotion programmes in households remains limited and the existing evidence is mixed. One of the earlier systematic reviews concluded that improved hand hygiene was associated with notable reductions in the incidence of influenza-like illnesses (Odds ratio = 0.46; 95% CI = 0.22, 0.96) (Warren-Gash, Fragaszy and Hayward, 2012[38]). But findings from subsequent studies have not been consistent with these results. For example, a more recent meta-analysis also confirmed that promoting hand hygiene in households can be effective against influenza infections (Veys et al., 2021[28]). In contrast, another meta-analysis found no evidence of protective effects of improved hand hygiene in households against laboratory-confirmed influenza (RR = 1.15; 95% CI = 0.57, 2.32) (Gozdzielewska et al., 2022[13]). Another recent meta-analysis concluded that improving hand hygiene can lead to very modest reduction in the risk of contracting acute respiratory infections, of the order of 3% (Mo et al., 2022[39]). These mixed results should be interpreted with caution due to the considerable differences in the design of the hand hygiene promotion programmes, outcomes measures used to assess the incidence of illnesses and methodological challenges.
- A deeper look into the existing evidence suggests that hand hygiene promotion at households should start before a household member is infected. The meta-analysis conducted by Veys and colleagues (2021[28]) noted that hand hygiene promotion falls short of preventing secondary influenza infections if implemented after an initial influenza case (i.e. index case) is identified within the same household. This finding is in line with results generated subsequently by Gozdzielewska and colleagues (2022[13]) who showed in that hand hygiene is also not associated with reductions in the rate of secondary infections of influenza-like illnesses following an index case.

- **Other community settings:** Evidence on the impact of hand hygiene practices in other settings (e.g. public transport) remains scant but promising. To date, no studies evaluated the effectiveness of hand hygiene promotion in public transportation networks. But previous studies showed that commuters' hands are frequently contaminated by pathogens (Judah et al., 2009[40]), including antimicrobial resistant bacteria such as meticillin-resistant *Staphylococcus aureus* (Lutz et al., 2014[41]), suggesting that hand hygiene promotion in public transport networks can be an important strategy to limit the spread of infections.

5.3.2. Encourage wearing face masks

Face masks (e.g. medical and non-medical masks [i.e. fabric] and respirators such as filtering facepiece [FFP] devices such as FFP2/FFP3 or N95] play a key role in community protection during outbreaks by reducing the amount of infectious respiratory particles an individual inhales (protection to the wearer); and by containing infectious respiratory particles an individual produces when infected, even if asymptomatic.

The World Health Organization (WHO) developed a series of guidelines to encourage best practices in mask wearing to curb the spread of SARS-CoV-2, the pathogen that caused the COVID-19 pandemic. These recommendations indicated that in community settings, masks should be worn in specific situations irrespective of the local epidemiological situation including (WHO, 2023[42]):

- following a recent exposure to the pathogen,
- when an individual has or suspects infection,
- when a person is at high risk of severe disease (e.g. persons aged 60 years and over, those with underlying comorbidities such as cardiovascular disease) and
- in crowded, closed or poorly ventilated indoor spaces.

For the general public in most everyday situations, a non-medical mask meeting minimum standards for filtration and breathability is considered adequate (WHO, 2021[43]). Symptomatic individuals are advised to wear a medical mask, in addition to self-isolate and seek medical attention. Respirators are recommended to be reserved primarily for healthcare settings, where they are worn when caring for suspected or confirmed cases and, without exception, during aerosol-generating procedures. In the community, respirators are not recommended for the general public, except for higher-risk individuals in crowded or poorly ventilated environments (WHO, 2023[44]).

The available evidence suggests that face masks can be effective in community settings, although some studies have not observed a measurable impact:

- Synthesis of evidence restricted to randomised controlled trials (RCTs) reported limited effects. One 2023 Cochrane review looked at high-quality evidence from 10 RCTs in community settings and concluded that wearing medical/surgical masks was associated with limited to no reduction in the incidence of influenza-like illnesses (RR = 0.95; 95% CI = 0.84, 1.09) and no observable declines in laboratory-confirmed influenza/SARS-CoV-2 (RR = 1.01; 95% CI = 0.72, 1.42) compared to no mask wearing (Jefferson et al., 2023[14]). An earlier meta-analysis that examined data generated only through RCTs found modest protective effects, with an 11% reduction (RR = 0.89; 95% CI = 0.81, 0.98) in the risk of respiratory infections attributable to mask wearing.
- However, analyses drawing on wider bodies of evidence report protective effects. Using data from RCTs combined with case-control and cohort studies, Xiao and colleagues (2020[17]) estimated in an earlier meta-analysis that mask wearing can reduce the infection caused by respiratory viruses by 56% in community settings. Another meta-analysis that evaluated the effectiveness of mask-wearing against pandemic and epidemic betacoronaviruses (e.g. SARS-CoV-2, MERS-CoV) in real-world settings concluded that increased mask wearing in community settings was associated

with around 44% reduction in the incidence of infections (RR = 0.56; 95% CI = 0.40, 0.79) (Chu et al., 2020[18]).

- One 2024 state-of-the-science review argued that much of this disagreement stems from how the evidence has been analysed rather than from genuine uncertainty about whether masks work (Greenhalgh et al., 2024[19]). Synthesising more than 100 reviews and selected primary studies across multiple disciplines, and re-analysing contested trials, this review suggested that RCT-only syntheses, including the 2023 Cochrane review ([14]), understate effectiveness by combining dissimilar settings, interventions and heterogeneous outcome measures within single pooled estimates. This review concluded that if worn correctly and consistently, masks reduce the transmission of respiratory infections and exhibit a dose-response effect with adherence (Greenhalgh et al., 2024[19]). It further argued that respirators are significantly more effective than medical or cloth masks, outperforming surgical masks by roughly eight- to 12-fold in filtering aerosols (Ibid).

Much like other community-based interventions, the effectiveness of mask-wearing interventions depends on the type of community setting. Recent evidence shows that school-based interventions can help curb the spread of infections and help avoid more disruptive measures such as quarantines or school closures. For example, one study conducted in the State of Nebraska in the United States in a school district with 23 000 students and nearly 3 000 staff found that there was no secondary transmission among exposed students when masks were worn in schools (Boutzoukas et al., 2022[45]). This study also found there was a 41% reduction in the frequency of quarantines required for students and school staff with a primary SARS-CoV-2 infection in the autumn semester when the masks were used compared to the previous spring semester when no mask-wearing intervention was in place. Promoting mask-wearing in households was also shown effective. In their meta-analysis, Xiao and colleagues (2020[17]) found that mask wearing was associated with a 40% reduction in the risk of respiratory infections. However, the authors noted that high levels of compliance with mask-wearing was a pre-requisite for ensuring such high levels of protection.

5.3.3. Enhance respiratory etiquette

Respiratory infections are typically transmitted through respiratory droplets contaminated with viruses and bacteria that are released when an infected individual coughs, sneezes or talks. Respiratory etiquette can interrupt the spread of respiratory infections by minimising the release of contaminated droplets (Wood et al., 2018[46])and by reducing the risk of indirect transmission through contaminated objects or surfaces (WHO, 2021[47]). An important limitation is that respiratory etiquette targets coughing and sneezing and it does not address transmission from presymptomatic,[3] asymptomatic[4] or sub-clinical infections[5] where airborne spread occurs through normal breathing and speaking.

Evidence on the effectiveness of improved respiratory etiquette remains scarce. One earlier systematic review and meta-analysis that examined the effectiveness of personal protective measures (e.g. mask wearing, hand hygiene) in the context of pandemic influenza identified no studies that attempted to measure the impact of any form of respiratory etiquette (Saunders-Hastings et al., 2017[48]). Similarly, no relevant studies were identified by an extensive literature review conducted by the WHO in 2019 to inform the recommendations on global preparedness against influenza pandemics (WHO, 2019[49]) and by a subsequent systematic review focussing on the effectiveness of non-pharmaceutical interventions in non-healthcare settings (Xiao et al., 2020[17]).

Much like these earlier works, the OECD review did not identify any studies that quantified the potential benefits associated with better respiratory etiquette. Despite the lack of robust scientific evidence, public health authorities strongly recommend bolstering respiratory etiquette considering its potential effectiveness, ease of adoption, acceptability and feasibility (WHO, 2019[49]; ECDC, 2022[50]; CDC, 2016[51]).

5.3.4. Enhance indoor ventilation

The risk of respiratory infections is elevated in poorly ventilated crowded or enclosed spaces (e.g. schools, offices, public transportation networks) due to the greater concentration of contaminated droplets, aerosols and airborne pathogens such as viruses that can suspend in the air for extended periods and spread more efficiently. Better indoor ventilation (i.e. the process by which clean air is introduced intentionally into enclosed spaces while the stale air is removed) and improved air hygiene can reduce the transmission of infections by regulating air quality, temperature and humidity, diluting or removing airborne contaminates and air pollutants (e.g. allergens) and reducing airborne disease transmission (WHO, 2021[52]; Li et al., 2007[53]).

Improving indoor ventilation can involve two methods:

- **Natural ventilation**: Natural ventilation relies on elemental forces such as wind and thermal buoyancy to facilitate air exchange through openings.
- **Mechanical ventilation**: Mechanical ventilation actively employs powered components such as fans and air ducts. Air filtration systems (e.g. High-Efficiency Particulate Air [HEPA] filters) can be integrated into mechanical ventilation systems to remove microorganisms and particulates.

The importance of good indoor ventilation has been long acknowledged in healthcare settings (Dai et al., 2021[54]). But the centrality of this measure in community settings only gained more prominence during the COVID-19 pandemic when it became clearer that crowded and poorly ventilated settings can facilitate the transmission of SARS-CoV-2 (Haddrell et al., 2024[55]).

In 2021, the WHO published guidelines and recommendations for improving indoor ventilation in the context of COVID-19 not only in healthcare settings, but also in non-residential settings (e.g. schools, commercial and religious spaces, workplaces) and residential settings (e.g. homes) (WHO, 2021[56]). In line with findings from recent studies (Thornton et al., 2022[20]), the WHO guidelines indicated that the decision to choose between mechanical/natural ventilation or a hybrid approach depends largely on the specific needs and requirements of the space, resource availability and budgetary considerations (WHO, 2021[56]).

Enhancing ventilation practices, whether by increasing the ventilation rate or by modifying the pattern of airflow, has been shown effective in reducing carbon dioxide and the risk of airborne infections. One recent systematic review that evaluated the relationship between indoor ventilation practices and the spread of coronaviruses (i.e. SARS-CoV-1, MERS-CoV, and SARS-CoV-2) concluded that increased ventilation was associated with reductions in the probability of disease transmission, the concentration of viruses in the air and droplet persistence (Thornton et al., 2022[20]).This study further indicated that increased ventilation was associated with reductions in exposure time to pathogens and increases in virus removal and virus particle removal efficiency.

Much like other IPC measures, the effectiveness of interventions to improve indoor ventilation depends on the community setting:

- **School-based interventions**: One study conducted in the Marche Region in Italy examined the impact of an intervention that equipped approximately 3% of the region's classrooms with mechanical ventilation systems between September 2021 and January 2022 (Buonanno et al., 2022[57]). The study found that a one unit increase in per capita ventilation rate was associated with a 12% to 15% reduction in the relative risk of SARS-CoV-2 infection. Another intervention carried out in the State of Georgia in the United States also showed that schools that improved indoor ventilation either through mechanical or natural ventilation methods achieved a 35% reduction in the incidence of SARS-CoV-2 infections (RR = 0.65; 95% CI = 0.43, 0.98) compared to schools that did not improve the existing indoor ventilation methods (Gettings et al., 2021[58]).

- **Workplace-based interventions**: Workplace-based interventions can be a promising option. One notable example comes from the Fukuoka prefecture in Japan. In this prefecture, the local public health authorities concluded that a COVID-19 outbreak in August 2021 was linked with insufficient ventilation practices in an office within a manufacturing factory (Kitamura et al., 2022[59]). In response, the existing ventilation systems were redesigned through a hybrid method that combined natural ventilation (e.g. opening doors and windows) and mechanical ventilation (e.g. installing electric and ventilation fans) techniques. The redesign of the ventilation systems led to a rise in the ventilation frequency while the number of employees who were permitted to work in the same office space increased without causing a new outbreak.

The benefits of indoor ventilation extend beyond curbing transmission to a broader set of health and economic co-benefits. Higher ventilation rates have been shown to lower indoor carbon dioxide, and combined with efficient filtration, reduce indoor fine particulate matter (PM2.5), though the magnitude of the potential gain depends also on outdoor air quality (Jones et al., 2021[60]). Reduced exposure to carbon dioxide and pollutants, in turn, is linked to improved cognitive function. For example, an earlier study showed that office workers recorded substantially higher performance under well-ventilated and low- CO_2 conditions (Allen et al., 2016[61]). In school settings, higher ventilation rates in classrooms have been associated with greater academic performance (Haverinen-Shaughnessy, Moschandreas and Shaughnessy, 2010[62]) and reduced illness-related absences (Mendell et al., 2013[63]).

5.4. Improving compliance with community-based IPC measures enhances the effectiveness of these interventions over time

Maintaining a robust culture of good practices in community-based IPC measures is paramount to safeguarding population health over time. Sustaining high levels of compliance can yield important reductions in the overall spread of infections in the community, which can reduce the reliance on healthcare resources (e.g. fewer extra days spent in hospitals), yield greater savings in healthcare expenditure and generate gains in productivity at work. When individuals and communities consistently adhere to the best practices in community-based IPC measures, these best practices can be solidified as societal norms and bolster efforts to better prepare for and respond to future disease outbreaks and pandemics.

The extent to which the community-based IPC measures can effectively safeguard population health depends largely on whether the community members practise them consistently and accurately. High-quality evidence on the level of compliance is scant but the limited evidence suggests low levels:

- One review conducted prior to the COVID-19 pandemic calculated that globally, only around 19% of the population reportedly wash their hands with water and soap (Freeman et al., 2014[64]). Hand washing prevalence was estimated to be low in OECD countries as well, with the estimates ranging from around 12% in Israel, 50% in the Netherlands and to 52% in the United Kingdom (ibid).
- A nationally representative survey in the United States found that prior to the COVID-19 pandemic, about 53% of respondents indicated that they remembered to wash their hands after coughing and sneezing (Haston et al., 2020[65]). A subsequent wave of the survey carried out during the COVID-19 pandemic found that this figure rose to 71% during the pandemic.
- One recent study that evaluated the level of compliance with mask wearing guidelines in 35 European countries in the winters of 2020 and 2021 concluded that the average mask use was around 61% (Spira, 2022[66]). This study reported considerable cross-country variation, with the highest levels of mask wearing being reported in Spain, Italy and Greece (95%, 91% and 84%, respectively) and lowest levels in Denmark and Norway (29% and 14%, respectively). In the United States, one nationally representative survey conducted in August-September 2020 suggested that 60% of the population wore facemasks (Kim et al., 2023[67]).

Considering the interplay between the level of compliance with and the effectiveness of interventions, it is important to examine the factors that influence people's willingness to comply with community-based IPC measures over time and consider these factors while designing, implementing and fine-tuning programmes. With this goal in mind, this section explores some of the factors that influence compliance including: 1) situational factors (e.g. during/aftermath of a disease outbreak or pandemic), 2) individuals' sociodemographic characteristics (e.g. age, sex, occupation), 3) the level of knowledge and understanding about disease transmission and the effectiveness of measures to limit the spread of diseases, 4) the spread of misinformation, 5) risk perceptions and personal beliefs and 6) social norms and beliefs (e.g. stigma).

5.4.1. Compliance ebbs and flows during/after disease outbreaks and pandemics

Compliance with best practices generally improves during disease outbreaks and pandemics. One survey conducted in the United States by the Centers for Disease Control and Prevention in June 2020 showed that compared to October 2019, the odds of remembering to wash hands was around 2.3 times higher among respondents after coughing, sneezing, or blowing their nose and 2 times higher before eating at a restaurant (Haston et al., 2020[65]). In a survey conducted in the United Kingdom, about 83% of respondents reported that they washed their hands more frequently at the time of the survey compared to the pre-pandemic period (Atchison et al., 2020[68]). Another survey conducted across 14 countries, including 9 OECD countries, found that the trends in hand hygiene mirrored the recent trends in COVID-19 related deaths and morbidity (Szczuka et al., 2021[69]). This survey showed that compliance with hand hygiene recommendations improved when there was a recent rise (2-weeks) in the number of COVID-19 cases and mortality. These findings are aligned with previous studies conducted in the context of other disease outbreaks (Park et al., 2010[70]; Meilicke et al., 2013[71]).

5.4.2. Sociodemographic characteristics influence compliance

At the individual level, certain demographic characteristics are closely linked to compliance. Evidence from several OECD and EU/EEA countries suggests that women tend to have a greater propensity to comply with community-based IPC measures such as hand hygiene, mask wearing and respiratory etiquette compared to men (Haston et al., 2020[65]; Brouard, Vasilopoulos and Becher, 2020[72]). Compliance patterns are also shaped by age, with older age groups generally having greater levels of compliance, including during disease outbreaks (Haston et al., 2020[65]; Nivette et al., 2021[73]; Kim et al., 2023[67]; Brouard, Vasilopoulos and Becher, 2020[72]). Socio-economic status, as measured by educational attainment and/or level of income, is another determinant of compliance patterns. In general, higher levels of education is associated with higher health literacy and greater compliance (Brouard, Vasilopoulos and Becher, 2020[72]; Kim and Yoon, 2022[74]). Economic considerations can also influence compliance patterns (Kim et al., 2023[67]).

5.4.3. Knowledge and awareness can motivate greater compliance

An important determinant of compliance relates to having knowledge and awareness around disease transmission routes. When people have accurate information about how IPC measures can help protect them effectively, they may be more motivated to adopt and sustain these behaviours. The general public's knowledge of disease transmission and awareness around the effectiveness of community-based IPC measures improved during the COVID-19 pandemic. For example, one telephone survey conducted in the United Kingdom in 2021 found that there were significant improvements in people's knowledge of hand hygiene and cough etiquette by March 2021 compared to the same time in 2020 (Read et al., 2022[75]). Yet, efforts to improve knowledge and awareness on their own are unlikely to increase compliance in the long term, especially in the presence of disinformation.

5.4.4. Disinformation has become an important source of non-compliance

Disinformation occurs when false information is shared with the goal of causing harm. Disinformation is different from misinformation, which is the act of sharing false information without the intention to cause harm (OECD, 2020[76]). While accurate knowledge and awareness can enhance compliance, exposure to disinformation can propel non-compliance.

The COVID-19 pandemic led to an unprecedented surge in the spread of disinformation, including the spread of harmful messaging around the effectiveness of many community-based IPC measures. The wave of disinformation undermined the pandemic response efforts in many OECD countries by crowding out the important information on the effectiveness of mitigation measures, weakening trust in public institutions (Pavela Banai, Banai and Miklošić, 2021[77]), creating confusion around the effectiveness of measures such as mask wearing and ultimately depressing people's willingness to comply with the recommended IPC measures in the community (Allington et al., 2020[78]).

The true extent and the impact of misinformation are difficult to measure. Most misinformation is thought to be disseminated online (e.g. social media platforms) and via messaging services that are not open to scrutiny from external observers and content moderators (OECD, 2020[76]). The deleterious effects of exposure to misinformation can be persistent. Recently, one randomised online study from the United States concluded that exposure to misinformation had a negative influence on the attitudes and intentions around mask-wearing (Mourali and Drake, 2022[79]). This study also demonstrated that while debunking false claims can partially improve attitudes and intentions, these positive effects can be washed out when people are exposed to misinformation for prolonged periods.

5.4.5. Risk perceptions and personal beliefs can impact compliance

Risk perception refers to people's personal beliefs and attitudes towards the risks that they face. Perceptions around the potential severity of disease can influence compliance because in situations where people do not perceive a significant health threat, they may be less inclined to comply with community-based IPC measures. Individuals with inaccurate perceptions around disease severity may adopt behaviours that can be difficult to change over time, undermining efforts to motivate greater compliance with community-based IPC measures in the long term.

Evidence generated during the COVID-19 pandemic showcases the relationship between risk perception and compliance. One study from Japan conducted during the first wave of the COVID-19 pandemic in 2020 showed that people who perceived SARS-CoV-2 as a significant threat to their own health were more likely to disinfect their hands (Murakami, Yamagata and Miura, 2023[80]). Another study conducted in the United States in March 2020 found a positive association between the likelihood of practicing IPC measures (e.g. hand washing and mask wearing) and the perceived likelihood of personally getting infected, as well as the perceived personal severity of potential infection (Wise et al., 2020[81]).

Personal views and perceptions around the effectiveness of community-based IPC measures can also influence compliance. One recent survey conducted across Austria, Czechia, Poland, Spain and the United Kingdom found that higher disbelief in the protective effects of masks was negatively correlated with mask wearing (Binter et al., 2023[82]). But positive beliefs and perceptions also do not guarantee high levels of compliance. One recent systematic review and meta-analysis with a global focus showed that globally, around 71% of respondents in the studies included in the review reported that they considered masks as an effective means of infection prevention regardless of the type of disease (e.g. COVID-19, SARS-CoV, MERS-CoV, H1N1 and H5N1) (Li et al., 2022[83]). Yet only around 68% reported that they would wear masks and only around 54% indicated that they actually wore them.

5.4.6. Societal norms influence health behaviours

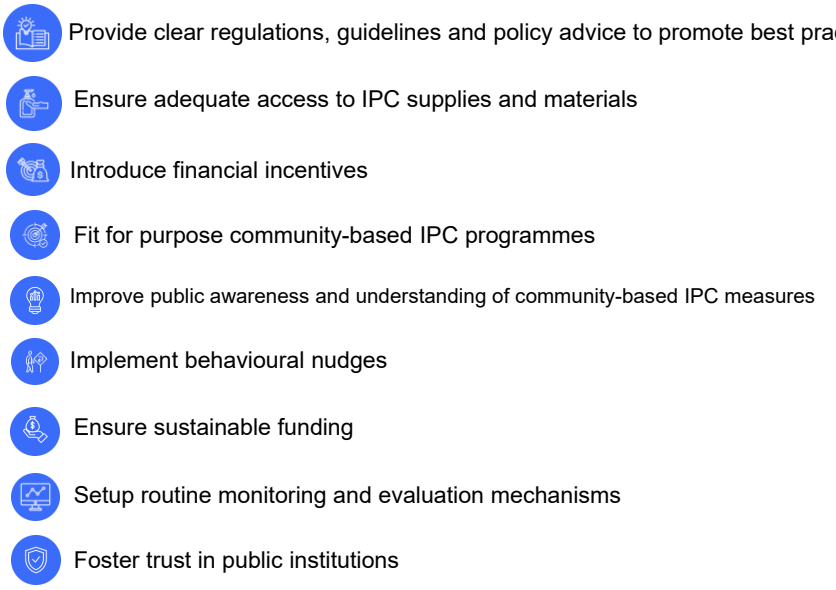
Societal norms can also shape compliance. In particular, stigma (i.e. a sense of negative social perception or disapproval towards a behaviour) can impact compliance patterns (Li et al., 2022[83]). Stigma typically arises from a fear of negative social judgement or disapproval towards a certain behaviour (Kim and Yoon, 2022[74]). One recent review of determinants of hand hygiene primarily in OECD countries showed that the risk of attracting social stigma, embarrassment or discrimination was a significant concern against adopting frequent hand hygiene (e.g. worries about creating a perception as “obsessive” or “overly fastidious”) (Teasdale et al., 2014[84]).

The dynamics between stigma and compliance are highly context dependent. Concerns around stigma can depress compliance in certain settings whereas it can produce the opposite effects in other contexts. For example, Japan achieved consistently high levels of compliance with mask wearing recommendations throughout the COVID-19 pandemic, with approximately 85% to 90% of the population reportedly wearing masks in public spaces (Nippon Research Center, 2023[85]). Mask wearing remained relatively high even after the mask wearing requirements were removed in 2023. Studies focussing on Japan’s experience with pandemic outbreaks suggested that social norms and beliefs dating back to the 1918 influenza pandemic promoted mask wearing (Wada, Oka-Ezoe and Smith, 2012[86]; Burgess and Horii, 2012[87]) and that the desire to conform with these social norms was a key driver of high levels of mask wearing (Li et al., 2023[88]).

5.5. OECD countries can deploy a wide range of policies to promote compliance with community-based IPC measures in the long term

This section presents nine policy options to motivate greater compliance with community-based IPC measures that can be used to address the underlying drivers of compliance in various contexts discussed in Section 5.3 (Figure 5.4). The policies highlighted in the section are not exhaustive and other policies exist including, for example, lifting public science literacy, introduce indoor air quality performance goals, investments in better indoor air quality and improved residential building quality. The policies listed in the figure were prioritised as each applies across all four community-based IPC measures focussed in this chapter.

Figure 5.4. Nine broad policy options OECD, EU/EEA and G20 countries can consider to enhance compliance with community-based IPC measures



Note: IPC = infection prevention and control.
Source: Based on OECD review.

5.5.1. Provide clear guidelines and policy advice to promote best practices

The first step in promoting higher compliance is to provide guidelines and policy advice. Clear guidelines and policy advice can play an important role in promoting higher individual- and community-level compliance by making it easier for people to understand the best practices (Box 5.4). Guidelines and policy advice can also help build a standardised and consistent approach that can be applied in various community settings. They can include performance targets and goals, which can help track compliance over time (Box 5.5) and tailor community-based programmes in accordance with the unique needs of each community.

Box 5.4. In the United States, the "Clean Air in Buildings Challenge" provides recommendations and guidelines to improve indoor ventilation in various community settings

In March 2022, the United States launched a new national call for action called the "Clean Air in Buildings Challenge", with the aim of improving indoor air quality and indoor ventilation in diverse community settings (EPA, 2022[89]). The guidelines targeted building owners and operators, organisational leaders and decision makers and explicitly underlined the importance of indoor ventilation to tackle infectious diseases that can spread through airborne particles and aerosols.

The initiative laid out four clearly defined strategies with concrete steps that, if implemented systematically, can improve indoor air quality and ventilation practices:

- Creating an action plan for clean indoor air in buildings that assesses indoor air quality, plans for upgrades and improvements and includes HVAC inspections and maintenance
- Optimise fresh air ventilation by bringing in and circulating clean outdoor air indoors
- Enhance air filtration and cleaning by increasing the use of central heating, ventilation, and air conditioning (HVAC) systems and in-room air cleaning devices
- Get the communities engaged in the action plans for clean indoor air in buildings by communicating with building occupants to increase awareness, commitment and participation in improving indoor air quality and health outcomes.

Source: EPA (2022[89]), *Clean Air in Buildings Challenge,* https://www.epa.gov/system/files/documents/2022-03/508-cleanairbuildings_factsheet_v5_508.pdf (accessed on 7 December 2023).

Box 5.5. Belgium's new regulatory framework on indoor air quality sets clear definitions and standards for good air quality

In November 2022, Belgium introduced new regulations to improve indoor air quality in all public spaces including workplaces (Service public fédéral Santé publique, 2022[90]). The new regulations clearly highlight the linkages between indoor ventilation and the spread of infectious diseases. They strongly encourage higher ventilation flow rates, which in turn, can help lower the concentration of viruses and other pollutants in indoor spaces.

An important aspect of the new regulations is that they clearly define what constitutes "good quality air" by setting reference levels for CO_2 concentration, minimum ventilation and air purification rates. While they do not oblige those responsible for the spaces to meet the reference levels, they can be used as performance targets to improve ventilation and/or air purification systems. To that end, the new regulations strongly encourage building owners and operators in public spaces to measure indoor air quality (e.g. with a CO_2 metre), assess the potential risks associated with the types of activities that take place in their premises and develop a list of potential causes of indoor pollution.

Source: Service public fédéral Santé publique (2022[90]), *Adoption de la loi sur la Qualité de l'air Intérieur,* https://www.health.belgium.be/fr/news/adoption-de-la-loi-sur-la-qualite-de-lair-interieur (accessed on 29 June 2023).

The preparation of guidelines and policy advice can be complex, requiring a collection and synthesis of the most recent evidence and identifying the best actions that can fit the needs of communities in setting. In response, many OECD countries and international organisations have been publishing guidelines and recommendations (Box 5.6) to support national and sub-national efforts (Table 5.2).

Table 5.2. Sample recommendations for community-based IPC interventions

Setting	Recommendations
Hand hygiene	
Commercial buildings	Provide universal access to hand hygiene stations upon entering and leaving buildings Adapt quantity and usability of the stations to promote optimal use and ensure regular equipment refilling
Public transport facilities	Provide universal access to hand hygiene stations ideally at any public transport facility, especially targeting major bus and train stations, airports and ports Mandate the use of hand hygiene stations before accessing public transport during the COVID-19 pandemic
All settings	Provide access to free hand hygiene supplies such as alcohol-based hand rub, soap and water Encourage frequent hand hygiene by the population whenever outside of private homes as a routine activity
Mask wearing	
In 4 key moments	In crowded, enclosed or poorly ventilated spaces Following a recent exposure to COVID-19 when sharing a space with others While sharing a space with a person displaying COVID-19 symptoms is COVID-19 positive and For individuals who are at high-risk of severe complications from COVID-19
Respiratory etiquette	
All settings	Cover mouth and nose when coughing or sneezing Use tissues and throw them away Wash hands or use a hand sanitiser every time after touching mouth or nose
Indoor ventilation	
Improving air circulation within buildings	Ensure existing HVAC systems are providing at least the minimum outdoor air ventilation requirement in accordance with ventilation design codes Increase the introduction of outdoor air beyond code-minimum requirements Use fans to increase the effectiveness of open windows. Rebalance or adjust HVAC systems to increase total airflow to occupied spaces when possible. Introduce indoor air quality performance goals Monitor and display air quality Encourage HVAC system maintenance Develop ventilation guidelines

Note: HVAC = heating, ventilation and air conditioning.
Source: Sample recommendations were extracted from (WHO, 2020[91]) for hand hygiene, from (WHO, 2023[42]) for mask wearing and adopted from (CDC, 2023[92]) for indoor ventilation.

Box 5.6. France puts forward a novel hygiene measure framework for preventing infectious diseases in the community

In 2023, France's High Council for Public Health (HCSP) issued new guidelines on the use of hygiene measures in community settings. The recommendations span ten core measures from hand hygiene to improved indoor ventilation and are intended for year-round application, with particular emphasis during outbreak seasons (Conseil de la santé publique, 2023[93]). They align closely with the principles of the Ottawa Charter for Health Promotion, notably its calls to develop sound public policy, create supportive environments, strengthen community engagement, build individual skills and reorient health services.

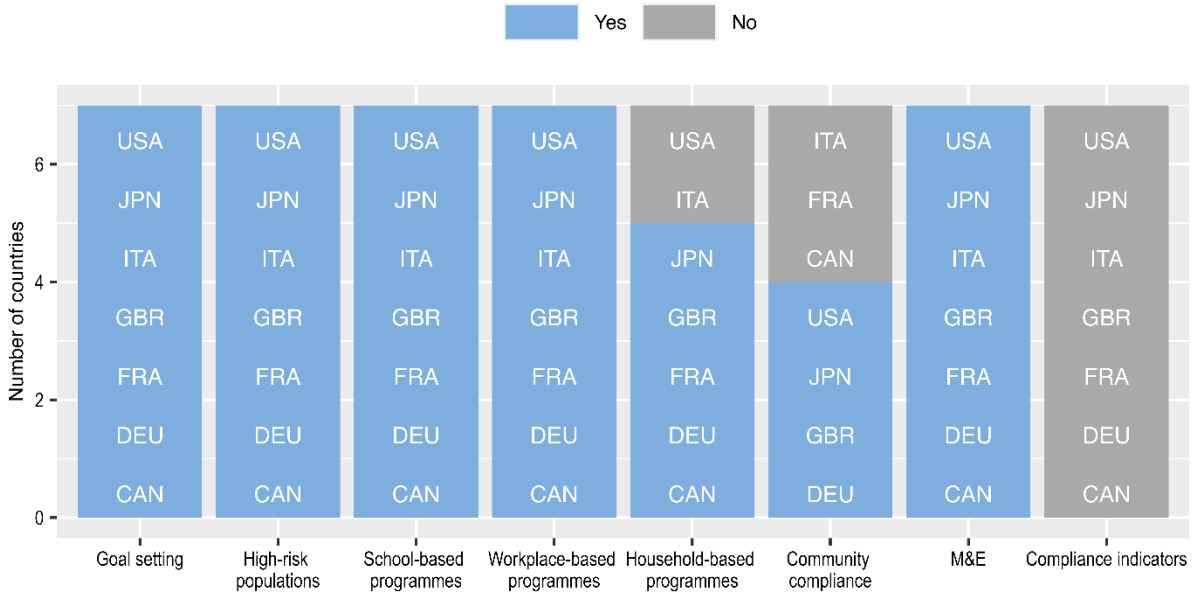
The HCSP also provides a set of broader recommendations aimed at reducing the overall burden of major infectious diseases. These include, but are not limited to, ensuring access to essential hygiene products for vulnerable populations (e.g. soap, water, personal hygiene supplies, household products and municipal shower facilities); establishing a monitoring committee to oversee universal hygiene measures and related communication; developing educational toolkits or hygiene kits alongside targeted communication campaigns; and systematically evaluating measures, for example, through health impact assessments where appropriate that extend beyond the health sector.

Source: Conseil de la santé publique, (2023[93]), *Mesures universelles d'hygiène pour la prévention des principales maladies infectieuses dans la population générale Collection Avis et Rapports*, https://www.hcsp.fr/explore.cgi/avisrapportsdomaine?clefr=1289 (accessed on 18 August 2024).

National pandemic preparedness plans typically include recommendations and policy advice for the implementation of community-based IPC measures. A deeper look into these documents points to their strengths and weaknesses (Figure 5.5). One positive finding is that all national pandemic preparedness plans in G7 countries set clear goals and objectives and clearly identify high-risk populations that should be considered during a disease outbreak. Frequently mentioned high-risk groups include children, pregnant women, older people and immunocompromised people. All these documents highlight the potential need for school- and workplace-based programmes in case of disease outbreaks. Covering the needs of households is also mentioned but less frequently.

Despite their strengths, national pandemic preparedness plans in G7 countries do not consistently discuss considerations around the centrality of compliance in the community with the vision that they lay out. Only 4 out of 7 national action plans mention the importance of ensuring high levels of compliance in the community. Even when compliance is discussed, this is usually done in a cursory manner and without putting forward any strategies to motivate greater adherence in the community. Finally, even though the importance of monitoring and evaluating the implementation of the activities highlighted in the national plans was discussed in all documents, none of these documents indicate having indicators to track community-level compliance over time.

Figure 5.5. In G7 countries, pandemic preparedness plans do not consistently address concerns around compliance



Note: Figure above shows whether the pandemic plan i) sets clear goals and objectives, ii) it references high-risk populations, including children, pregnant women, older people and immunocompromised people, iii) highlights the need for school-, workplace- and/or household-based programmes in the case of outbreaks, iv) mentions the importance of ensuring high levels of compliance in the community, v) refers to the importance of monitoring and evaluating the implementation of the activities highlighted in the national plans and vi) includes indicators that can enable tracking of compliance in the community over time. M&E = monitoring and evaluation of the implementation. The list of pandemic preparedness plans and other relevant documents reviewed by the OECD are provided in Annex Table 5.C.1.
Source: OECD review.

5.5.2. Ensure adequate access to supplies and materials

Compliance can also be influenced by the availability of IPC supplies and materials (e.g. soap dispensers and facemasks), especially during disease outbreaks. In the early days of the COVID-19 pandemic, shortages in facemasks and hand sanitisers were pervasive globally and in many OECD countries. In response, 18 out of 24 OECD Members and accession countries that participated in the OECD survey distributed free-of-charge masks and 16 countries distributed handwashing materials through national and sub-national programmes. Some OECD countries have also taken initiatives to distribute air purifiers as part of a broader effort to ensure a safe return to schools (Box 5.7).

Evidence suggests that in OECD, IPC supplies and materials were in short supply in certain community settings even before the COVID-19 pandemic. For example, one study from the Netherlands showed that 43% of playrooms lacked either a sink, soap dispenser in reach of children or a towel facility (van Beeck et al., 2015[94]). Another study from New Zealand found that around 15% of public toilets lacked soap (Wilson and Thomson, 2021[95]). Findings from these studies broadly align with those showing that interventions that combine activities to increase the accessibility of IPC supplies and materials with efforts to increase awareness and understanding tend to produce greater compliance compared to activities that solely focus on educational or behavioural interventions.

Box 5.7. A school-based programme in Australia used air purifiers and high efficiency particulate air filters to facilitate safe return to in-person teaching during the COVID-19 pandemic

One school-based programme implemented in the State of Victoria in Australia between 2021 and 2022 aimed to facilitate safe return to in-person teaching by improving indoor ventilation practices (Government of the State of Victoria, 2023[8]). As part of the programme, the Department of Education provided eligible schools with around 111 000 air purifiers and enough HEPA filters to cover every classroom for two years. These types of filters are generally considered to be highly efficient in removing airborne contaminants, making them increasingly crucial for ensuring high indoor air quality. Extra air purifiers were held in storage to account for potential increases in enrolment and/or the addition of new classrooms. In addition, natural ventilation practices (e.g. doors and windows, engaging in outdoor learning during warmer seasons) were encouraged. The State of Victoria was estimated to allocate over USD 190 million to the programme for two years of implementation. The Department of Education assessed the implementation of the programme in a sample of schools. This evaluation concluded that a key challenge involved finding a balance between ventilation strategies and ensuring a comfortable learning environment, as well as potential trade-offs around energy and thermal efficiency.

Source: Government of the State of Victoria (2023[8]), *School operations – Ventilation and Air Purification,* https://www2.education.vic.gov.au/pal/ventilation-air-purification/policy.

5.5.3. Financial incentives

Financial incentives have long been used to promote good public health practices such as encouraging the prudent use of antibiotics (Yoshikawa et al., 2021[96]). Financial incentives can be in the form of rewards and penalties. Both types of financial incentives have been shown effective. The potential impact of financial incentives on compliance rates is likely to depend on a range of factors such as the community context, public attitudes, social and cultural norms, and the magnitude of the penalty/reward.

Positive financial incentives (e.g. rewards, subsidy programmes) can be considered especially when cost considerations create a barrier against adoption. For example, mechanical ventilation imposes a range of upfront and operating costs, which can influence the selection of ventilation strategy (Table 5.3). One recent multi-country survey conducted in 7 OECD countries (i.e. Austria, Belgium, Denmark, Estonia, France, Norway and the United Kingdom) showed that high capital costs were highlighted as one of the main barriers hindering the widespread adoption of mechanical ventilation systems (Zukowska et al., 2020[97]). In this case, using positive financial incentives (e.g. rewards, subsidy programmes) can be one option to encourage building operators and owners. Despite their promise, financial incentives remain an underutilised tool, as only Austria, Germany, Israel, Japan and the United Kingdom reported in the OECD survey that they used some type of financial incentive to promote better indoor ventilation practices during the COVID-19 pandemic.

Table 5.3. Sample cost estimates for various ventilation interventions

Ventilation strategy	Up-front cost	Ongoing maintenance requirements and incremental energy usage
Using fans to increase effectiveness of open windows	<USD 100	• No ongoing maintenance requirements • Incremental energy use varies, depending on HVAC system capacity and ambient outdoor conditions
Adding in-room HEPA fan/filter systems	Approximately USD 500	• Must inspect/replace HEPA filter per manufacturer instructions • Low incremental energy use
Adding upper room ultraviolet germicidal irradiation (UVGI) [Typical classroom requires 2-3 fixtures]	< USD 1 500 (approx. per fixture)	• Must clean/inspect/replace UVGI lamps per manufacturer instructions • Low incremental energy usage

Note: HEPA = high efficiency particulate air; HVAC = Heating, ventilation and air conditioning; UVGI = Ultraviolet Germicidal Irradiation.
Source: Adapted from CDC (2023[92]).

In contrast, negative incentives (i.e. penalties, disincentives) impose a cost for failing to engage in the desired behaviours. Negative incentives can be considered when compliance with certain IPC practices is crucial to ensure public health and to discourage non-compliance. For example, the OECD survey found that 17 out of 24 OECD Members and accession countries imposed financial penalties for non-compliance with mask wearing regulations during the COVID-19 pandemic. Countries that consider implementing negative incentives should carefully think through the severity of the penalties that they plan to impose. Penalties with mild consequences (e.g. warnings or small fines) might act as a reminder and encourage greater compliance without inciting strong negative reactions whereas stronger penalties may be perceived as punitive.

5.5.4. Design and implement effective community-based IPC programmes

Community-based interventions tend to be more effective when they involve multiple components. For example, one earlier systematic review found that hand hygiene education alone was only moderately effective (RR=0.86; 95% CI = 0.73, 1.00) against respiratory illness (Aiello et al., 2008[1]), whereas an intervention that combined hand hygiene education with the distribution of nonantibacterial soap was associated with greater reductions in respiratory illness rates (RR=0.49; 95% CI = 0.40, 0.61). More recently, Ejemot-Nwadiaro and colleagues (2021[25]) also showed that in school settings, interventions that combined both the distribution of hand-washing supplies and promotional materials were more effective in reducing the incidence of diarrhoea episodes compared to interventions that relied solely on awareness raising (IRR = 0.66; 95% CI = 0.58-0.75 vs. IRR = 0.84, 95% CI = 0.67-1.05).

Decisions around the duration of the implementation also matter. Changing habits and behaviours around hand hygiene, mask-wearing and respiratory etiquette takes time and solidifying habits and behaviours requires long-term efforts. Educational messages, behavioural nudges and financial incentives may be repeated over an extended period for people to internalise new habits and behaviours. Previous studies show that the effectiveness of hand hygiene interventions improve over time (Aiello et al., 2008[1]), aligning with results from other health promotion activities (Cradock et al., 2014[98]).

Interactions between different public health objectives should be carefully weighed in the design of IPC measures in the community. For example, as highlighted in the 2021 WHO roadmap, certain interventions such as mosquito screening may inadvertently hamper the rate of natural ventilation (WHO, 2021[52]). Keeping in mind that many OECD countries are experiencing a surge in vector-borne diseases, adopting comprehensive approaches that take into account various public health objectives (e.g. strengthening vector control) while improving indoor ventilation remains a key consideration (Semenza and Paz, 2021[99]).

Another key consideration is the unintended consequences arising from the implementation of these programmes. For instance, improving indoor ventilation can increase energy consumption and utility bills and lead to a higher carbon footprint. This was the case when the city of Pamplona in Spain introduced new guidelines that promoted greater use of natural ventilation (e.g. opening all doors and windows at the end of each class and during short breaks) in order to halt the spread of SARS-CoV-2 between March 2020 and January 2021. One study that examined the impact of this initiative found that while the new guidelines led to a 55% reduction in CO_2 concentration in indoor spaces in schools, they also resulted in a marked rise in heat consumption during winter (Monge-Barrio et al., 2022[100]). Recent evidence suggests that mechanical ventilation systems with heat recovery units could reduce the additional heating demand. For example, one study in Italy in a school setting found that mechanical ventilation systems equipped with heat recovery units cut the ventilation share of energy loss to 5% and delivered overall energy savings above 30% (Stabile et al., 2019[101]).

5.5.5. Improve public awareness and understanding

Educational initiatives and mass education campaigns can play a vital role in improving compliance by enhancing people's awareness and knowledge of infection prevention and control in the community, dispel misinformation while promoting accurate guidelines and best practices. These initiatives can reach a wide audience quickly and effectively. Repeated exposure to the messages highlighted by these initiatives can help reinforce and maintain high levels of adherence with the best community-based IPC practices in the long term.

Throughout the COVID-19 pandemic, the OECD Members and accession countries made substantial efforts to inform the public about the spread of SARS-CoV-2 and strategies to slow its transmission in the community (Figure 5.6). Specifically, 22 out of 24 OECD Members and accession countries reported that they launched public awareness campaigns to promote hand hygiene and mask wearing and 20 countries had campaigns to promote respiratory etiquette during the COVID-19 pandemic. However, only a fraction of these campaigns had monitoring and evaluation arrangements that could be a basis for fine-tuning/modifying the implementation arrangements. Some countries continued their educational initiatives in the aftermath of the pandemic. For example, Slovenia reports that the National Institute of Public Health has been implementing awareness raising activities to encourage best practices in respiratory etiquette and indoor ventilation in the general public.

In addition to mass media campaigns, the OECD Members and accession countries used free-of-charge phone lines/websites to facilitate access to accurate information about the effectiveness of community-based IPC measures. Of the 24 OECD Members and accession countries reported in the OECD survey that they had free-of-charge phone lines/websites to provide accurate information on hand hygiene, mask wearing and respiratory etiquette. However, much like larger scale awareness campaigns, only a fraction of these phone lines/websites were finetuned/modified based on feedback received through monitoring and evaluation mechanisms.

Figure 5.6. OECD Members and accession countries frequently relied on mass media campaigns during the COVID-19 pandemic

Number of countries that reported organising mass media campaigns during the COVID-19 pandemic to promote greater compliance with community-based IPC measures



Note: This graph presents the number of countries that responded to the questions "How did your country encourage better hand hygiene/mask-wearing/respiratory etiquette in the community during the COVID-19 pandemic?" by selecting the option "Organise mass media campaigns to encourage best practices in hand hygiene/mask-wearing/respiratory etiquette". Levels of implementation include: No plans = No plans for implementation; Regional/sub-national = Activities/programmes were implemented at the regional/sub-national level; National = Activities/programmes were implemented at the national level; National, M&E = Implementation of activities/programmes at national level were fine-tuned/modified based on monitoring and evaluation activities. The list of countries that participated in the survey is provided in Annex Table 5.A.1.

Source: Country self-assessment responding to the 2023-2024 OECD survey on Maintaining Infection Prevention and Control Measures in the Community.

Robust evidence on the effectiveness of mass media campaigns on motivating greater compliance with community-based IPC measures remains limited but available data suggests promising results. For example, one social media campaign launched in 2020 in the Netherlands disseminated best practices in hand hygiene through a news article with infographics published in a newspaper with 2 million readers and a video campaign designed by an influencer with a following of around 80 000 people (Yousuf et al., 2020[102]). This campaign resulted in notable improvements in hand hygiene behaviours. Exposure the infographics alone was positively associated with improved hand-washing practices (Odds ratio [OR] adjusted for age, gender and educational attainment = 1.31; 95% CI = 1.22-1.40). Importantly, exposure to both the infographics and the video campaign compounded the positive impact of this intervention on hand hygiene behaviours (adjusted OR = 2.14; 95% CI = 1.83-2.50). These findings are broadly aligned with other studies conducted in non-OECD countries (Hanson et al., 2020[103]; Scott et al., 2008[104]).

Existing evidence focussing on the effectiveness of initiatives that aim to improve awareness and understanding around various public health challenges underline that these activities should carefully consider several factors including:

- **Identifying the target audience**: Creating an effective mass media campaign requires to clearly identify the target audience of the activities aiming to improve awareness and understanding (Tidwell et al., 2019[105]). Once the target audience is defined, the specific design features of informational activities can be carefully tailored to achieve the highest levels of effectiveness (Box 5.8).
- **Using clear and compelling public health messaging:** Previous studies focussing on the effectiveness of interventions to improve the public's understanding and awareness of public health challenges such as antimicrobial resistance underline the importance of using clear and compelling public health messages that are tailored to specific population groups (e.g. school-children and parents) (Price et al., 2018[106]; Parveen et al., 2022[107]).
- **Evaluating the effectiveness of educational initiatives**: Evidence emerging from studies focussing on educational initiatives suggests that defining specific and measurable goals early on (e.g. increasing the frequency of hand washing, improving knowledge around respiratory hygiene) is crucial to help assess the effectiveness of these interventions (Yousuf et al., 2020[102]). Regular evaluations of educational initiatives can help identify the areas that need to be fine-tuned in the implementation of these activities.

Box 5.8. School-based interventions can consider using vocal, visual and interactive elements to enhance their effectiveness

Vocal and visual elements can grab the attention of young children

One pilot study in the United Kingdom tested the effectiveness of persuasive space graphics (e.g. graphic elements integrated within an architectural environment) in 3 schools and one museum (Dingman, Wu and Murphy, 2020[108]). This study found that graphic reminders increased the frequency of handwashing by about 50% after two to three months, coupled with enhancements in the average quality of the handwashing. In the United States, one programme targeting pre-school children 3-5 years of age used a blacklight technology to visually demonstrate the residual contamination after washing hands (Dingman, Wu and Murphy, 2020[108]). This study reported improvements in hand hygiene behaviours over five months.

Interactive elements can also augment compliance

Using interactive elements can also augment compliance. One RCT conducted in Türkiye evaluated the effectiveness of a hand hygiene intervention in two kindergartens (Arıkan et al., 2018[109]). The intervention group participated in four sessions where a clown provided information about microbes, demonstrated proper handwashing techniques, and engaged the children in interactive activities and videos. The results showed a 34.6% difference in microbial contamination between the intervention and control groups. Another randomised controlled trial from the United Kingdom evaluated the impact of an educational programme called "A Germ's Journey", which targeted younger children between 4 and 5 years of age (Younie et al., 2020[110]). The intervention involved presenting children with books, online games and a gel to make them observe residual contamination after handwashing. This intervention was associated with a 40% increase in children's knowledge of how germs are transferred and an 18% improvement in observed handwashing behaviours such as washing under fingernails.

Source: Dingman, Wu and Murphy (2020[108]),"*School-based, blacklight handwashing program can improve handwashing quality and knowledge among pre-school aged children*", https://doi.org/10.1016/j.evalprogplan.2019.101731; Arıkan et al. (2018[109]), "*The Effect of Therapeutic Clowning on Handwashing Technique and Microbial Colonization in Preschool Children*", https://doi.org/10.1111/jnu.12392; Younie et al. (2020[110]), "*Improving young children's handwashing behaviour and understanding of germs: The impact of A Germ's Journey educational resources in schools and public spaces*", https://doi.org/10.1371/journal.pone.0242134.

5.5.6. Behavioural nudges

Establishing and maintaining good IPC habits can be challenging even in settings where the knowledge of IPC measures is already high. Behavioural nudges can be considered as an alternative strategy to motivate greater compliance. Unlike other approaches such as financial incentives, behavioural nudges (e.g. visual cues, reminders, defaults, improving convenience and gamification) aim to guide individuals' behaviours without directly regulating their choices.

Instead, behavioural nudges attempt to influence behaviours by making the desired behaviours more visible, attractive or convenient for its target audience. During the COVID-19 pandemic, 14 out of 24 OECD Members and accession countries reported in the OECD survey that they encouraged the use of contactless credit card payments in businesses in order to improve the convenience of financial transactions for customers. This intervention was thought to reduce the incidence of SARS-CoV-2 by minimising the physical contact between the payment terminals, reducing the need for using cash – cash can be a source of infections become it can chance hands frequently – and finalising transactions faster.

The choice of the specific behavioural nudge should consider the target audience. For example, in day care/school-based programmes, it might be more beneficial to use gamification strategies (Box 5.9), whereas workplace programmes may consider using rewards and team-based activities targeting employees (Box 5.10).

Box 5.9. e-Bug Project in the United Kingdom uses gamification strategies to promote healthy IPC behaviours among children and young people

The e-Bug Programme, operated by the United Kingdom Health Security Agency, is a health education programme that aims to promote healthy IPC behaviours (e.g. respiratory etiquette) among children and young people (e-Bug Project, 2022[111]). It provides free educational materials and resources for educators, parents, caregivers and community leaders. The e-Bug Programme approach provides important lessons for using gamification strategies designed specifically for a young audience.

The e-Bug educational materials also make use of various gamification strategies to promote greater engagement depending on the playing needs and cognitive abilities of children in various age groups (e-Bug Project, 2022[111]). For example, the e-Bug Junior Game, targeting children between 9-12 years of age, is designed similarly to fast-engaging platform games (e.g. Mario series), fast-reaction games (e.g. Whack-a-mole) and quiz games. Typically, in these games, the player is around the same size as a bacterium, navigates the environments in which that they exist, and they earn points/rewards through interactions with microbes (e.g. the player throws a soap at harmful microbes to wash them off.) In comparison, the e-Bug Senior Game, targeting older students between 12-14 years of age makes use of the Problem-Based Learning methodology. The players are typically given a detective style investigative scenario related to a disease outbreak in Europe whereby they are expected to find the source of infection/contamination in order to successfully complete the game.

Source: e-Bug Project (2022[111]),*KS1/KS2/KS3 Respiratory Hygiene Experiment – Snot Gun Runway,* https://www.youtube.com/watch?v=0fXQWJzxtII (accessed on 15 November 2023).

Box 5.10. Employee wellness programmes can consider team-based activities and rewards to promote better compliance

One employee-wellness programme conducted in a private company in the State of Georgia in the United States for 3-months between 2012 and 2013 provides useful lessons for designing workplace-based IPC programmes that can promote greater compliance among employees (Thompson and Rew, 2015[112]). This programme aimed to improve hand hygiene behaviours among more than 1 600 employees working in an office building through a multi-modal programme that combined messaging with behavioural nudges. Educational messages included information on bacterial pathways, germ fears, anxiety and myths and IPC practices that employees can use to interrupt the transmission of diseases. Educational messages were disseminated through posters and fliers and weekly emails.

Behavioural nudges such as team-based activities and rewards can help motivate compliance

Employees were voluntarily assigned to small and co-operative teams. Each employee monitored their level of healthy habits each day (e.g. washing hands with hot water and soap, use of hand sanitisers etc.). The programme organisers assigned points to employees for participating in key activities. The programme organisers carried out regular bacterial audits to assess the contamination levels in dedicated employee spaces and common areas. Teams were awarded points for successfully reducing the contamination levels in their associated spaces. Team scores and ranking were announced on a weekly basis to create an environment of competition. At the start of the programme, hand hygiene products were labelled "Wash, Wipe and Sanitize" and were made easily accessible (e.g. in desks, common areas and near critical touch points such as elevators) in order to make it more convenient for employees to practise hand hygiene.

Team-based activities and rewards can help motivate compliance

An evaluation of the employee wellness programme showed a 37% reduction in the contamination levels across all the surfaces and equipment measured in the office space compared to the baseline. The programme was also associated with notable reductions in healthcare spending, with the average monthly cost of medical services associated with minor illnesses across employees reducing from USD 45.96 in six months before the start of the programme to USD 32.88 in 6 months after the programme ended. The programme was also shown to yield gains in productivity at work, with a 13% reduction in the number of days absent from work due to ill health.

Source: Thompson and Rew (2015[112]), "*The Healthy Workplace Project: Results of a Hygiene-Based Approach to Employee Wellness*", https://doi.org/10.4278/ajhp.130830-ARB-459.

The OECD survey showed that the OECD Members and accession countries relied frequently on two types of behavioural nudges in the context of the COVID-19 pandemic to promote greater compliance: 1) visual cues and 2) Short messaging services (SMS)-based reminders.

Visual cues

Even before the COVID-19 pandemic, visual cues were increasingly used to nudge healthy behaviours. During the COVID-19 pandemic, OECD Members and accession countries frequently relied on visual reminders to promote best practices (Box 5.11). For example, 23 out of 24 OECD Members and accession countries reported in the OECD survey indicated that they placed visual cues in highly visible areas to promote hand hygiene, mask wearing and respiratory etiquette during COVID-19.

Box 5.11. Behavioural nudges are an integral part of Ireland's approach to enhancing hand hygiene in public spaces

In 2020, Ireland put together a list of key approaches and 10 concrete steps that can be used to improve hand hygiene in public places (Irish Department of Health, 2025[113]). The recommended approaches and actions aimed to address various drivers of compliance, ranging from the accessibility of hand hygiene materials to raising the awareness of individuals on the benefits of better hand hygiene.

A key important feature of Ireland's approach entails using behavioural nudges (e.g. visual cues in key spaces, modelling good behaviours by managers and supervisors) that promote developing and sustaining good hand hygiene behaviours and combining these nudges with other measures that ensure adequate access to hand hygiene materials.

Table 5.4. Example approaches that can be used to improve hand hygiene in public places

Key approaches	Actions
Ensure awareness of the benefits of and techniques for good hand hygiene	• Make people aware of the benefits of good hand hygiene • Make people aware that they/their family are probably not using the correct techniques • Show the required HH steps
Provide visual cues in restrooms to remind people to wash and dry hands	• Provide visual reminders in restrooms (e.g. posters above the sink, on the back of stall doors and above urinals) • Install automatic towel dispensers that dispenses a towel upon approach to the sink • Add directional arrows from stalls to sinks • Use audio-visual reminders
Ensure that hand sanitisers are available, visible and easy to use	• Make hand sanitisers available when handwashing is not feasible • Place the location of hand sanitiser dispensers at convenient points to maximise use • In the direct routes that people walk (e.g. at the centre of an entrance lobby) • Within easy reach (e.g. on carts as well as walls, at the entrance to rooms) • Before/after tasks are completed (e.g. entry to / exit from a shop or room) • Where people normally take a pause (e.g. at an elevator) • Ensure that signage for hand sanitiser dispensers are available • Do not limit access to the dispenser • Do not diminish the visibility of visible dispensers • In informational materials, keep text to minimum
Model good behaviours, help staff to form HH habits and provide regular feedback	• Managers, supervisors and influencers can model good behaviours • Provide regular performance feedback on compliance • Help staff link hand hygiene with common events (e.g. getting to work, start of meetings)

Source: Adapted from Irish Department of Health (2025[113]), *Using Behavioural Science to Improve Hand Hygiene in Workplaces and Public Places,* https://assets.gov.ie/73613/c5b00da7b6c14afca8de2bf729697d9c.pdf (accessed on 3 May 2023).

A growing body of evidence suggests that visual cues are an effective means to motivate greater compliance with community-based IPC measures. Earlier studies conducted in healthcare settings demonstrated that incorporating visual cues into the physical environments led to improvements in hand washing rates among health workers over time (McGuckin and Govednik, 2013[114]). Results from subsequent studies conducted in community settings concur with these findings. For example, one study conducted in the State of North Carolina in the United States involved installing visual cues (e.g. motion activated dispensers that automatically presented towels and soap dispensers) in public bathrooms (Ford et al., 2014[12]). This study showed a nearly 23% increase in towel use and around 13% increase in soap use. A subsequent study conducted in the State of Carolina used large, red arrow shaped stickers as visual cues (Blackwell, Goya-Tocchetto and Sturman, 2017[115]). The stickers were purposefully placed as lines

directing people from urinals/stalls to hand washing stations in order to create a natural flow. This study found a 15% overall increase in hand washing practices.

Visual cues have also been shown to encourage better indoor ventilation practices, though the evidence points to uneven effects. One study in Denmark alternated two-week periods in which teachers and students were instructed to open windows in response to visual CO_2 feedback against periods of normal ventilation. This study found that the use of the visual cue was associated with more frequent window opening (Wargocki and Da Silva, 2014[116]). A more recent study installed a display alerting teachers when CO_2 exceeded set thresholds and recorded a 19.5% reduction in concentrations (Rawat et al., 2025[117]). This study also reported, however, a rise in classroom PM particulates as windows were opened more often and energy use increased due to heat loss. In comparison, one study in Denmark compared alternative retrofits across adjacent classrooms and found that visual feedback alone did not motivate window opening: display-equipped classrooms matched manually operated ones at up to 17% of occupied time, against 49% to 71% under automatic control (Heebøll, Wargocki and Toftum, 2018[118]).

Text- and/or voice-based reminders

Many countries turned to text- and/or voice-based reminder services as part of their COVID-19 information campaigns though there were substantial differences in the design and implementation. For example, some countries such as Germany relied on national-level initiatives to promote better hand hygiene, respiratory etiquette and mask wearing whereas other countries such as Australia adopted a more decentralised approach by implementing regional/sub-national programmes.

In 2020, the WHO launched a new message library to address the increasing demand for SMS-based public health messaging (WHO, 2020[119]). This message library collated a list of suggested messages designed to inform the general public on a variety of topics including, infectious diseases and disease transmission and community-based IPC measures such as hand hygiene, mask wearing and respiratory etiquette (Table 5.5). The suggested messages were short and easy to understand and countries that considered using them were encouraged to adapt them to the local contexts and languages.

Table 5.5. Sample messages included in the WHO COVID-19 message library to promote compliance with community-based IPC measures

Theme	Sample message
Handwashing	Wash your hands after coughing or sneezing, when caring for the sick, when preparing food, before eating, after toilet use, after handling animals
Mask-wearing	Before putting on a mask, clean hands with alcohol-based rub or soap and water. Avoid touching the mask while using it and remove it from behind
Respiratory etiquette	Stop the spread: Cover your mouth and nose with a bent elbow or tissue when you cough or sneeze. Dispose of used tissues immediately and wash hands regularly.

Source: WHO (2020[119]).

Even before the COVID-19 pandemic, SMS-based messaging initiatives have been shown to propagate a rise in healthy behaviours, such as smoking cessation (Scott-Sheldon et al., 2016[120]), greater adherence to prescribed medications and higher treatment completion rates (Alipanah et al., 2018[121]; Orr and King, 2015[122]). Evidence generated during the COVID-19 pandemic suggests that SMS-based interventions can be effective, but their impact is generally modest. One recent study from Korea found that the emergency text messages in 2020 sent by the national and local governments during the COVID-19 pandemic were positively associated with preventive behaviours. Specifically, receiving and reading emergency text messages was associated with approximately 12.6% rise in mask wearing and almost 8% increase in hand washing (Lee and You, 2021[123]). A randomised controlled trial conducted in the city of

Sao Paulo in Brazil in 2020 also suggested that receiving a text message was associated with significant increases in the probability of wearing a mask when leaving home in the last seven days and a greater likelihood of adhering to social distancing guidelines (Boruchowicz et al., 2020[124]). Importantly, these studies emphasised that the effectiveness of SMS-based messaging is highly sensitive to the frequency and framing of the messages.

5.5.7. Set up routine monitoring and evaluation systems

Monitoring and evaluating the implementation of community-based IPC interventions can be an effective strategy to fine-tune the design of these interventions and helps improve the level of compliance in the general public. Routine monitoring and evaluation can provide an opportunity to identify the bottlenecks in the implementation and the factors that may hinder the public's level of compliance with the IPC measures.

Monitoring and evaluation remains an overlooked area in national and international guidelines. One recent study concluded that only 4% of international guidelines on hand hygiene recommend supporting or bolstering the existing monitoring systems or developing new monitoring systems aligned with global hygiene indicators (MacLeod et al., 2023[125]). Consistent with this finding, the OECD survey also found that only 7 out of 24 OECD Members and accession countries incorporated monitoring and evaluation plans in their national pandemic preparedness plans, legislation, policies and/or programmes to track the mask wearing practices in the community. Similarly, only 5 countries include monitoring and evaluation plans focussing on hand hygiene and respiratory etiquette and only 2 countries have similar plans for monitoring indoor ventilation practices.

Establishing routine monitoring and evaluation systems for community-based IPC interventions can be difficult because these programmes can be resource intensive, requiring funding and technical expertise. Compliance may vary considerably even among members of the same community, requiring a deep understanding of the community and the unique contextual factors that drive the level of adherence. As discussed in Section 5.3, these contextual factors can be dynamic, for example, due to the trajectory of disease outbreaks. Collection of reliable data can also be challenging because these programmes often rely on self-reported measures, which can be biased.

Despite these challenges, building monitoring and evaluation mechanisms for community-based IPC measures is feasible as part of efforts to prepare for future outbreaks. Table 5.6 presents sample strategies that OECD countries can consider strengthening the monitoring and evaluation of community-based IPC interventions.

Table 5.6. Sample methods and approaches to routine monitoring and evaluation of community-based IPC interventions

Methods	Sample approach
Phone polling	Use phone polling to reach a sample of the community members, with the aim of examining attitudes and perceptions around the community-based IPC interventions and gathering feedback around the implementation of existing programmes.
Use social media and digital platforms	Use analytics from various social media and digital platforms to assess the attitudes and perceptions around community-based IPC measures and to identify misconceptions or misinformation hindering compliance.
Focus group discussions	Organise focus group discussions with the members of the community to systematically assess their attitudes and perceptions regarding community-based IPC measures and to identify the factors that hinder high levels of compliance.
Environmental sampling	Regularly collect environmental samples from surfaces and areas in public spaces with high circulation of people to examine the levels of contamination.
Routine data collection	Field questionnaires/surveys to collate self-reported data on compliance. Consider including questions about the frequency of best practices in hand hygiene, mask-wearing and respiratory etiquette; knowledge around best practices; and factors that hinder/promote compliance.

Methods	Sample approach
Surveillance systems to track the trends in disease outbreaks	Monitor the number of reported cases for selected infection types and examine the trends over time to take into account the trajectory of local disease outbreaks (e.g. during/aftermath of an outbreak).
Combining data gathered from various sources	Combine data gathered through various methods (e.g. phone polling, surveillance data) to get a more complete picture of the implementation of existing programmes.

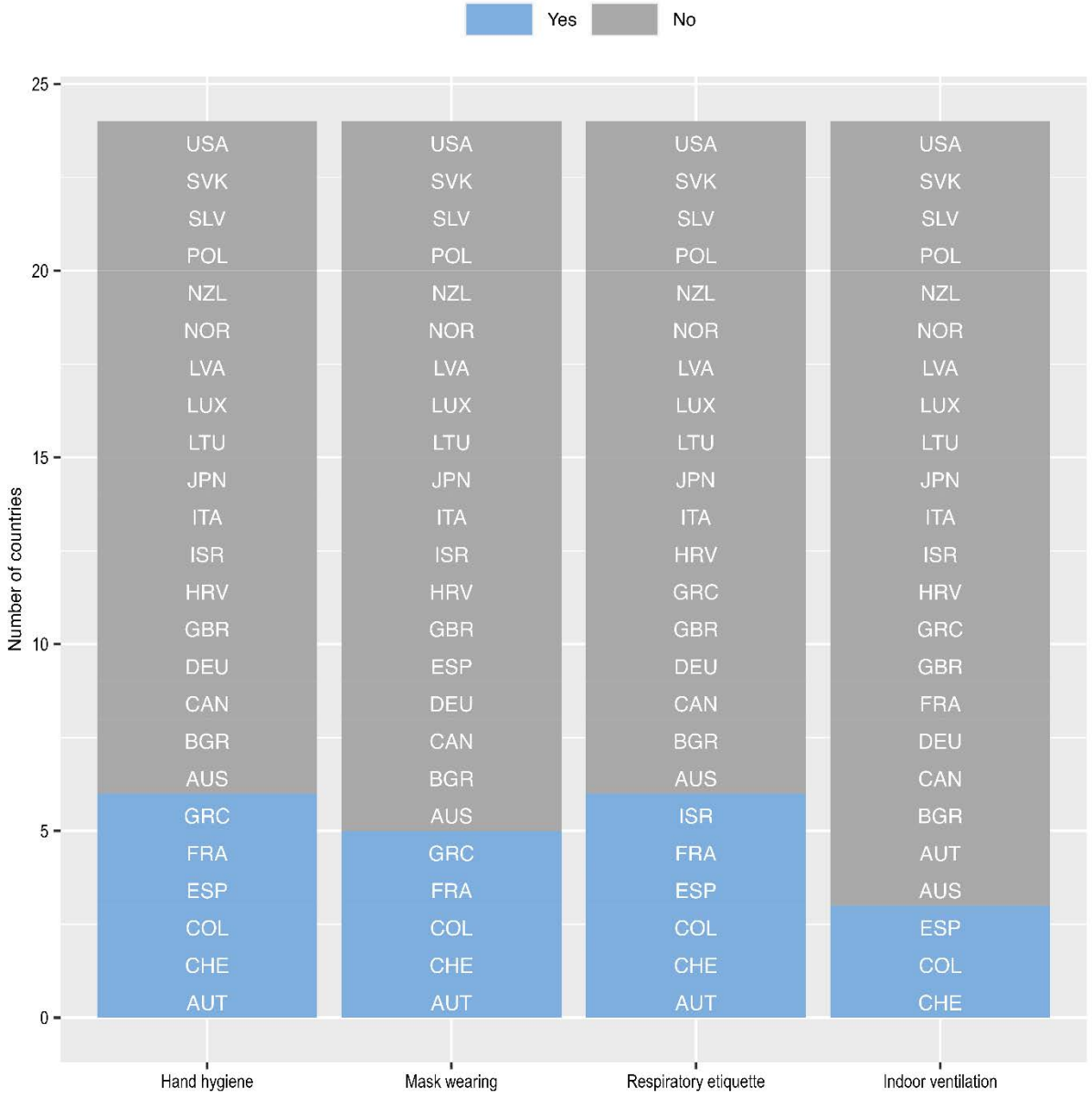
Source: OECD review.

5.5.8. Ensuring sustainable funding for community-based IPC programmes

The effective implementation of community-based IPC programmes requires that they receive a consistent and sustainable flow of funds. Yet, the OECD survey revealed that lack of financial resources is among the most important barriers against the implementation of community-based IPC programmes (Figure 5.7). Only 6 out of 24 OECD Members and accession countries reported in the OECD survey that there is a dedicated budget to support the implementation of activities to promote hand hygiene and respiratory etiquette in the community. Lack of sufficient funding was a crucial challenge for community-based activities to promote mask wearing and indoor ventilation, with only 5 and 3 countries reporting to have dedicated funding for these activities.

Figure 5.7. Most OECD Members and accession countries do not allocate a budget to support the implementation of community-based IPC measures

Number of countries that reported currently having a dedicated budget to support the implementation of community-based IPC measures



Note: This graph presents the number of countries that responded to the questions "Is there a dedicated budget to support the implementation of IPC measures in the community (hand hygiene/mask-wearing/respiratory etiquette/indoor ventilation) in the existing national action plan(s) on pandemic preparedness, pandemic influenza or other major infectious diseases with epidemic potential, legislation, policies and/or programmes?". The list of countries that participated in the survey is provided in Annex Table 5.A.1.
Source: Country self-assessment responding to the 2023-2024 OECD survey on Maintaining Infection Prevention and Control Measures in the Community.

Countries that consider bolstering the scale up of their community-based IPC programmes can allocate financial resources to these programmes as part of efforts to strengthen the resilience of their health systems to future outbreaks and pandemics.

5.5.9. Build trust in public institutions

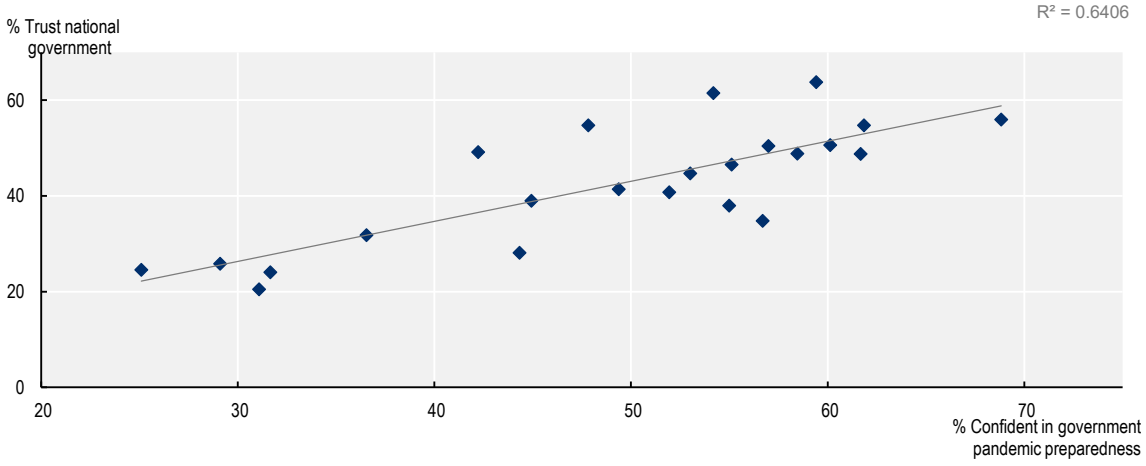
The previously discussed policy options can directly impact the level of compliance with community-based IPC measures. In addition to these strategies, the OECD countries can benefit from indirect strategies that can supplement these direct strategies. One vital indirect strategy is to build trust in public institutions. The OECD Trust Framework defines trust as "a person's belief that another person or institution will act consistently with their expectation of positive behaviour" (OECD, 2017[126]). High levels of trust in public institutions can enhance the level of compliance by offering people the confidence that individuals or institutions will act in accordance with their expectations (Brezzi et al., 2021[127]).

Broadly, the level of trust in public institutions can influence the level of compliance with community-based measures aiming to limit the spread of infections. One recent study with a global focus also showed that trust in the government was correlated with SARS-CoV-2 infection and attributable mortality (Bollyky et al., 2022[128]). In OECD, emerging evidence suggests that this finding might be explained by the differences in the levels of compliance between high-trust and low-trust settings. For example, one recent study used data from 17 OECD countries to demonstrate that geographic regions characterised by high levels of trust managed to slow the spread of SARS-CoV-2 at a much higher pace compared to low-trust regions (Bargain and Aminjonov, 2020[129]). Higher levels of compliance with measures to limit mobility for non-necessary activities was the main factor that explained the differences in the pace of reduction in SARS-CoV-2 infections between high-trust and low-trust regions.

Previous OECD research showed that trust in public institutions can also correlate with perceptions around the level of preparedness for the next pandemic. The 2021 OECD Survey on Drivers of Trust in Public Institutions found that on average, nearly 50% of all respondents across 23 OECD countries expressed confidence that their government would be ready in the event of a future pandemic (OECD, 2022[130]). Importantly, the OECD survey showed that there is an association between the level of trust in the national government and people's perceptions around pandemic preparedness (Figure 5.8). In general, governments were considered to be better prepared for the next pandemic in countries with greater trust in the national governments.

Figure 5.8. Perceptions around pandemic preparedness and trust in the national government are positively correlated

Share of respondents reporting trust in national government and share of respondents who consider it likely that government institutions will be prepared to protect people's lives in the event of a future pandemic, 2021



Note: This scatterplot presents the share of "trust" responses to the question "On a scale of 0 to 10, where 0 is not at all and 10 is completely, how much do you trust your national government?", equal to the values of responses 6-10 on the response scale, on the y axis. The x axis presents the share of "likely" responses to the question "If a new serious contagious disease spreads, how likely or unlikely do you think is it that government institutions will be prepared to protect people's lives?", equal to the values of 6-10 on the response scale. More information provided at https://www.oecd.org/en/topics/trust-in-government.html.
Source: Based on Figure 4.2. in (OECD, 2022[130]).

Evidence exploring the links between trust in public institutions and community-based IPC measures remains scarce. Yet, recent experiences from OECD countries offer important lessons to create greater trust in public institutions, which in turn can promote greater compliance with community-based IPC measures:

- **Increase satisfaction with healthcare services:** The 2026 OECD Trust Survey indicates that positive experiences that meet expectations build confidence more broadly in public institutions and uses satisfaction with healthcare services as a signal of changing trust in the health system (OECD, 2026[131]). It finds that trust rose between 2023 and 2025 but remains below 2021 levels: Across the 19 OECD countries with data for all three years, satisfaction among recent users of healthcare services fell from 63% to 55% before recovering to 58% in 2025. Satisfaction has been shown consistently higher among respondents who or whose family members used a health service in the past 12 months (OECD, 2026[131]).
- **Use easily accessible, transparent and consistent communication:** Prior OECD analyses emphasise the importance of providing easily accessible, clear, concise and consistent messaging in strengthening trust in public institutions (OECD, 2021[132]). During the COVID-19 pandemic, many OECD countries chose public health communication strategies that emphasised open, transparent and clear communication, coupled with motivational messages as well as expressions of care (OECD, 2020[76]). One recent study that evaluated the impact of New Zealand's communication strategy during the COVID-19 pandemic concluded that strategic and transparent public health messaging contributed to building trust with the public institutions at a time of

heightened uncertainty and motivated public support for the mitigation measures (e.g. mask wearing, hand hygiene, respiratory etiquette) (Beattie and Priestley, 2021[133]).

- **Partner with trusted messengers:** Leveraging partnership with trusted public figures (e.g. healthcare professionals, community leaders etc.) can contribute to the credibility and community-wide acceptance of best practices. Trusted public figures are generally perceived as a credible source of information (Merchant, South and Lurie, 2021[134]). When the messages are delivered by trusted individuals, people are more inclined to accept and practise the recommended best practices, leading to greater compliance (Ibid). For example, one recent study argued that in Norway, general practitioners played a key role in disseminating information for strategies to limit the spread of COVID-19, leading to measurable rises in healthcare institutions, particularly in the public sector (Skirbekk, Magelssen and Conradsen, 2023[135]).
- **Get buy-in from community members:** Involving the community members in the design and implementation of community-based IPC measures early on is crucial to create a sense of ownership and motivating compliance. This can be particularly important for community-based IPC measures, because they often intend to promote behaviour change at the individual level. For example, one school-based hand hygiene programme in the city of Almería in Spain actively involved the entire school community, including parents and caregivers in its implementation (Azor-Martinez et al., 2021[136]). A study that evaluated the effectiveness of this programme concluded that schools that actively involved the entire school community was more effective in promoting greater levels of hand hygiene compliance compared to schools that only targeted students and school staff.
- **Encourage multisectoral co-operation and collaboration:** Multisectoral co-operation and collaboration can also help boost trust in public institutions by demonstrating a unified front to tackling challenges that have consequences outside of the health sector. As discussed in Section 5.3, community-based IPC measures offer important non-health gains (e.g. reduced school absenteeism), underlining the centrality of multisectoral action. Existing evidence generated primarily through the initiatives in OECD countries suggests that multisectoral collaboration can be boosted through early involvement of non-health stakeholders in the design and implementation of programmes, showcasing the non-health benefits and harmonising the methods and metrics to evaluate the impact of these programmes (Kriegner et al., 2020[137]).

5.6. Conclusions

Community-based IPC measures can help mitigate the spread of viral and bacterial infections, as well as antibiotic resistant infections, while yielding substantial non-health benefits such as lower levels of school absenteeism and greater productivity at work. The COVID-19 pandemic showcased the centrality of these measures for pandemic preparedness and response, but the existing evidence points to critical gaps in their implementation and low levels of compliance.

The OECD Members and accession countries have in their arsenal a wide range of policies that can be used to motivate greater compliance in the long term. Successful implementation of these policies requires a careful consideration of the unique contextual factors that drive the level of compliance. Establishing regular monitoring and evaluation mechanisms will be key to examine the level of compliance over time and fine-tune the design features of the existing programmes.

Strengthening the IPC capacity in community settings will require new investments. As the OECD Members and accession countries continue to think through strategies to ensure the resilience of their health systems, community-based IPC measures should be prioritised.

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Annex 5.A. List of countries participated in the 2023-2024 OECD Survey on Maintaining Infection Prevention and Control in the Community

Annex Table 5.A.1. Countries participating in the 2023-2024 OECD survey on Maintaining Infection Prevention and Control Measures in the Community, as of 3 April 2024

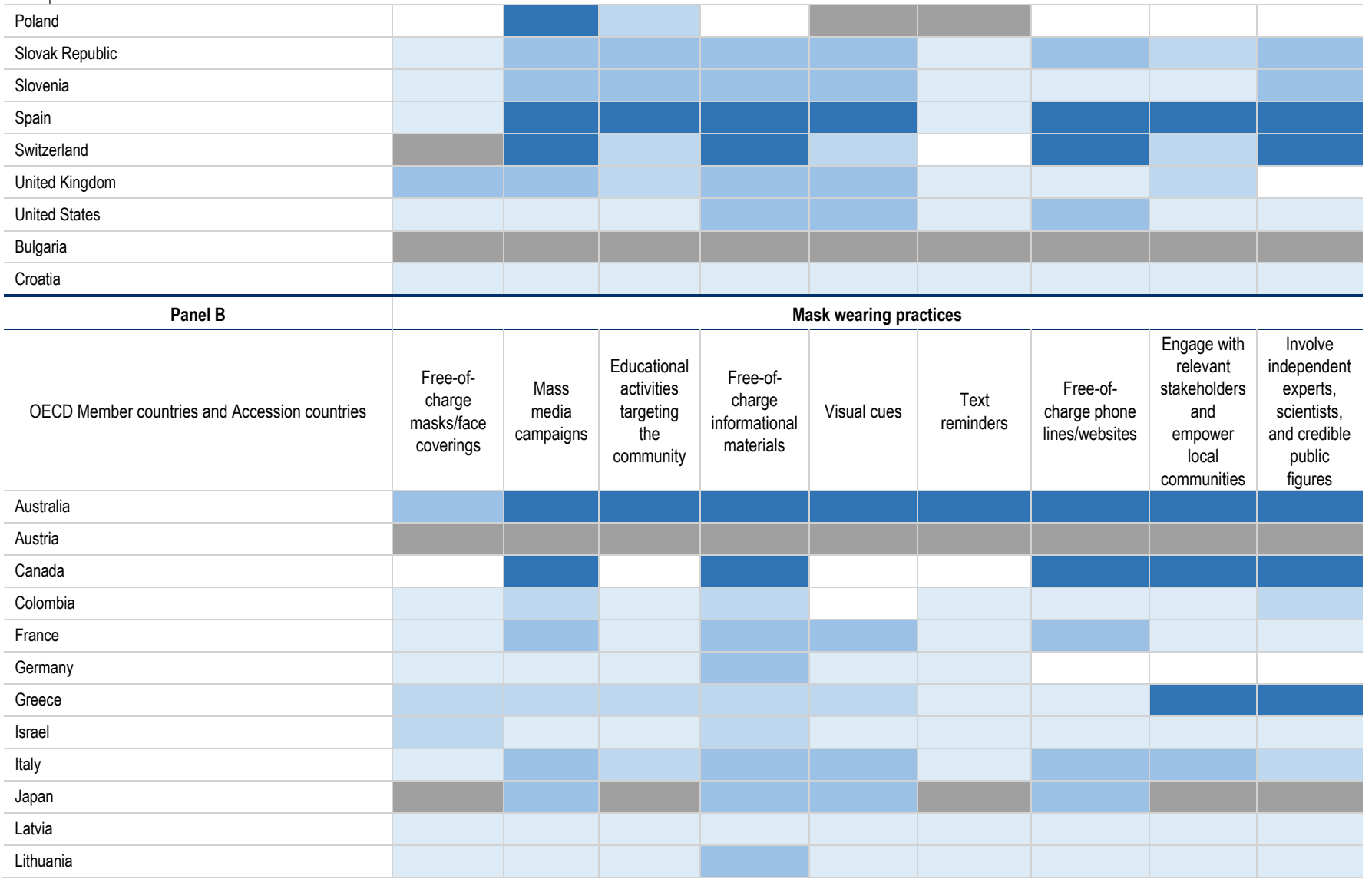
Country	Participation in the policy survey
Australia	Participated
Austria	Participated
Belgium	Did not participate
Canada	Participated
Chile	Did not participate
Costa Rica	Did not participate
Colombia	Participated
Czechia	Did not participate
Denmark	Did not participate
Estonia	Did not participate
Finland	Did not participate
France	Participated
Germany	Participated
Greece	Participated
Hungary	Did not participate
Iceland	Did not participate
Ireland	Did not participate
Israel	Participated
Italy	Participated
Japan	Participated
Korea	Did not participate
Latvia	Participated
Lithuania	Participated
Luxembourg	Participated
Mexico	Did not participate
Netherlands	Did not participate
New Zealand	Participated
Norway	Participated
Poland	Participated
Portugal	Did not participate
Slovak Republic	Participated
Slovenia	Participated
Spain	Participated
Sweden	Did not participate
Switzerland	Participated
Türkiye	Did not participate
United Kingdom	Participated
United States	Participated

Country	Participation in the policy survey
Bulgaria	Participated
Brazil	Did not participate
Croatia	Participated
Peru	Did not participate
Romania	Did not participate

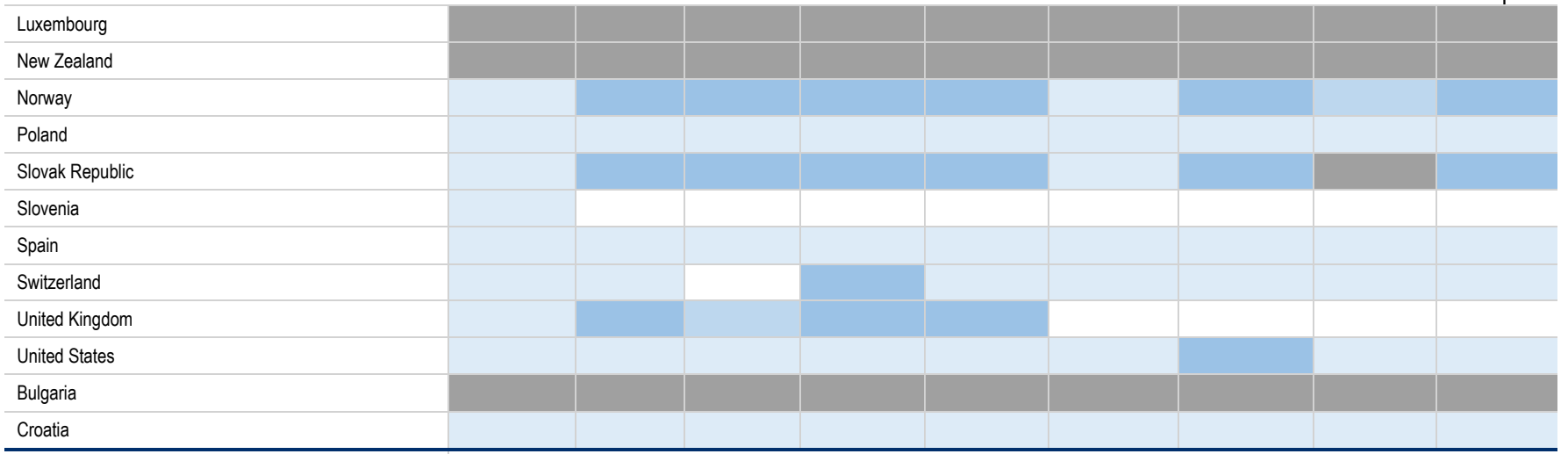
Annex 5.B. Community-based IPC Implementation Dashboard

Annex Table 5.B.1. Dashboard on the implementation of policy options to promote community-based IPC programmes in OECD Member and Accession countries

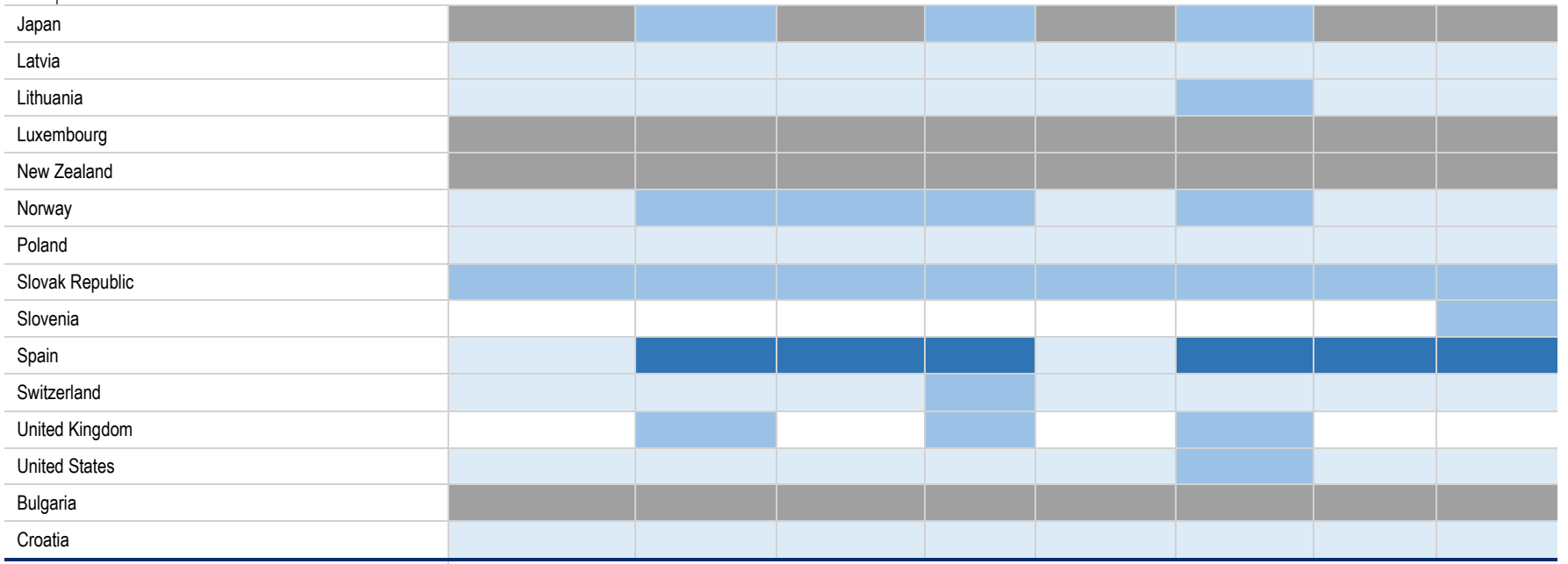
Panel A	Improving Hand Hygiene								
OECD Member countries and Accession countries	Free-of-charge handwashing materials	Mass media campaigns	Educational activities targeting the community	Free-of-charge informational materials	Visual cues	Text reminders	Free-of-charge phone lines/websites	Engage with relevant stakeholders and empower local communities	Involve independent experts, scientists, and credible public figures
Australia									
Austria									
Canada									
Colombia									
France									
Germany									
Greece									
Israel									
Italy									
Japan									
Latvia									
Lithuania									
Luxembourg									
New Zealand									
Norway									



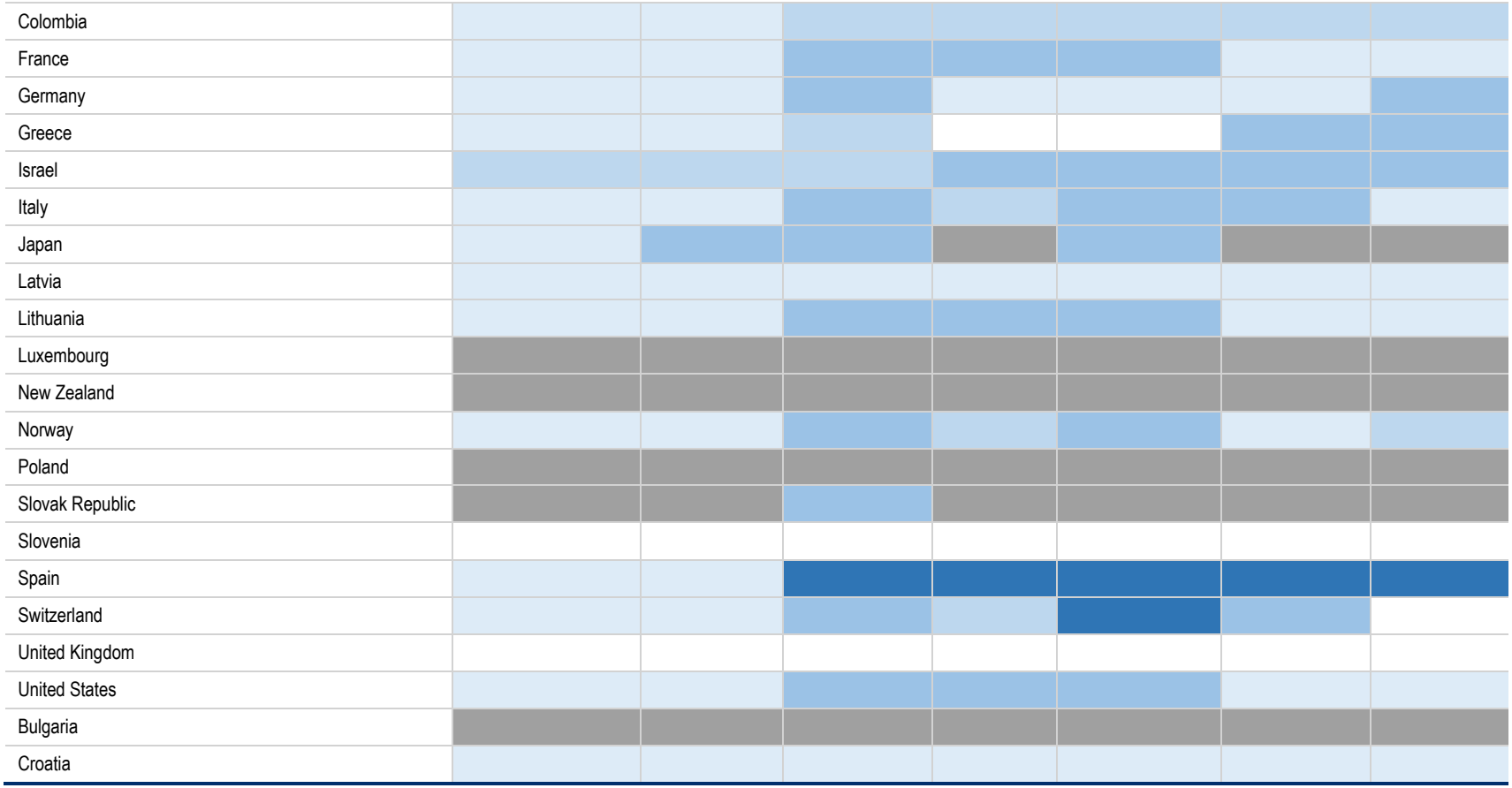
Panel B	Mask wearing practices								
OECD Member countries and Accession countries	Free-of-charge masks/face coverings	Mass media campaigns	Educational activities targeting the community	Free-of-charge informational materials	Visual cues	Text reminders	Free-of-charge phone lines/websites	Engage with relevant stakeholders and empower local communities	Involve independent experts, scientists, and credible public figures
Australia									
Austria									
Canada									
Colombia									
France									
Germany									
Greece									
Israel									
Italy									
Japan									
Latvia									
Lithuania									



Panel C	Respiratory etiquette							
OECD Member countries and Accession countries	Promote cashless/contactless payment systems in stores	Mass media campaigns	Educational activities targeting the community	Visual cues	Text reminders	Free-of-charge phone lines/websites	Engage with relevant stakeholders and empower local communities	Involve independent experts, scientists, and credible public figures
Australia								
Austria								
Canada								
Colombia								
France								
Germany								
Greece								
Israel								
Italy								



Panel D	Indoor ventilation						
OECD Member countries and Accession countries	Distribute free of charge portable air filters, including HEPA filters	Financial incentives to promote the purchase of portable air filters, including HEPA filters	Encourage natural ventilation in indoor spaces	Encourage regular maintenance and/or redesign of mechanical ventilation systems in public and private buildings	Develop guidelines and recommendations focussing on best practices in indoor ventilation	Engage with relevant stakeholders and empower local communities	Involve independent experts, scientists, and credible public figures
Australia							
Austria							
Canada							



Note: HEPA = High efficiency particulate air.
No plans for implementation
Activities/programmes were implemented at the regional/sub-national level
Activities/programmes were implemented at the national level
Implementation of activities/programmes at national level were fine-tuned/modified based on monitoring and evaluation activities
Unsure/Other
No answer
Source: Country self-assessment responding to the 2023-2024 OECD survey on Maintaining Infection Prevention and Control Measures in the Community.

Annex 5.C. List of influenza pandemic preparedness plans from G7 countries included in the OECD analysis

Annex Table 5.C.1. List of national influenza pandemic preparedness plans reviewed by the OECD

Country	Pandemic preparedness plan
Canada*	Canadian Pandemic Influenza Preparedness: Planning Guidance for the Health Sector
France	Plan national de prévention et de lutte "Pandémie grippale" 2011 Recommandations Sanitaires Generales Dans Le Cadre De La Lutte Contre Les Maladies Respiratoires Hivernales Et Le Covid-19
Germany	Nationaler Pandemieplan Teil I Strukturen und Maßnahmen Wissenschaftlicher Teil des Nationalen Influenza-Pandemieplans (Teil II)
Italy	Italy 2020 Piano strategico-operativo nazionale di preparazione e risposta a una pandemia influenzale (PanFlu) 2021-2023
Japan	新型インフルエンザ等対策政府行動計画
United Kingdom	UK Influenza Pandemic Preparedness Strategy 2011
United States	National Strategy for Pandemic Influenza Implementation Plan

Note: *The Public Health Agency of Canada has been developing Canada's Pandemic Preparedness Plan 2026-2027 to ensure the country is ready to respond to future pandemics. The plan is being produced in collaboration with provinces and territories; First Nations, Inuit and Métis partners and pandemic preparedness experts. It sets out a flexible framework and a harmonised approach to pandemic preparedness across the federal, provincial and territorial health sector. It concentrates on respiratory pathogens with pandemic potential. Canada reports that the technical components of the plan, which will become available throughout 2027, will be closely linked to the World Health Organization's Preparedness and Resilience for Emerging Threats framework, with five components: Emergency Co-ordination, Collaborative Surveillance, Community Protection, Clinical Care, and Access to Countermeasures.

Notes

[1] In this chapter, community settings include households, public settings (e.g. schools, public transport) and private settings and exclude settings where healthcare is routinely delivered (e.g. healthcare centres, clinics and hospitals). Long-term care facilities are also excluded.

[2] Respiratory etiquette refers to the practice of covering one's mouth and nose when sneezing or using a tissue or elbow after sneezing.

[3] Asymptomatic infection refers to an infection in which the infected person does not develop symptoms, despite being infected and often capable of transmitting the pathogen.

[4] Presymptomatic infection refers to an infection in a person who will go on to develop symptoms, observed during the interval between acquisition of the pathogen and the onset of those symptoms.

[5] Sub-clinical infection refers to an infection that does not produce illness recognisable on clinical examination either because signs are absent or because they are too mild or atypical to meet a clinical case definition.

6 Learning from COVID-19 to improve pandemic preparedness indices for future health crises

This chapter evaluates the role of pandemic preparedness and response indices in appraising global readiness for health crises, with particular attention to the gaps exposed by COVID-19. It starts by providing a detailed analysis of six of the most commonly used preparedness indices, including their strengths and weaknesses. It then assesses their ability to predict performance, measured using percentage changes in life expectancy between 2019 and 2021, for 51 OECD, European Union/European Economic Area, and Group of 20 countries. The resulting analysis allows to determine which indices most accurately reflected actual preparedness and performance. The chapter also emphasises the importance of considering social, economic, and institutional vulnerabilities in preparedness indices, which are often overlooked but have a significant impact on pandemic response. The chapter concludes with recommendations for improving these indices to improve future pandemic preparedness and response.

In Brief

Key messages

Pandemic preparedness and response are essential public health functions

- Given the global public health threat posed by pandemics, it is crucial to improve pandemic preparedness and response. Pandemic preparedness and response encompass actions aimed at effective readiness for responding to disease outbreaks, focussing on prevention policies, and mitigation programmes to minimise susceptibility to risks.

Indices are a useful tool to evaluate a country's preparedness for pandemics, reflecting response capacities and pandemic impacts

- To better prepare for future health threats, it is important to assess how well countries can detect and respond to outbreaks.
- Indices enable countries and decision makers to identify capacity strengths and weaknesses, benchmark against other countries and efficiently allocate resources, maintain transparency and accountability. Further, they help to detect early threats, advance policy development, and foster global health security and strengthen international collaboration, since pandemics cannot be managed only at the national level.

The COVID-19 pandemic revealed that there are still gaps and indices have not managed to fully capture the key dimensions of preparedness

- An assessment of six widely used pandemic preparedness and response indices developed pre-pandemic highlight that most indices are biased in favour of countries with more resources and certain characteristics, including political systems and trust, specific cultures and demographic attributes. This lack of contextualisation and inability to account for dynamic response capabilities creates biases in benchmarking. Further, existing indices are likely founded on lessons learned from past pandemics and are subject to data constraints that likely affect reporting. Also, indices often leave out essential political and governance issues.
- The States Parties Annual Report (SPAR) and Infectious Disease Vulnerability Index (IDVI) indices showed stronger correlations with changes in life expectancy during COVID-19 compared to the INFORM Risk Index and the Epidemic Preparedness Index (EPI), largely due to their focus on factors directly relevant to managing infectious disease outbreaks (public health communication, adhering to international health regulations (IHR) and addressing structural vulnerabilities).

During the COVID-19 pandemic, countries with higher social vulnerability faced increased mortality rates

- Measuring population vulnerabilities is crucial for understanding how underlying risks and weaknesses influence a country's pandemic preparedness and response. Measures of vulnerability against disasters encompass health, economic, social, institutional, or deferential, and cognitive or communicative dimensions. Understanding the indicators of vulnerability can help policymakers better manage pandemics in these communities.

While some preparedness indices failed to predict certain outcomes of the COVID-19 pandemic, they remain crucial for international benchmarking

- There are a range of ways to strengthen indices for future pandemics. For example, future indices should include fixed characteristics of countries and a range of population vulnerabilities. Future indices should also include sociopolitical and governance variable as they have a large effect on outcomes during a pandemic. Other characteristics that should be highlighted include aspects related to international collaboration and the inclusion of biological and environmental risks. Finally, it is essential that the capacity to mobilise rapidly is included due to the dynamic nature of pandemics.

6.1. The importance of pandemic preparedness and response

Pandemic preparedness and response is an essential public health function that address the actions needed to ensure effective readiness for disease outbreaks (Fatiregun and Isere, 2017[1]). Broadly, pandemic preparedness and response is defined as "having the knowledge, capacities, and systems that work to reduce vulnerability and enhance resilience" (World Health Organization, 2023, p. ix[2]). Pandemic preparedness and response enables countries to focus more effectively on prevention policies and mitigation programmes, thereby minimising their susceptibility to threats. It also involves the government's ability to anticipate (and mitigate) a potential global public health emergency by developing necessary knowledge and capacities. This includes everything from the comprehension of the hazards, the building of capacities for risk foresight and assessment, and the establishment of risk management protocols (OECD, 2022[3]).

Pandemic preparedness and response indices are used to identify deficits in preparedness. Over the years, many indices have been developed to measure how health systems and countries are able to respond to pandemics. Each pandemic preparedness and response index measures various aspects of a country's ability to effectively combat the pandemic and protect their citizens, though indicators used in each index often vary. Pandemic preparedness and response indexes identify strengths and gaps, which in turn, can help guide how resources are allocated and policies are developed, support accountability mechanisms, and enhance global health security.

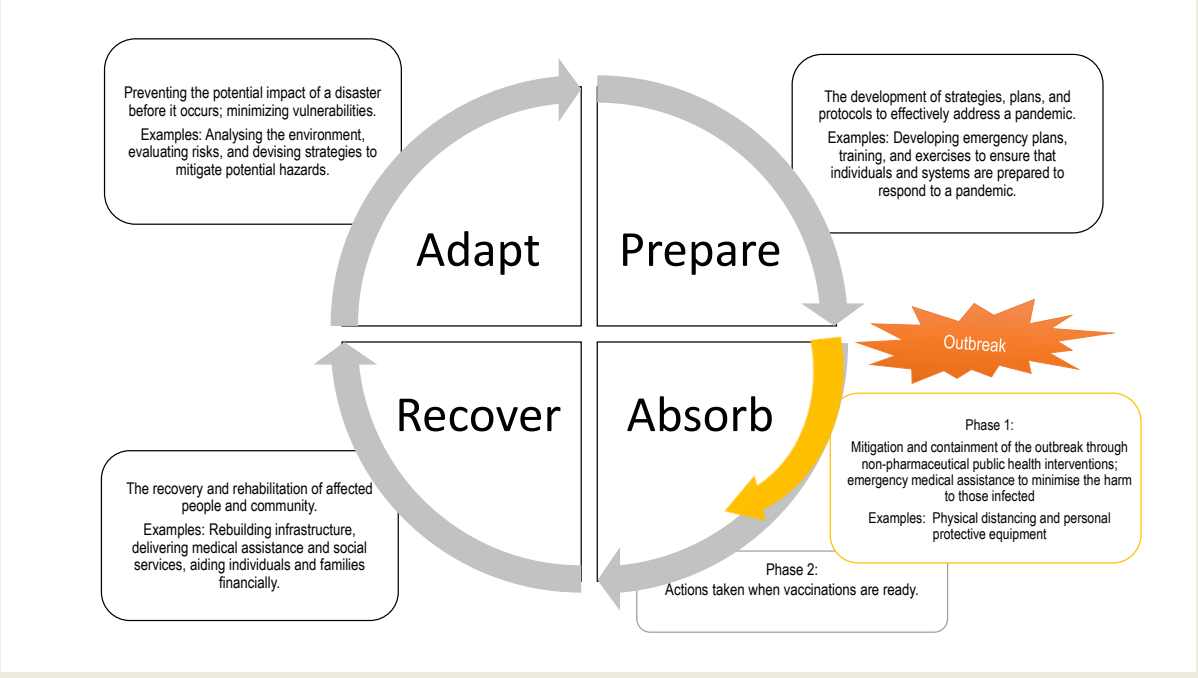
However, the COVID-19 pandemic revealed that there are still gaps and indices have not managed to fully capture the key dimensions of preparedness. Despite high rankings, many countries experienced severe COVID-19 burdens, highlighting gaps in our understanding of why these indices failed to provide accurate assessments. There is a need to strengthen indices for future pandemics, which requires an examination of the factors they overlooked, such as population vulnerabilities and intangible aspects like public trust and perception during a health crisis.

Pandemic preparedness and response indexes are often structured around cycles of disruption, each phase representing distinct preparedness activities and responses (Box 6.1). This chapter focusses on the early phases of an emerging epidemic outbreak. The first stage (Figure 6.1), "prepare" involves a government's ability to anticipate and ready itself for a potential pandemic, building knowledge and creating risk management protocols for sectors like the pharmaceutical industry (OECD, 2022[3]). Following an outbreak, the "absorption" stage begins, where governments actively respond to the crisis. This stage aims to reduce the impact on public health, welfare, and the economy. During the early absorption phase, governments implement non-pharmaceutical interventions (NPIs) like lockdowns, school closures, and workplace adjustments to slow the virus's spread, until vaccines become available to the public (OECD, 2023[4]).

Box 6.1. A resilience framework is utilised as a starting point to understand a country's ability to deal with shocks, such as pandemics

Resilience goes beyond crisis preparedness; it enables systems to absorb shocks and recover swiftly. The disruption cycle aligns with the resilience framework, offering a structured approach to understanding the impact of events like pandemics on systems and communities. This cycle includes four stages – prepare, absorb, recover, and adapt – and highlights the importance of proactive over reactive measures (Figure 6.1). Pandemic preparedness and response indices, developed alongside resilience frameworks, aim to assess how well countries can respond to these stages in the event of a crisis. This framework captures the range of resilience activities, enabling the assessment of strengths and weaknesses in pandemic response. Each phase involves specific actions, such as planning and capability enhancement in preparedness, and risk mitigation in adaptation. Effective indices should therefore evaluate the impact of policies across all phases of the disruption cycle. (The recent OECD report, "Ready for the Next Crisis? Investing in Health System Resilience" (2023[4]) provides more detailed information on the OECD resilience framework).

Figure 6.1. Pandemic preparedness and response indices are often based on the disruption cycle



Note: The examples shown in the figure are illustrative rather than exhaustive and may vary according to the characteristics of the outbreak and the wider context.

Source: Adapted from Kachali et al. (2022[5]), *Are preparedness indices reflective of pandemic preparedness? A COVID-19 reality check,* https://doi.org/10.1016/j.ijdrr.2022.103074; Kentikelenis and Seabrooke (2021[6]), *Organising knowledge to prevent global health crises: a comparative analysis of pandemic preparedness indicators*, http://doi.org/10.1136/bmjgh-2021-006864; Fakhruddin, Blanchard and Ragupathy (2020[7]), *Are we there yet? The transition from response to recovery for the COVID-19 pandemic,* https://doi.org/10.1016/j.pdisas.2020.100102; OECD (2023[4]) *Ready for the Next Crisis? Investing in Health System Resilience,* https://doi.org/10.1787/1e53cf80-en; OECD (2022[3]). First lessons from government evaluations of COVID-19 responses: A synthesis, https://doi.org/10.1787/483507d6-en.

The increasing risk of pandemics underscores the need to better understand pandemic preparedness and response and develop relevant policy indicators (Jeanne et al., 2023[8]; Oppenheim et al., 2019[9]). The risk of pandemics has risen due to globalisation, environmental degradation, urbanisation, and increased human-wildlife interaction. Globalisation accelerates disease spread through increased travel, trade, and livestock farming, while factors like population growth and climate change are expected to further exacerbate the threat (please see the OECD publication on environmental health and strengthening resilience to pandemics (2023[4]) for more information). COVID-19 had a profound global impact, and it serves as a reminder of the potential for future pandemics.

Acknowledging these gaps, this chapter begins by explaining the importance of pandemic preparedness and response indices, detailing how they function and their significance. Then, this chapter provides an in-depth review of six indices that were developed before COVID-19, designed to compare general preparedness across multiple dimensions globally. These indices are evaluated based on their ability to predict performance, measured by the percentage change in life expectancy from 2019 (pre-COVID-19) to 2021 (post-initial-COVID-19 impact). Rather than ranking countries, the focus is on identifying which indices most accurately reflect pandemic performance, a critical factor in assessing preparedness. This chapter also explores indicators used to evaluate vulnerability within pandemic preparedness and response frameworks, highlighting their strengths and limitations. Special focus is given to how these indices capture social, economic, and institutional vulnerabilities, which significantly affect outcomes but are often overlooked. Next, the chapter explores indicators used to evaluate vulnerability in the context of pandemic preparedness and response and concludes by identifying areas for improvement and offering recommendations for enhancing pandemic preparedness and response.

6.2. A guide to pandemic preparedness and response indices: What they are, how they work and why they matter?

6.2.1. Why and how is a country's ability to respond to an emerging pandemic measured?

Assessing a country's ability to prepare helps identify gaps in healthcare and public health systems and evaluate its capacity to quickly detect, contain, and mitigate the spread of epidemics. This ensures timely and effective responses, reduces the impact on public health and the economy, and strengthens global efforts to prevent future outbreaks. By understanding these capabilities, governments can develop policies to improve resilience and readiness for future pandemics. Specifically, well-designed and effective pandemic preparedness and response indices can support decision makers by helping them to:

- **Detect early threats and allocate resources effectively**: Help countries improve ability to detect and respond to emerging threats, enabling more effective disease control (Brainard et al., 2023[10]). Indexes may also provide governments, international organisations and nongovernmental organisations (NGOs) a means to prioritise resource allocation for pandemic preparedness and response initiatives (Ravi et al., 2020[11])**.**
- **Benchmark against other countries and promote accountability**: Allow countries to measure their preparedness against global standards and compare their performance with other countries (Brainard et al., 2023[10]), promoting the sharing of best practices and collaboration in pandemic response (Goniewicz et al., 2023[12]). This standardised framework would also promote governments' accountability for their preparedness efforts (Falk et al., 2023[13]), with transparency being essential to maintaining public trust in government and public health authorities (Grabar-Kitarović and Phumaphi, 2023[14]). Further, benchmarking allows countries to identify strengths and weaknesses in their capacities to advance policy development. Provide a framework for evaluating a country's ability to prevent, detect, and respond to pandemics. Through the assessment of

diverse indicators, indices facilitate the identification of both strengths and areas requiring enhancement within a country's public health infrastructure (World Health Organization, 2023[15]).

- **Contribute to global security and collaboration**: Promote the exchange of best practices, lessons, and resources among nations to collectively strengthen global health security (Ravi et al., 2020[11]). Also promote international exchange of experiences and collaboration by establishing a common language and framework for discussion (Jit et al., 2021[16]).

Effective pandemic preparedness and response and response efforts require an understanding of how communities and systems are structured in relation to disease transmission and the specific vulnerabilities of different populations. Since the replacement of the World Health Organization's (WHO) International Health Regulations (IHR 1969) in 2005 (enforced from 2007), significant efforts have been made to quantify overall risks and evaluate the vulnerabilities of diverse populations at national, regional, and global scales (Box 6.2). For example, following the commencement of the IHR, countries were required to annually self-report their compliance with the IHR using the online IHR Monitoring Tool (IHRMT), with the outcomes of these evaluations documented in the States Parties Annual Report (SPAR).

Box 6.2. The WHO's International Health Regulations provide a legal framework for the establishment of countries' pandemic preparedness and response strategies

Last updated in 2005, the WHO's International Health Regulations (IHR) serve as a legal framework aimed at preventing, protecting against, controlling, and responding to the international spread of epidemic diseases and management of emergencies. The IHR mandates countries to establish preparedness plans for public health crises and regularly assess and update them. Effective preparedness plans require not only technical and expert guidance, but also clear legal and governance arrangements that enable timely activation of response measures, including well-defined decision-making processes and responsibilities across relevant authorities. The IHR is the sole international legal treaty empowering the WHO to function as the primary global surveillance system.

The IHR can be utilised to evaluate a country's readiness for pandemics, with countries required to annually self-report their compliance with the IHR using the online IHR Monitoring Tool (IHRMT). Countries report on eight core capacities, encompassing legislation, policy, co-ordination, surveillance, response, preparedness, risk communication, human resource capacity, and laboratory capabilities, across four hazard categories: zoonotic events, food safety events, chemical events, and radiation emergencies. The outcomes of these evaluations are collected in the States Parties Annual Report (SPAR) and/or the Joint External Evaluation (JEE) Tool, both discussed later in this Chapter.

There are challenges inherent in implementing the IHR and managing disease outbreaks on a global scale. One factor contributing to these challenges is resource constraints, as the IHR requires member states to have the necessary resources for prompt detection, assessment, notification, and reporting of disease outbreaks, yet many states lack these resources, resulting in delays in response and increased risk of uncontrolled spread. Additionally, there exists a significant imbalance in costs and benefits between the state where the outbreak originates and other states, with the affected state bearing the burden of allocating resources to comply with IHR surveillance requirements and combat the disease, potentially leading to adverse economic consequences such as decreased tourism and international trade; however, successful containment of the disease within the affected state benefits all other states.

Source: World Health Organization (2022[17]) *Joint external evaluation tool: International Health Regulations (2005), third edition,* https://www.who.int/publications/i/item/9789240051980; Sohn et al. (2021[18]), *The problems of International Health Regulations (IHR) in the process of responding to COVID-19 and improvement measures to improve its effectiveness*, https://doi.org/10.35500/jghs.2021.3.e18; Broberg (2020[19]), *A Critical Appraisal of the World Health Organization's International Health Regulations (2005) in Times of Pandemic: It Is Time for Revision*, http://doi.org/10.1017/err.2020.26

6.2.2. Pandemic preparedness and response indices are important to understand national health security

Pandemic preparedness and response are most often measured with indices that assess, compare, and are intended to enhance a country's ability to combat disease outbreaks. Numerous institutional and academic indices have emerged to gauge a country's pandemic preparedness and response, reflecting response capacities and pandemic impacts, and serving as tools to assess and enhance readiness. These indices facilitate the evaluation of national health security and help to bolster international capabilities in pandemic response. In this chapter, six indices are evaluated, including the: Epidemic Preparedness Index (EPI), Global Health Security Index (GHSI), Infectious Disease Vulnerability Index (IDVI), INFORM Risk Index, Joint External Evaluation (JEE) and the IHR State Party Self-Assessment Annual Report (SPAR). Note that although the INFORM Risk Index was not originally designed to measure pandemic preparedness and response, it was quickly adapted for this purpose and became widely used during the COVID-19 pandemic; it is therefore included in this chapter. The included indices were developed prior to the COVID-19 outbreak, enabling international comparisons and assessing general preparedness across multiple dimensions, rather than focussing on a single aspect. A summary of all mentioned indices is provided in Table 6.1. In the EU context, other relevant tools also exist, including the Public Health Emergency Preparedness Assessment (PHEPA), carried out by the European Centre for Disease Prevention and Control under Regulation (EU) 2022/2 371 and drawing partly on the SPAR questionnaire.

Table 6.1. Pandemic preparedness and response indices are used to assess and benchmark the health security capacities of a country

Name	Purpose	Start (frequency)	Method of evaluation	Owner	Categories
Epidemic Preparedness Index (EPI)	Measures a country's capacity to detect and respond to infectious disease events	2019 (n/a)	Secondary data: Open source	Academics (New York University) United States	Public health infrastructure, Physical infrastructure, Institutional capacity, Economic resources, Public health communication
Global Health Security Index (GHSI)	Assesses and benchmarks health security capabilities	2019 (every 2 years)	Secondary data: Open source	Nuclear Threat Initiative (NTI), Johns Hopkins Centre for Health Security, Economist Intelligence Unit (EIU) United States	Prevention, Detection and reporting, Rapid response, Health system, Compliance with international norms, Risk environment
Infectious Disease Vulnerability Index (IDVI)	Detects the most vulnerable countries to infectious disease epidemics	2016 (n/a)	Secondary data: Open source	Research and Development Corporation (RAND), United States	Demographics, Healthcare, Public health, Disease dynamics, Political domestics, Political-international, Economics
INFORM Risk Index	Assesses national and community-specific vulnerabilities and risks to threats	2017 (annually)	Self-reported	European Union (EU) European	People at risk, Vulnerability, Lack of coping capacity

Name	Purpose	Start (frequency)	Method of evaluation	Owner	Categories
IHR Joint External Evaluation (JEE)	Assesses the capacity of a country in preventing, detecting and responding to public health events	2016 (every 4-5 years)	Self-reported from country surveys and expert evaluation	World Health Organization (WHO) under IHR International	Prevent, Detect, Respond, IHR-related hazards and POE and border health
IHR State Party Self-Assessment Annual Report (SPAR) *	Help countries monitor their progress in developing the required public health capacities	2010 (annually)	Self-reported from country surveys	World Health Organization (WHO) under IHR International	Legislation and financing, IHR co-ordination and NFP functions, Zoonotic events and the human-animal interface, Food safety, Laboratory, Surveillance, Human resources, National health emergency framework, Health service provision, Risk communication, POE, Chemical events, Radiation emergencies

Notes: * The second edition of SPAR was released in 2021, featuring 15 capacities and 35 indicators, compared to 13 capacities and 24 indicators in the first edition. As this table is used to demonstrate the performance of the indices prior to COVID-19, the first edition of the tool is reported. IHR = International Health Regulations; POE = Points of entry; NFP = National IHR Focal Point – Contacts designated by each State Party serve as the national centre for IHR communications with the WHO IHR contact points. Indicators regarding points of entry may indicate a collaborative plan or agreement between the public health system and border control authorities to identify suspected and potential cases among international travellers, as well as to trace and quarantine their contacts during a public health emergency (World Health Organization, 2022[17]).

Source: Oppenheim et al. (2019[9]), *Assessing global preparedness for the next pandemic: development and application of an Epidemic Preparedness Index*, http://doi.org/10.1136/BMJGH-2018-001157; Ravi et al. (Ravi et al., 2020[11]) The value proposition of the Global Health Security Index, http://doi.org/10.1136/bmjgh-2020-003648; Moore et al. (2017[20]) *Identifying Future Disease Hot Spots: Infectious Disease Vulnerability Index*, www.rand.org/t/RR1605; Inter-Agency Standing Committee and European Commission (2024[21]), *INFORM REPORT 2024: 10 years of INFORM,* https://data.europa.eu/doi/10.2760/555548; World Health Organization (2022[17]), *Joint external evaluation tool: International Health Regulations (2005), third edition,* https://www.who.int/publications/i/item/9789240051980; World Health Organization (2021[22]), *International Health Regulations (2005): States Parties Self-assessment annual reporting tool, second edition,* https://www.who.int/publications/i/item/9789240040120; World Health Organization (2018[23]), *International Health Regulations (2005): Guidance document for the States Parties self-assessment annual reporting tool,* https://www.who.int/publications/i/item/9789240040120.

Different methods of assessing preparedness have their strengths and limitations. Three of the six methods use third-party evaluations rather than solely relying on a country's self-assessment, which can reduce bias in reporting. For example, the GHSI uses secondary data from national reports and global databases to evaluate policy and healthcare system readiness (methodology details are in Annex 6.A). Similarly, the WHO's Framework for Economic Vulnerabilities and Risks to Pandemics (FEVR) measures economic resilience post-pandemic (see Box 6.3). Methods like the JEE, which involve external evaluations and use open-source data, support transparency and inter-country data sharing (detailed in Annex 6.B). While such assessments provide contextual insights and credibility to the assessment, they are often time- and resource-intensive (Oppenheim et al., 2019[9]). In contrast, indices based on self-reported data can be susceptible to information bias, as countries may interpret survey questions differently due to cultural differences or unclear wording, potentially affecting data accuracy and validity.

Box 6.3. Leading international organisations created a framework to assess the economic and health vulnerabilities associated with pandemics

In October 2021, the G20 established the Joint Finance and Health Task Force (JFHTF) to strengthen global co-ordination between finance and health sectors for pandemic prevention, preparedness, and response. The initiative also aimed to assess health, social, and economic vulnerabilities associated with pandemics. To achieve this, the Task Force, in collaboration with the WHO, World Bank, IMF, and European Investment Bank, developed the Framework for Economic Vulnerabilities and Risks (FEVR). FEVR integrates data across health, social, and economic domains to support policy dialogue and guide investments in preparedness. Recently, a joint publication by the OECD, WHO, and World Bank applied this framework through integrated modelling, simulating pandemic scenarios to evaluate the impact of different response strategies and the benefits of investing in preparedness, drawing on experiences from COVID-19, Spanish flu, SARS, and swine flu. For more details, please refer to the source below.

Source: World Health Organization et al. (2023[24]), *Report on Economic Vulnerabilities and Risks to Pandemics and Potential Policy Measures*, https://g20.in/content/dam/gtwenty/gtwenty_new/document/aug_docs/2_new_G20_Report_FEVR_Paper2Report.pdf; OECD/WHO/The World Bank (2024[25]), Strengthening pandemic preparedness and response through integrated modelling, https://doi.org/10.1787/5f046115-en.

Pandemic preparedness and response indices employ diverse methodologies to assess a country's ability to prevent, detect, and respond to future pandemics. The six tools presented in Table 6.1 utilise a combination of secondary and self-reported data in their development. These indices vary in the number of categories used to evaluate pandemic preparedness and response, ranging from three in the INFORM Risk Index to seven in the GHSI and IDVI, and 15 in the SPAR. Comparison of the indices indicator by indicator was not possible given the high number, however, the indicators used to evaluate each index often overlapped. The six indices measured 11 "index themes" presented in Table 6.2, which were created to clarify and compare the aspects of preparedness each index covered. Main conclusions from Table 6.2 include:

- **The indices collectively cover common themes related to pandemic preparedness and response, with unique priorities across indices**. Pandemic preparedness and response indices collectively cover a broad spectrum of themes, with overlaps in core areas such as healthcare capacity, infrastructure, and response capabilities, including indicators like healthcare access, epidemiology workforce, and financing for pandemic response. Yet, each index, emphasises certain themes based on its unique focus and purpose. For example, the IDVI was developed to capture vulnerabilities within both health systems and populations, so it thoroughly covers vulnerable populations but may overlook aspects like public health communication.
- **Preparedness indices address common themes but vary in scope and depth, particularly in addressing vulnerable populations.** While pandemic preparedness and response indices share common themes, their scope and depth of coverage vary significantly, particularly regarding vulnerable populations and coping capacity. The GHSI, JEE, and SPAR are the most comprehensive, each covering 10 of the 11 index themes, respectively, including healthcare infrastructure, economic resources, risk communication, and surveillance, with substantial detail. However, the GHSI and JEE lack data on vulnerable populations and coping capacity, which considers understanding the at-risk groups and the assessment of their ability to handle crises. Indicators like literacy rates, refugee populations, undernourishment, and gender equality, which are crucial for understanding vulnerabilities, are often neglected. In contrast, the IDVI, with its narrower scope, excels at capturing health disparities and vulnerabilities.

- **Co-ordination and governance are key themes but are emphasised differently across indices.** Most indices strongly emphasise governance and political co-ordination, assessing national frameworks and legislative support for effective responses. However, the focus varies from local to national to international perspectives. The GHSI, IDVI, JEE, and SPAR assess compliance with international norms, particularly IHR-related hazards and border health. Compliance with international norms is understandably a priority for the JEE and SPAR, as both were developed by the WHO under the framework of the IHR. This is why they emphasise IHR standards, whereas other indices may focus more on domestic health capacities. Indicators used to evaluate this theme commonly include participation in international agreements, IHR reporting, and cross-border agreements. It is worth noting that indices less focussed on international compliance may excel in other areas. For example, INFORM, while placing less emphasis on international norms, is strong in evaluating biological and environmental risks beyond pandemics – an area less prioritised by EPI, GHSI, and IDVI.

Table 6.2. Preparedness indices measure a variety of public health themes

Index theme	EPI	GHSI	IDVI	INFORM*	JEE	SPAR	Explanation	Category examples	Indicator examples
Prevention and public health systems	✓	✓	✓	✓	✓	✓	Related to the broader healthcare framework that supports disease prevention and management; a strong public health system includes broader health capabilities.	Public health infrastructure, Health system, Prevention	Access to healthcare, Healthcare worker access to healthcare, Access to improved sanitation facilities source
Infrastructure and institutional capacity	✓	✓	✓	✓	✓	✓	"Physical infrastructure," referring to facilities; "institutional capacity," meaning organisational structures and resources, are essential for effective healthcare delivery.	Health services provision, Human resources, Physical infrastructure	Physician density, Hospital beds, Epidemiology workforce capacity
Economic resources and financing	✓	✓	✓	✓	✓	✓	Captures the financial and economic resources available to support pandemic preparedness and responsiveness.	Economic resources, Legislation and financing	Financing for emergency response, Public healthcare spending per capita
Public health risk communication	✓	✓			✓	✓	Includes communication strategies to be utilised during health emergencies. [1]	Public health communication, Risk communication	Public health systems communication, Risk communication planning, Internet users
Detection, reporting, and surveillance	✓	✓			✓	✓	Index captures the country's surveillance this allows for proper detection which should result in timely reporting.	Detection and reporting, Surveillance	Indicator and event-based surveillance and reporting systems, Transparency of surveillance data, Coverage and use of electronic health records
Response and rapid action		✓		✓	✓	✓	There is a focus on methods for rapid and optimal response to health crises.	Rapid response, Respond	Emergency response operation, Private sector involvement in response planning, Activating response plans
Vulnerable populations and coping capacity		✓	✓	✓			Index measures vulnerabilities of the population, acknowledging that vulnerable populations are often those with less coping capacity.	Vulnerability, people at risk	Literacy rates, Refugee population, Undernourishment, Gender equality
Compliance with international norms – IHR-related hazards and border health		✓	✓		✓	✓	These categories focus on IHR and border health measures such as the importance of monitoring POE for health risk.	Compliance with international norms, POE, IHR Co-ordination	Participation in international agreements, Official IHR reporting, Cross-border agreements
Biological/environmental (Zoonotic or human-animal interface)		✓		✓	✓	✓	Captures risks related to biological or environmental risks such as through zoonotic diseases.	Zoonotic events and human-animal interface, Laboratory	Biosafety training/practices, National planning for zoonotic diseases or pathogens, Animal health workforce

Index theme	EPI	GHSI	IDVI	INFORM*	JEE	SPAR	Explanation	Category examples	Indicator examples
Co-ordination and political legislation	✓	✓		✓	✓	✓	The index captures whether there are national efforts for co-ordination during pandemics, along with appropriate legislative functions, emphasising the importance of cohesive governance and political support in pandemic preparedness and response.	Political domestics, National health emergency framework	Government effectiveness, National public health emergency preparedness and response plan
Other emergencies (food borne, chemical and radiation emergencies)				✓	✓	✓	Index collects information on other types of emergencies that require similar preparedness and response mechanisms.[2]	Food safety, Radiation emergencies, Chemical events	Resources for detection and alert for chemical safety, Enabling environment in place for management of radiation emergencies

Note: 1. IDVI had communication strategies measured by number of televisions, cell phones and internet users, but not specifically for public health measures.
2. Human conflict was measured in the INFORM.
IHR = International Health Regulations; POE = Points of entry; NFP = National IHR Focal Point – Contacts designated by each State Party serve as the national centre for IHR communications with the WHO IHR contact points.
Source: See Table 6.1.

6.3. To what extent did pandemic preparedness and response indices reflect countries' "performance" during COVID-19?

Understanding which indices best predicted country performance during COVID-19 is crucial for improving preparedness for the next pandemic. This section compares indices to identify those that most effectively capture a country's ability to contain the detrimental effects of the pandemic on population health. Such an analysis is vital for preparing for future pandemics, as it identifies the crucial elements underpinning effective preparedness. The performance of the index is assessed by considering the per cent change in life expectancy from 2019 (pre-COVID-19) to 2021 (post-initial-COVID-19 shock). Changes in life expectancy were scaled to each country's baseline age expectancy, allowing for fair comparisons by reflecting the proportional impact of the pandemic. Life expectancy was chosen as the performance indicator because it captures both direct and indirect health impacts and due to its wide availability across countries. It reflects mortality from COVID-19 and the broader strain on healthcare systems, including effects on non-COVID-related health outcomes. Additionally, life expectancy accounts for longer-term consequences like excess deaths and health system resilience, offering a robust measure that supports the assessment of the indexes over multiple preparedness dimensions and is less influenced by data-reporting differences or testing capacity.

The goal was not to rank countries but to determine which indices most accurately captured pandemic performance. Fifty-one countries (OECD, EU/EEA, and G20 members) were ranked into quintiles for each index in Table 6.3. Rankings were normalised based on the total countries assessed in each index (e.g. GHSI and IDVI: 195 countries; INFORM: 191; SPAR: 175; EPI: 188; the JEE index was excluded due to limited comparability, as each country receives an individual report with scores assigned to specific technical areas rather than an overall ranking). This rank-based approach provided a clear view of relative performance, standardising differences across baseline health outcomes. As such, a country with a score of 1 on an index is in the highest quintile (lightest blue in Table 6.3), indicating it was predicted to be among the most prepared, while a score of 5 indicates the lowest quintile (darkest blue in Table 6.3), or least prepared. Note that the quintile rank is derived from the entire assessment, including countries not listed in the table as they fall outside the scope of this work. In Table 6.3, green shading denotes an average index score closer to 1 or a positive change in life expectancy (scaled to each country's baseline age expectancy) between 2019 and 2021, whereas red highlights a higher average score on indices or a negative change in life expectancy.

Table 6.3. Country rank varies by pandemic preparedness and response index

Countries	EPI	GHSI	IDVI	INFORM	SPAR	Average of indices	△ in Life Expectancy (%)
Argentina						2	-1.4%
Australia						1.2	0.5%
Austria						1.4	-0.9%
Belgium						1	-0.2%
Brazil						2.2	-1.5%
Bulgaria						2	-5.1%
Canada						1.2	-0.8%
Chile						1.6	0.5%
China						2	0.5%
Colombia						3.2	0.3%
Costa Rica						1.8	0.3%
Croatia						1.8	-2.4%
Cyprus						2	
Czechia						1.6	-2.7%

Countries	EPI	GHSI	IDVI	INFORM	SPAR	Average of indices	△ in Life Expectancy (%)
Denmark						1	0.0%
Estonia						1.4	-2.3%
Finland						1	-0.2%
France						1.4	-0.7%
Germany						1.2	-0.6%
Greece						2.2	-1.9%
Hungary						1.6	-2.9%
Iceland						1.4	0.0%
India						3	-0.7%
Indonesia						2.6	-2.2%
Ireland						1.4	-0.5%
Israel						1.6	-0.4%
Italy						1.2	-1.1%
Japan						1.2	0.1%
Latvia						1	-0.5%
Lithuania						1.6	0.4%
Luxembourg						1.6	0.0%
Malta						1.2	-3.1%
Mexico						2	0.0%
Netherlands						2.4	
New Zealand						1	0.3%
Norway						1.2	-1.0%
Peru						1	0.2%
Poland						3	0.2%
Portugal						1.6	-3.1%
Republic of Korea						1.2	-3.3%
Romania						2.2	-3.8%
Saudi Arabia						2.2	
Slovak Republic						1.4	-4.2%
Slovenia						1.2	-1.1%
South Africa						2.2	-0.6%
Spain						1	-0.8%
Sweden						1.2	-0.1%
Switzerland						1	-0.1%
Türkiye						2.8	0.0%
United Kingdom						1	0.0%
United States						1.4	-3.1%
Average	1.5	1.3	1.5	2.0	1.8		

Note: Changes in life expectancy were scaled to each country's baseline age expectancy to reflect the proportional impact of the pandemic in each setting. The rank of each country was based on data available closest to the pre-2020 period: EPI (August 2018), GHSI (October 2019), IDVI (September 2016), INFORM (2019), and SPAR (2019). A score of 1 indicates a country was in the highest quintile (lightest blue), reflecting the most preparedness, while a score of 5 represents the lowest quintile (darker blue), or least preparedness. The quintile rank is derived from the entire assessment, including countries not listed in the table as they fall outside the scope of this work. Green denotes an average index score closer to 1 or a positive change in life expectancy between 2019 and 2021, whereas red highlights a higher average score on indices or a negative change in life expectancy.

Source: See Table 6.1 for index sources; OECD (2023[26]), *Health at a Glance 2023: OECD Indicators*, https://doi.org/10.1787/7a7afb35-en.

While there is no clear relationship between the indices and average life expectancy change, most countries scored well, as shown by the lightest blue shade. Indices generally favour high-income countries, even when their performance does not align with their rankings. INFORM shows the most variation, ranking the 51 countries across all five quintiles, while SPAR covers the top four quintiles. On average, countries scored highest in the INFORM index and lowest in the GHSI, suggesting the GHSI ranked these countries

as more likely to perform well during the pandemic. To determine which index best predicted the per cent change in life expectancy across countries during the COVID-19 pandemic, two analyses were run. Firstly, the correlation between each index score and the per cent change in life expectancy was evaluated. Then, a regression analysis for each index to obtain R-squared values, which indicate the proportion of variance in life expectancy change explained by each index, was also computed. These two results are shown below in Table 6.4.

Table 6.4. Predictive strength of pandemic preparedness and response indices and per cent change in life expectancy

Metric	SPAR	IDVI	GHSI	EPI	INFORM
R-squared	0.189	0.088	0.020	0.019	0.003
Correlation Coefficient	-0.435	-0.297	-0.142	-0.137	0.057

Note: R-squared values indicate the extent to which changes in life expectancy are explained by each index. A higher R-squared value reflects a stronger ability of the index to predict changes in life expectancy. As such, the R-squared values in this table indicate the proportion of variance in life expectancy change explained by each index, with higher values reflecting stronger predictive power. Correlation coefficients describe the direction and strength of the relationship. Negative values indicate that countries ranked as better prepared (lower index scores) generally experienced smaller declines in life expectancy, while positive values suggest little or no meaningful relationship. EPI = Epidemic Preparedness Index), GHSI = Global Health Security Index, IDVI = Infectious Disease Vulnerability Index, JEE = Joint External Evaluation, SPAR = State Party Self-Assessment Annual Report.

Findings suggest that SPAR and IDVI were the most effective indices for predicting life expectancy outcomes during COVID-19, while the INFORM showed the weakest predictive power. Countries rated as more prepared by the SPAR and IDVI generally had better life expectancy outcomes, with per cent increases getting as high as 0.5% in certain countries Table 6.3. Note that the SPAR is a self-assessment instrument and as such results may be influenced by national reporting practices, including potential differences in interpretation and the risk of over- or under-reporting preparedness capacities. The SPAR showed the strongest relationship with life expectancy change, with an R-squared value of 0.189 (18.9%) and a correlation coefficient of -0.435 Table 6.4. The negative correlation indicates that countries with higher SPAR preparedness (i.e. scores closer to 1) generally experienced less decline or even improvement in life expectancy during COVID-19. This suggests that the SPAR index was relatively effective in predicting life expectancy impacts, with better-prepared countries (lower scores) seeing smaller declines or better outcomes. The IDVI also showed some predictive power, with an R-squared of 0.088 (8.8%) and a correlation coefficient of -0.297. While weaker than SPAR, the IDVI still showed that countries ranked as more prepared (scores closer to 1) tended to have less adverse changes in life expectancy. The INFORM index had the weakest predictive power for life expectancy changes during COVID-19, with an R-squared value of 0.003 (0.32%) and a correlation coefficient of 0.057, followed by EPI at 0.019 (1.9%) and correlation coefficient of -0.137. This indicates that INFORM 2019 explained almost none of the variation in life expectancy, suggesting it did not effectively capture aspects of preparedness relevant to these outcomes.

These results align with emerging evidence. A systematic review of nine studies (2020-2024) found that higher SPAR scores generally correlated with lower COVID-19 incidence and mortality, though some high-scoring countries still experienced severe outbreaks (Santalucia et al., 2025[27]). Similarly, regression analysis showed that higher SPAR and GHSI scores were associated with fewer cases and deaths, but only during the first eight weeks after a country's first case – particularly in smaller countries and those with stronger human resource capacities for pandemic preparedness and response (Duong et al., 2021[28]).

6.3.1. Which aspects of preparedness were most related to performance?

The SPAR and IDVI indices demonstrated stronger correlations with changes in life expectancy during COVID-19 compared to INFORM and the EPI, largely due to their focus on factors directly relevant to managing infectious disease outbreaks. SPAR captures aspects of countries' operational readiness – such as public health risk communication, disease detection and reporting, and compliance with international health regulations – which are important for limiting mortality and sustaining health system functionality during a pandemic. Similarly, IDVI reflects broader systemic resilience by incorporating socio-economic conditions, health system capacity, and governance stability. Although broader in scope than SPAR, these dimensions align with structural factors that influence pandemic outcomes. Together, these characteristics help explain the stronger observed association between SPAR and IDVI and life expectancy changes.

In contrast, INFORM and the EPI showed weaker correlations with life expectancy changes, albeit for varied reasons. While INFORM focusses on general disaster vulnerability and lacks health-specific metrics, the EPI primarily assesses national-level capacities like healthcare infrastructure, financing, and governance, which may not fully capture the operational readiness needed during a pandemic. INFORM's weaker association may be due to its broader scope and limited emphasis on public health-specific measures. Designed to assess general vulnerability to disasters, INFORM incorporates metrics such as exposure to natural hazards, conflict risk, and socio-economic inequality, which are less directly tied to pandemic-related outcomes. While INFORM includes vulnerability as a key component, its interpretation of vulnerability is less specific to health system fragility and operational preparedness. Unlike SPAR and IDVI, INFORM does not prioritise indicators related to disease surveillance, risk communication, or healthcare system preparedness – factors that were crucial for reducing mortality and maintaining population health during the pandemic. The EPI focusses on structural aspects of preparedness, such as healthcare systems and resources, but it does not fully consider real-time response capabilities, including rapid disease detection, outbreak tracking, or effective public communication – factors that were especially important during COVID-19. It also places greater emphasis on pre-existing capacities and may overlook how well countries adapted to the unique and evolving challenges of the pandemic. As a result, the EPI showed a weaker relationship with changes in life expectancy across countries. This highlights the importance of using indices that balance long-term preparedness with the capacity to respond quickly in a crisis.

Measuring vulnerabilities is crucial for understanding how underlying risks and weaknesses influence a country's pandemic preparedness and response. The IDVI does this well by looking at factors like income inequality, access to healthcare, and government stability, which all play a big role in how well a country can respond to health crises. These kinds of vulnerabilities help explain why some countries were hit harder by COVID-19 than others. Conversely, SPAR, INFORM and the EPI do not focus enough on these issues. INFORM looks broadly at disaster risks but doesn't include specific measures of healthcare access or inequalities that can worsen health outcomes during a pandemic. The EPI, while focussed on epidemic preparedness, mostly evaluates national-level systems like healthcare infrastructure but does not consider how vulnerabilities like poverty or regional differences can make some groups more at risk. SPAR also does not explicitly include themes surrounding vulnerabilities; the only indicator that ascertains any information regarding the topic is in the indicator on community engagement, where a question evaluates if there are any mechanisms for systematic community engagement in public health emergencies. By leaving out these important factors, SPAR, INFORM and EPI do not fully capture the challenges from population vulnerabilities that can affect a country's performance during a pandemic. This shows how important it is for preparedness measures to include a focus on vulnerabilities to get a clearer picture of risk and resilience. The next section delves into the importance of vulnerability during a pandemic.

6.4. The importance of understanding population vulnerability during a pandemic

6.4.1. What is vulnerability and why does it matter in the context of pandemic preparedness and response?

During the COVID-19 pandemic, countries with higher social vulnerability faced increased mortality rates. Vulnerable populations are broadly defined as groups of people who face exclusion and discrimination based on factors such as age, disability, race, ethnicity, gender, income level, migratory status, and those who are involved in conflicts or are stateless (Tan et al., 2023[29]). During pandemics, these groups face greater challenges in accessing healthcare facilities and implementing preventive measures like lockdowns, leading to increased vulnerability, higher infection risks, and greater community transmission. Therefore countries, especially those with higher social vulnerability indices, should be particularly concerned about the pandemic's impact on their most vulnerable populations.

Understanding the indicators of vulnerability can help authorities better manage pandemics in these communities. Identifying and categorising indicators of vulnerability help countries to establish appropriate pandemic prevention and mitigation programmes. Benchmarking regions based on these identified indicators is beneficial for recognising areas that are more vulnerable and have the potential to become pandemic hotspots. Consequently, policymakers can use this information to allocate resources based on needs, such as providing additional vaccines, medical personnel, and medications, to these vulnerable regions during their planning and decision making regarding pandemic planning.

6.4.2. How can we measure the vulnerability of populations to a new pandemic?

Measures of vulnerability against disasters encompass health, economic, social, institutional or deferential, and cognitive or communicative dimensions. Vulnerability arises from individual or group characteristics and conditions, including social inequalities, urbanisation, education, and income levels, which affect their ability to prevent, respond to, and recover from disasters. A 2023 study categorised the types of vulnerability in context of the COVID-19 pandemic into five categories: health, economic, social, institutional or deferential, and cognitive or communicative vulnerability (Table 6.5) (Tan et al., 2023[29]). These determinants highlight the complex interaction of various factors in a country that influence vulnerability. While there are a variety of indicators to measure vulnerable populations, less visible populations are often overlooked in pandemic preparedness and response plans (see Box 6.4).

Table 6.5. Measures of vulnerability against pandemics encompass a range of factors

Definitions, examples, and indicators used to measure the different types of vulnerabilities in a population

Vulnerability and definition	Examples	Example indicators to measure respective vulnerability
Health: Serious health conditions, lack of access to healthcare services, inadequate financial protection for health needs	Chronically ill individuals, terminally or seriously ill persons, indigenous people, migrant workers with poorer baseline health statuses, people living with comorbidities, people lacking access to healthcare services	- % population living with obesity, hypertension, diabetes - Health risk score - Percentage population (and children) without access to health insurance - Number of physicians per 1000 population
Economic: Income shocks induced by epidemics that can lead to sudden and systemic poverty.	Dependent persons, individuals in adverse employment conditions (unemployed, temporary, or part-time employment, migrant workers, etc.); those with adverse financial conditions; those lacking digital connectivity	- % living below poverty line - Gini income inequality index - Unemployment rate - Percentage population with access to internet and/or mobile phone

Vulnerability and definition	Examples	Example indicators to measure respective vulnerability
Social: Disadvantage in the distribution of accessing social goods and services	Populations living in poor-quality housing or overcrowded housing; socially isolated individuals; and populations vulnerable to violence (sex workers, domestic violence victims)	- % mobile homes - Population density or crowding - Number of houseless persons - Percentage households with electricity, piped water, sufficient water supply, sewage disposal
Institutional or deferential: Subjection to the formal authority of others or informal subordination.	Prisoners, institutionalised elderly, individuals in institutions, school-age children	- Population aged 18 and younger - Percentage persons in institutionalised group quarters such as prisons, nursing homes - Percentage of children living at school
Cognitive or communicative: Reduced capacity to understand and communicate effectively	Children, migrant populations, individuals with speech and/or hearing impairments, those struggling with communication due to low subjective well-being or poor mental health	- Illiteracy rate - Percentage of children where none of residents have completed primary school - Refugee or migrant populations - Percentage of households with a disability

Note: Indicators included in this Table serve as an example of commonly used indicators that could be used to capture the corresponding vulnerability and are not meant to be exhaustive or comprehensive.
Source: Fallah-Aliabadi et al. (2022[30]), *Social vulnerability indicators in pandemics focussing on COVID-19: A systematic literature review*, http://doi.org/10.1111/phn.13075; Tan et al. (2023[29]), Mitigating the impacts of the COVID-19 pandemic on vulnerable populations: Lessons for improving health and social equity, http://doi.org/10.1016/j.socscimed.2023.116007.

Box 6.4. While there are a variety of indicators to measure vulnerable populations, less visible populations are often overlooked

Most countries included *visible* vulnerable populations in their COVID-19 responses, but often neglected less visible and hidden populations in formal policy responses. Evidence from the COVID-19 pandemic suggests that countries prioritised visible vulnerable populations, i.e. measurable populations. This included the elderly population and groups based on health vulnerabilities, such as immunocompromised individuals (those living with asthma or diabetes, for example) and were a key focus in the early phase of COVID-19 vaccination plans. While health vulnerabilities were prominent during the pandemic, other intersecting vulnerabilities created far-reaching impacts on these populations. For example, less visible and hidden populations, such as migrant workers, refugees, sex workers, prisoners, and people with disabilities, were largely neglected in formal policy responses (Tan et al., 2023[29]).

A country's ability to account for its vulnerable populations is linked to its capacity to measure them, as well as the situation that the country was in prior to the pandemic. During the COVID-19 pandemic, some countries were better at accounting for these groups, while others were limited in this capacity. For example, the Centres for Disease Control and Prevention (CDC) in the United States has a comprehensive Pandemic Influenza Plan that includes considerations for vulnerable populations, such as those with underlying health conditions, the elderly, and disadvantaged communities. Additionally, the CDC and Agency for Toxic Substances and Disease Registry (ATSDR) developed the Social Vulnerability Index (SVI) to identify communities that may need support during emergencies. The SVI considers various social factors contributing to vulnerability, including socio-economic status, minority status, and housing. The SVI uses 16 U.S. census variables to help local officials identify communities that may need support before, during, or after disasters. However, though the United States had the mechanisms in place to measure vulnerable groups, COVID-19 exposed challenges within the health system in fully meeting the rising caseloads and health needs of those populations, particularly in areas with existing health inequalities.

While "hidden" populations are a heterogeneous group, some may be at greater risk during a pandemic. Migrant workers, for example, were greatly affected by COVID-19. This is because this group particularly those who earn low wages face higher risks due to precarious working and cramped living conditions. Additionally, restricted access to healthcare due to certain legal and policy restrictions within a country can increase transmission risks and adverse outcomes, as many migrants are excluded from national pandemic plans.

Source: Tan et al. (2023[29]), Mitigating the impacts of the COVID-19 pandemic on vulnerable populations: Lessons for improving health and social equity, http://doi.org/10.1016/j.socscimed.2023.116007; Molenaar (2022[31]), *Vulnerable groups in pandemic times: A cross-country synthesis of pandemic preparedness plans and evaluations of specific COVID-19 public health responses,* http://doi.org/10.13140/RG.2.2.36691.45606; CDC (2024[32]), *National Pandemic Strategy*, https://www.cdc.gov/pandemic-flu/php/national-strategy/index.html; ATSDR and CDC (ATSDR and CDC, 2024[33]), *CDC/ATSDR Social Vulnerability Index (CDC/ATSDR SVI): Overview*, https://www.atsdr.cdc.gov/placeandhealth/svi/index.html.

6.5. Room for development: What can be improved in pandemic preparedness and response indices?

Rankings and indices are supposed to show how well a country can handle a pandemic, but COVID-19 revealed that they were not accurate (Stoto, Nelson and Kraemer, 2023[34]). At the country level, health outcomes during the first wave of COVID-19 were primarily negatively correlated with the expected preparedness rank in the indices, such as those in Table 6.1. For instance, a country's rank on indices such as the INFORM and GHSI did not necessarily reflect how well country responded to and were affected by the pandemic.[1] The reasons for which the indices have not effectively predicted COVID-19 preparedness for many countries include:

- **Indices are biased in favour of countries with more resources and certain characteristics**: Indices generalise the situation across countries and overlook the diverse demographics, cultures, and political landscapes within them (Kachali et al., 2022[5]). Many indices lack contextualised or country-specific factors, such as political trust (Grabar-Kitarović and Phumaphi, 2023[14]). For instance, during the COVID-19 pandemic, countries ranked at the top were often similar in terms of development levels, primarily coming from high-income nations, which is clear also in Table 6.3. This high ranking could be attributed to a bias favouring countries with more advanced reporting systems, which are more prevalent in high-income countries, and only partially predict the ability of a country to respond to crises. It is important to point out that the inverse is not necessarily true; it is not that countries with lesser levels of income necessarily performed better during the pandemic. Instead, it highlights that the indices, in their current format, favoured attributes often present in health systems of countries with higher levels of income. Even the GHSI, which previous studies have deemed as a comprehensive evaluation with 140 items, has faced doubts about its validity and reliability. These concerns raise the possibility of miscalculations and misinterpretations (Kachali et al., 2022[5]).
- **Their lack of contextualisation and inability to account for dynamic response capabilities:** Many indices generalise conditions across countries, ignoring differences in demographics, cultures, political systems, and key factors such as political trust. Socio-economic issues, including inequality, public compliance with health measures, and population structure, are often inadequately captured. Furthermore, physical characteristics, such as whether a country is an island, its size, and its population density, significantly affect response to an emerging pandemic but are rarely incorporated into these evaluations. The ability of a country to adapt and respond to a pandemic as it unfolds is crucial but often overlooked. Dynamic response capability is a key determinant of pandemic preparedness and response since pandemics are inherently

unpredictable. They require constant adjustments in strategy, resources, and public health measures. As such, preparedness is not just about having strong systems in place but also about being able to react to new threats, update plans with fresh evidence, and act quickly. Indices that overlook this dynamicity risk miscalculating the strength of systems to innovate and adapt, like increasing testing capabilities or developing new treatments. As a result, indices fail to reflect the nuanced factors that determine a country's actual ability to manage pandemics.

- **Existing indices are likely founded on lessons learned from past pandemics:** The novel COVID-19 pandemic was exacerbated by factors such as the novel nature of the virus, asymptomatic transmission, and increased spread facilitated by globalisation. While previous indices have been developed based on lessons learned from past epidemics, these events often differed in terms of their severity, transmission dynamics, and impact (Bollyky et al., 2022[35]). For instance, some epidemics like severe acute respiratory syndrome (SARS) were successfully contained, while others like the 2009 H1N1 influenza had lower mortality rates. Additionally, the pace of transmission varied, with diseases like human immunodeficiency virus (HIV) spreading more slowly (Kachali et al., 2022[5]). Existing preparedness indices are not adequately updated to address the unique challenges of modern societies, particularly in the context of extensive air travel (Jeanne et al., 2023[8]). This lack of adaptation has contributed to disparities between rankings in indices and actual performance during the COVID-19 pandemic (Kachali et al., 2022[5]).
- **Data constraints affected reporting:** While the IHR requires WHO member countries to establish preparedness plans for public health crises and regularly assess and update them, not all member countries fully adhere for a breadth of reasons. Some countries face constraints in implementing recommendations due to limited resources or are hesitant to adapt systems following WHO's outbreak notifications due to potential economic losses (Kachali et al., 2022[5]). Additionally, some countries experienced challenges such as missing data or reporting lags, which may lead to an incomplete or inaccurate understanding of the situation, potentially overlooking crucial dimensions necessary for an effective response. Furthermore, retrospective data corrections and rapid changes to case definitions may occur, posing difficulties that cannot be easily addressed by data compilers but could have contributed to inaccuracies in the indices (Badker et al., 2021[36]).
- **Indices measure *only* what can be observed, leaving out political and governance issues**: Indices prioritise structural and measurable aspects of the health system, such as capacity, laboratory infrastructure, financing, surveillance, and emergency response operations. While these factors are important to measure, indices often lack robustness in assessing qualitative aspects that are hard to quantify but essential in pandemic preparedness and response. The COVID-19 pandemic highlighted the critical role that these governance-related measures (including trust, (mis)information, co-operation, and collaboration, but also response capacities, societal and community involvement, and whole-of-government co-ordination) play in effectively managing such crises; these attributes have influenced countries' capacity to prepare proactively, respond promptly, and achieve equitable recovery while safeguarding community public health. Neglecting these factors has contributed to the skewing of existing indices in favour of high-income countries. For more information on issues related to governance, please refer to the OECD Framework on drivers of public trust and the OECD's 2023 Trust Survey (OECD, 2024[37]; Brezzi et al., 2021[38]). Further, this has underestimated the significance of leadership and societal involvement in translating policy planning into action (Tan et al., 2021[39]).
- **Index questions do not accurately capture the ability of a country to scale up response and production of supplies**: Traditional indicators are based on data availability that may not adequately predict a country's preparedness for pandemics like COVID-19. While many indices include various health system and capacity indicators such as healthcare personnel, medical equipment, and access to care, COVID-19 demonstrated the limitations of relying solely on these measures (Kentikelenis and Seabrooke, 2021[6]). COVID-19 overwhelmed healthcare systems in

certain regions, leading to challenges in managing both COVID-19 and non-COVID-19 patients, which contributed to additional mortality. This highlights the importance of incorporating the ability to scale up the supply of resources into existing preparedness indices, which was not commonly included in indexes. Another example of this overlooked factor was the capability to ramp up production of masks and personal protective equipment (PPE), crucial components in the COVID-19 response, yet deficient in some countries (Kachali et al., 2022[5]).

Although standard preparedness indices failed to predict COVID-19 outcomes, it does not mean that they should be dismissed. Even if the theoretical level of a country preparedness did not correspond to the facts, and do not prevent countries from experiencing severe COVID-19-related consequences, this should not be a reason not to use indices as a guide. Instead, the experience with COVID-19 should prompt discussions on how to better understand and improve our capacity to measure preparedness for future pandemic responses. For instance, the COVID-19 pandemic underscored significant disparities in countries' preparedness infrastructures, directing attention to areas needing improvement. This underscores the importance of further investigating the development and enhancement of preparedness indices (Kachali et al., 2022[5]). Some suggestions for improving how indices are utilised and/or the data collected are discussed in the next section.

6.5.1. How can existing indices be strengthened for future pandemics?

During COVID-19, preparedness rankings failed to reliably predict countries' performance, exposing flaws in global pandemic response systems. Post-COVID-19 pandemic, it is crucial to reassess how preparedness is measured (Legido-Quigley et al., 2023[40]). Below are some frequently overlooked traits that could enhance future pandemic indices:

- **Take account fixed characteristics of countries:** Fixed-country characteristics such as greater geographic connectivity (i.e. the degree to which different locations or regions are connected to each other through various means of transportation, communication, or other networks), population age, income level, or limited experience in handling pandemics can elevate a country's risk level and therefore should be taken into account (Rose et al., 2021[41]). Ignoring these factors can bias our understanding of preparedness, as seen during COVID-19, where rankings often favoured high-income countries, raising questions about the adaptability and relevance of such frameworks in diverse contexts (Legido-Quigley et al., 2023[40])
- **Include a range of population vulnerabilities: COVID-19** has been a pandemic of inequality, hitting marginalised and disadvantaged people the hardest; inequality has played a big role in explaining why the pandemic affected people's lives and jobs so differently (Sirleaf and Clark, 2021[42]). As highlighted earlier in this chapter, including a wide range of vulnerability indicators – such as health, economic, social, institutional, and cognitive factors – can help policymakers identify and compare areas at greater risk. This allows them to allocate resources more effectively and create customised plans to prevent and manage pandemics. Targeted actions, like prioritising vaccine distribution, sending medical teams, and ensuring necessary supplies, can reduce inequalities and strengthen resilience against future pandemics.
- **Include sociopolitical and governance variables:** These factors, like social polarisation, political trust, social cohesion, and perceptions of corruption, have a big effect on extra deaths during the COVID-19 crisis. Many indices overlook important qualitative factors such as leadership, community engagement, at the national, regional, and international level. For example, during COVID-19, some leaders failed to take responsibility or create clear strategies to stop the spread of the virus, which was made worse by ignoring scientific evidence (Sirleaf and Clark, 2021[42]). Failing to adequately address intangible elements like building trust within societies or confidence in political leaders, which are challenging to measure and quantify, is essential (Legido-Quigley et al., 2023[40]). During COVID-19, strong political leadership was crucial to enforce pandemic

protocols and build trust in the government's response. Additionally, the levels of trust among people and in government institutions are essential because public health capacity alone is not enough if not effectively utilised (Rose et al., 2021[41]). The concept of trust in the context of a pandemic will be explored more in other chapters.

- **Include international collaboration in future indices:** Enhancing preparedness indices requires countries to collaborate more effectively, sharing resources and information to expedite decision making. Strengthening international collaboration entails improving the capacity to provide necessary services and supplies promptly, as well as reacting swiftly to circumstances such as implementing social distancing measures. While international co-operation is underscored in indices like the IHR and GHSI, challenges emerged during the initial phases of the COVID-19 response due to disagreements among experts and conflicting country interests. These aspects were not adequately factored into assessments of pandemic preparedness and response (Kachali et al., 2022[5]).
- **Adopt a One Health approach:** Most of the indices reviewed in this chapter include biological or environmental hazards as part of their assessment frameworks, but few fully capture the interconnected drivers of disease emergence. Population growth, land-use change, food production practices, and environmental degradation are accelerating the spread of new pathogens – most of which originate in animals and are amplified by human activity and global mobility. To address these risks, future preparedness assessments should adopt a comprehensive One Health perspective that that engages human, animal, and environmental health sectors to assess risk, support co-ordinated action, and respond effectively to emerging or re-emerging infectious diseases. This includes integrating animal health surveillance, environmental monitoring, and human-wildlife interface indicators, as well as strengthening co-ordination across relevant programme areas and domestic environmental agencies with the necessary technical expertise. Incorporating these dimensions would help identify emerging threats early and prevent spillover events. Effective pandemic planning therefore requires sustained cross-sectoral collaboration to operationalise the One Health approach (Sirleaf and Clark, 2021[42]).
- **Include capacity to mobilise rapidly:** Countries with poor pandemic preparedness and response often lacked the capacity to quickly mobilise resources and co-ordinate effectively between national and local level. This can result in inconsistent implementation of critical measures like testing, contact tracing, and vaccine distribution, while also straining healthcare systems and fostering public mistrust. Measuring and strengthening a country's capacity to quickly mobilise is essential to ensure a timely and co-ordinated response to fast-moving health threats, preventing unnecessary escalation and loss of life (Sirleaf and Clark, 2021[42]).

6.6. Conclusions

Pandemic preparedness and response are a critical public health function, but COVID-19 has revealed major gaps in how preparedness was assessed. While indices are designed to identify weaknesses, they often fail to address the full complexity of preparedness, particularly social vulnerabilities, and a country's ability to adapt and scale-up during health crises. As such, this chapter reviews six pandemic preparedness and response indices, highlighting their strengths and limitations. SPAR and IDVI showed stronger correlations with changes in life expectancy during COVID-19, while INFORM and EPI were less strongly associated. However, all indices shared common shortcomings: they often favoured wealthier countries, overlooked critical factors like governance and trust in institutions, and failed to account for public health communication and response capabilities or scalability.

Despite these issues, preparedness indices remain valuable tools for evaluating preparedness. To improve their effectiveness, future indices should incorporate fixed country characteristics, social vulnerabilities,

and political and governance factors. They should also include biological and environmental risks to reflect the realities of emerging health threats. By aligning preparedness measurements more closely with operational capacities, these tools can better support countries in building resilience to future pandemics.

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Annex 6.A. The Global Health Security Index (GHSI) utilises open-source data to benchmark a country's health security capacity

The GHSI, developed by the Nuclear Threat Initiative (NTI), Johns Hopkins Centre for Health Security, and the Economist Intelligence Unit (EIU), served as the first comprehensive health security capacity assessment of the member countries subscribed to the 2005 IHR. The GHSI is a benchmarking index, that serves as an objective tool for assessing countries on a national level annually. The GHSI employs a comprehensive multidimensional framework, comprising six categories: 1) Prevention of pathogen emergence or release; 2) Early detection and reporting of potential international epidemics; 3) Rapid response and epidemic spread mitigation; 4) Adequate health system infrastructure to treat the sick and protect health workers; 5) Commitments to enhancing national capacity, financing plans, and adherence to global norms; and 6) Overall risk environment and country vulnerability to biological threats. These categories encompass specific indicators and sub-indicators, measured using publicly available data and validated by external experts. Indicators include factors such as healthcare access, epidemiology workforce, disease surveillance systems, laboratory capacity, emergency response protocols, and compliance with international health regulations.

Annex Figure 6.A.1. GHSI employs a comprehensive multidimensional framework



Source: Economist Impact (2021[43]) *GHS Index Methodology*, https://ghsindex.org/.

Within these indicators are sub-indicators, with each sub-indicator incorporating data from multiple questions. For instance, "healthcare access" includes three sub-indicators: access to healthcare, paid medical leave, and healthcare worker access to healthcare. Each question (171 in total) receives a score based on predefined criteria. For example, for the question on guaranteed paid sick leave, a country that has paid sick leave would score a value of 2, whereas a country with unpaid sick leave would be assigned a value of 1, and a country without any would score a value of 0 for that question. These individual scores feed into sub-indicators (96), which then contribute to indicators (27), categories (6), and ultimately the final scores.

The GHSI assigns overall scores between 0 and 100 to each country, with higher scores indicating better preparedness in health security. This scoring system enables thorough assessments of strengths and weaknesses, aiding countries in identifying areas for enhancement and guiding investments in health security. Additionally, the GHSI offers flexibility by allowing adjustments to the weights assigned to each category and indicator within its data model. This feature enables the interpretation and application of the index's findings according to varying assumptions about their relative importance.

Annex 6.B. The Joint External Evaluation (JEE) measures country-specific status and progress in developing capacity to prevent, detect and rapidly respond to public health threats

The first step of the JEE process involves a self-assessment carried out by the country with multisectoral involvement, utilising the JEE tool and country implementation guide. This self-evaluation covers four categories, including: 1) Prevent; 2) Detect; 3) Respond and 4) International Health Regulation (IHR) – related hazards and points of entry and border health. These four categories encapsulate 19 capacities outlined in the tool, which cover a variety of topics, including linking public health and severity authorities, surveillance, human resources, health services provision, and health emergency management. Within each of the 19 capacities, there exists a varying number of indicators. For instance, there are three indicators in the "surveillance" category, and each of the indicators measures different aspects of a country's public health surveillance capacities. Table 6.3 presents one of the indicators within the surveillance category, namely the indicator "Early warning surveillance function." This indicator assesses the functionality of the country's public health surveillance system and its ability to identify potential events of concern for public health and health security. In the JEE tool, each indicator is evaluated using a scoring system ranging from "1" (indicating no implementation) to "5" (indicating full implementation, including testing, review, and exercise, with sustainable capability). A single score is assigned to each indicator based on consensus regarding the country's current implementation, facilitated by "technical area questions" to guide evaluators.

Annex Table 6.B.1. The early warning surveillance indicator assesses the effectiveness of a public health surveillance system in detecting potential pandemics

Level	Early warning surveillance function
Level 1	National strategy, guidelines and/or SOPs for surveillance are not available or under development
Level 2	National strategy, guidelines and/or SOPs for surveillance have been developed but not implemented. The surveillance system is functioning but lacks systematic immediate reporting or weekly reporting of events and/or data
Level 3	National strategy, guidelines and/or SOPs for surveillance have been developed and are being implemented at the national level. The surveillance system provides immediate and weekly reporting of events and/or data with lab results integrated
Level 4	National strategy, guidelines and/or SOPs for surveillance have been developed and are being implemented at the national and intermediate levels. The surveillance system provides immediate and weekly reporting of events and/or data with lab results integrated and integration between indicator-based surveillance and event-based surveillance
Level 5	National strategy, guidelines and/or SOPs for surveillance for all hazards linking all sectors have been developed and implemented at national, intermediate, and primary public health (at primary level, community participation can be achieved through community-based surveillance. Event-based surveillance is a key part of syndromic surveillance and community-based surveillance) levels; and the system is exercised (as applicable), reviewed, evaluated and updated on a regular basis, with improvement at all levels in the country, with all components linked to one national surveillance system

Note: This indicator is measured for priority epidemic prone diseases conducted according to international standards. In this indicator, surveillance is defined in the report as the systematic ongoing collection, collation and analysis of data for public health purposes and the timely dissemination of public health information for assessment and public health response, as necessary.
Source: World Health Organization (2022[17]), *Joint external evaluation tool: International Health Regulations (2005), third edition,* https://www.who.int/publications/i/item/9789240051.

Following the self-evaluation, an external JEE team comprising of international subject matter experts conducts on-site visits to review data and hold meetings organised by the host country. These assessments involve descriptive and qualitative analysis, with countries expected to provide supporting documentation. Evaluators engage in peer-to-peer discussions with host country experts to reach a consensus. The final report includes scores, a narrative on existing capacities, identified gaps, challenges, and recommendations. Key findings are condensed into three to five priority actions for each of the 19 technical areas.

Notes

[1] Studies often use simple measures like total cases and deaths at a fixed point in time to assess a country's pandemic response; however, this approach overlooks the multifaceted definition of success, including different health outcomes, types of interventions, and timing, as well as economic and social disruptions. Therefore, early success may not reflect later stages, especially with the introduction of vaccines. Also, total cases and deaths do not show differences within countries, like socio-economic or geographic disparities. (Stoto, Nelson and Kraemer, 2023[34]).

7 Targeted non-pharmaceutical interventions play a key role in safeguarding population health and the economy in the early phases of pandemics

This chapter presents findings from modelling the health and economic impacts of scaling up eight non-pharmaceutical interventions to control the spread of infectious agents under five outbreak scenarios. It also examines key factors influencing population compliance with these interventions. The results are provided for 51 OECD, European Union/European Economic Area and Group of 20 countries. The chapter concludes with a discussion on the implications of these findings.

In Brief

Key messages

- Non-pharmaceutical interventions (NPIs) are core public health measures used during outbreaks when pharmaceutical interventions are not yet available. By reducing the frequency of person-to-person interactions or making those interactions safer, NPIs help slow disease transmission, protect population health and prevent healthcare systems from reaching a breaking point. They also buy critical time for the development, production and deployment of pharmaceutical countermeasures.
- During the COVID-19 pandemic, OECD, European Union(EU)/European Economic Area (EEA) and Group of Twenty (G20) countries adopted different combinations of NPIs, adjusting the mix and stringency of measures as the pandemic evolved. In the early months of COVID-19, almost all EU/EEA and G20 countries implemented sweeping measures, including school and workplace closures, travel restrictions and lockdowns. By the second half of 2021, most countries shifted towards more targeted approaches and by the end of 2022, highly stringent NPIs were largely lifted.
- The majority of available evidence suggests that NPIs can help mitigate the spread of outbreaks. However, the magnitude of their precise effectiveness remains difficult to measure due to the high level of variation in their design and implementation across settings. Despite their protective effects on population health and the economy, they also come with a broad range of unintended consequences (e.g. on the labour market, mental health, educational outcomes). Policymakers who consider applying NPIs should carefully weigh options that would help maximise both the health and economic outcomes.
- Applied to five scenarios based on pathogens similar to those with pandemic potential (i.e. Ebola-like, avian influenza-like, influenza A-like, coronavirus-like and measles-like outbreaks), the OECD Strategic Public Health Planning Model (SPHeP) for pandemic preparedness and response (PPR) shows:
    - The timing of scaling up NPIs is critical. When NPIs are implemented early and effectively, reliance on lockdowns can be reduced substantially. Using lockdowns as a last resort in the absence of other NPIs in place is both less effective in saving lives and more damaging to economies in 50 OECD, EU/EEA and G20 countries (11.7%-28.9% decline in gross domestic product [GDP] in the first nine months of the outbreak). Across most outbreak scenarios, timely and robust deployment of NPIs is sufficient to avoid lockdowns altogether.
    - Across all outbreak scenarios, the modelled NPI packages could considerably reduce the health impacts of pandemics. Even the least stringent option, combining community-based infection prevention and control (IPC) and voluntary quarantines (i.e. the “Safer contact” package) is estimated to avert at least 40% of deaths in the first nine months of the outbreak compared to an unmitigated outbreak, while resulting in moderate economic impacts (2.5%-8.6% decline in GDP).
    - A layered implementation of NPIs, which would entail adding more stringent measures as needed, can protect population health while limiting economic disruption. Escalating to the “Reduced contact” package (i.e. the “Safer contact” package plus expanded teleworking, domestic travel restrictions and mandatory quarantines) is sufficient to avert the vast majority

of deaths across most scenarios. This approach helps cushion economic losses in all outbreak scenarios.

- When implemented early and effectively, escalating to the "Reduced contact" package can avoid the need for more disruptive interventions such as school closures and international travel restrictions.
- However, the overall effectiveness of NPIs depends strongly on the level of public compliance with the recommended public health actions. When compliance is low, lockdowns may be necessary to control disease transmission.
- Wastewater surveillance can enhance the protective impacts of NPIs by supporting earlier and more targeted action. In a coronavirus-like outbreak, guiding the "Safer contact" package with wastewater data could prevent an additional 41% of deaths across the 51 OECD, EU/EEA and G20 countries included in the analysis that would have otherwise occurred when relying solely on data gathered from clinical surveillance. Wastewater surveillance can remove the need for lockdowns in many cases and support more targeted lockdowns, reducing their duration by up to 90% in certain scenarios.

7.1. Non-pharmaceutical interventions are key to safeguarding population health and the economy in the early days of pandemic outbreaks

Non-pharmaceutical interventions (NPIs) are core public health measures used during outbreaks. These measures, ranging from physical distancing to hand hygiene and mask wearing, aim to slow transmission without relying on pharmaceutical tools such as therapeutics, diagnostics or vaccines. By reducing the frequency of person-to-person interactions or by making such interactions safer, NPIs help protect vulnerable populations, prevent health systems from reaching a breaking point and preserve essential healthcare services. They also create the necessary time and space for the development, production and deployment of pharmaceutical countermeasures once they become available. Even after vaccines or therapeutics are deployed, NPIs continue to reduce transmission, extend protection to those who are not vaccinated or only partially protected and help contain new variants.

NPIs have long been part of the public health response to outbreaks. They formed the foundation of response efforts during the 2003 SARS outbreak, the 2009 H1N1 influenza pandemic and the 2012 MERS-CoV epidemic (Björk et al., 2025[1]). However, it was the COVID-19 pandemic that tested these interventions on a global scale. Countries adopted different combinations of NPIs, often adjusting the mix and stringency of measures as epidemiological conditions evolved. While some governments relied on compulsory restrictions, others placed greater emphasis on guidance and voluntary adherence. Across all settings, effective implementation required sustained co-ordination between national and subnational authorities, close engagement with communities and timely communication to maintain public trust and compliance.

This chapter examines the effectiveness of NPIs in safeguarding population health and mitigating wider economic disruption during the initial phases of large-scale outbreaks caused by pathogens with epidemiological traits similar to those with pandemic potential. The analysis focusses on eight NPIs that were widely applied across OECD countries during COVID-19 (OECD, 2023[2]); consistent with international guidance on pandemic preparedness and response (PPR) (Independent Panel, 2021[3]) and they are supported by evidence that enables robust modelling of their impacts. The chapter also considers how these interventions interact with broader PPR capacities, including surveillance systems such as wastewater monitoring, which can enhance the timely detection of viral activity and support more targeted application of NPIs. The analysis concentrates on how these interventions mitigate transmission within

communities rather than their potential role in preventing cross-border spread. Preparing a broader clinical response, for example through the stockpiling of antivirals and other therapeutics or the procurement and deployment of vaccines, lies outside the scope of this chapter. While these pharmaceutical countermeasures are essential components of PPR, the analysis focusses specifically on NPIs that can be deployed in the early phases of an outbreak, before such tools become available at scale.

A distinction can be drawn between two categories of investment in pandemic risk management. Primary prevention seeks to reduce the risk of pathogen spillover from animals to humans at its source, for example, through curbing deforestation, regulating the wildlife trade and strengthening biosecurity at the human-animal interface. These activities aim to help reduce the risk of an outbreak occurring in the first place. Post-emergence preparedness and response, by contrast, comprises the measures deployed once a pathogen is already circulating in human populations, including NPIs and medical countermeasures. The analysis presented in this chapter concerns the latter. This focus does not imply that prevention is a lower priority. A growing body of evidence indicates that primary prevention promises a favourable return on investment (Dobson et al., 2020[4]), with one assessment estimating its annual cost at less than one-twentieth of the value of lives lost each year to emerging zoonoses (Bernstein et al., 2022[5]).

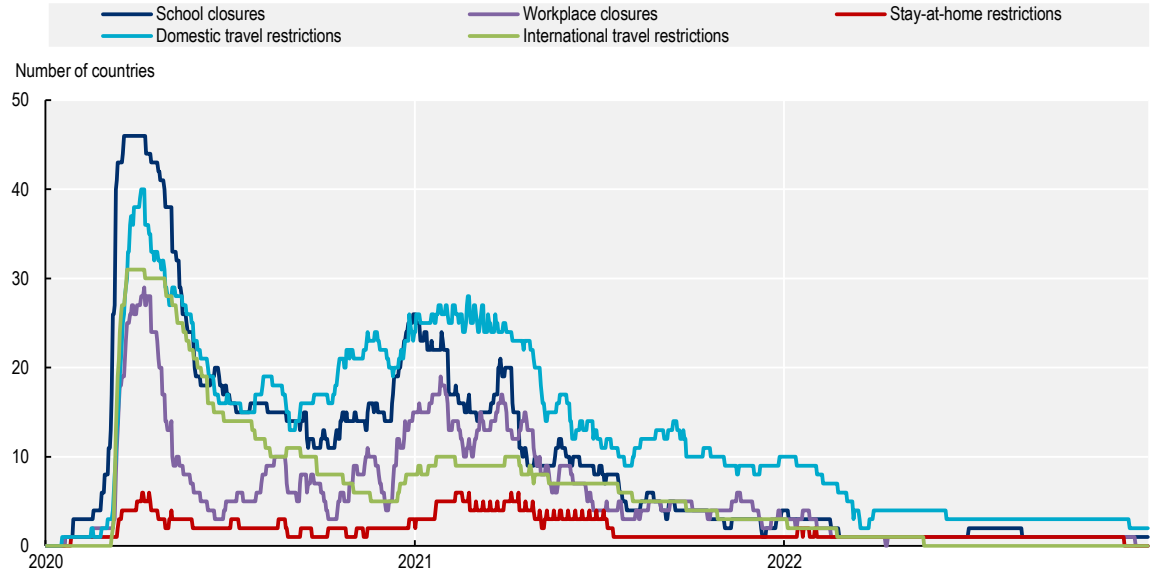
The chapter is structured as follows. It starts by reviewing the evidence on the implementation of the selected NPIs across 51 OECD, EU/EEA and G20 countries during the COVID-19 pandemic, as well as the evidence on the effectiveness of each intervention. Next, the chapter explores the latest evidence on the factors that determine the level of public compliance with the NPIs. The chapter then reports the results on the health and economic impacts of implementing the selected NPIs under five pandemic scenarios discussed in Chapter 3, with particular attention to the added value of wastewater surveillance. The chapter concludes by discussing key policy considerations and implications of findings.

7.2. The varied paths of NPI roll-out during the COVID-19 pandemic

From late January to March 2020, almost all OECD, EU/EEA and G20 countries introduced sweeping measures, from school and workplace closures and stay-at-home orders to domestic and international travel restrictions (Figure 7.1). For example, some countries implemented highly restrictive stay-at-home orders that required people to remain in their homes with only certain exceptions (e.g. daily exercise or essential trips). These measures came with deep short-term economic consequences, from lost economic output to supply chain disruption, but countries accepted them as the price of preventing uncontrolled transmission and health system collapse (OECD, 2020[6]). Countries started to shift their approaches by the second half of 2021, with many countries replacing highly stringent NPIs with more targeted measures (e.g. adapted schooling approaches instead of long-term nationwide school shutdowns). By the end of 2022, NPIs that caused substantial disruption in daily life were largely lifted across all 51 countries included in the analysis.

Figure 7.1. OECD, EU/EEA and G20 countries relied heavily on restrictive NPIs in the early stages of COVID-19

Number of countries that implemented the selected non-pharmaceutical interventions, OECD, EU/EEA and G20 countries, 1 January 2020 to 31 December 2022



Note: The figure represents the number of countries that implemented the selected NPIs on each day between 1 January 2020 and 31 December 2022. School closures refer to restrictions that require closing all levels of schooling; Workplace closures refer to restrictions that require closing (or work from home) for all-but-essential workplaces (e.g. grocery stores, doctors); Stay-at-home restrictions refer to requirements for not leaving the house with exceptions for daily exercise, grocery shopping and essential trips or minimal exceptions (e.g. allowed to leave once a week or only one person can leave at a time); domestic travel restrictions refer to restrictions on internal travel between regions/cities and international travel restrictions refer to ban on international travel from/to for all regions or total border closure.
Source: Data retrieved from Hale et al. (2021[7]), the Oxford COVID-19 Government Response Tracker (OxCGRT).

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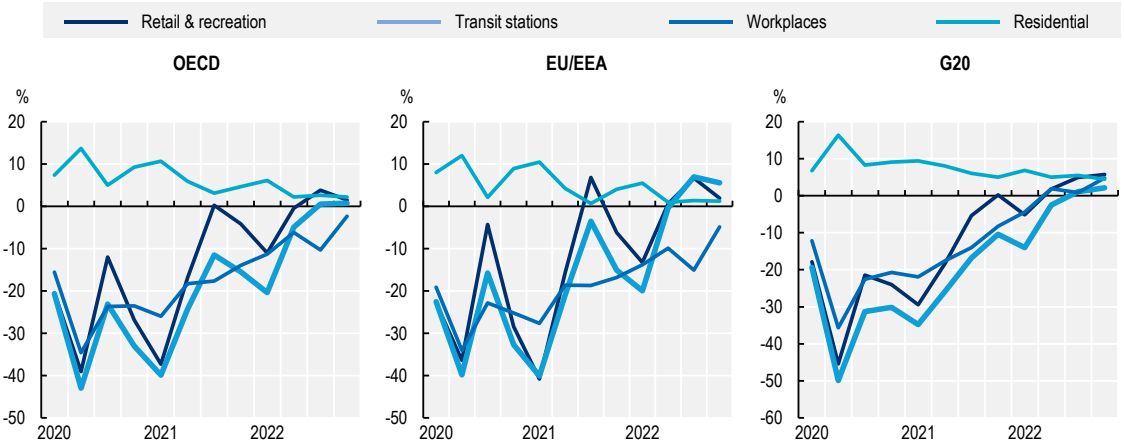
7.2.1. Physical distancing measures

Physical distancing measures are, at their core, a set of interventions that aim to keep people apart often enough to slow the spread of disease. By limiting close contact, physical distancing can minimise the risk that an infected individual will pass a disease to a susceptible individual, as was documented in previous outbreaks such as MERS-CoV, SARS-CoV-1 and SARS-CoV-2 (Chu et al., 2020[8]). During the COVID-19 pandemic, countries rolled out a wide range of physical distancing measures. Some banned small gatherings, while others limited the mobility of certain vulnerable groups (e.g. older people), shut down businesses and/or imposed full lockdowns (OECD, 2023[2]). The timing and strictness of physical distancing measures also varied not only across countries but also between regions within the same country.

The COVID-19 pandemic led to a stark shift in mobility patterns across OECD, EU/EEA and G20 countries in the early days of the outbreak (Figure 7.2). In the OECD, for example, retail, transit and workplace mobility fell dramatically by the second quarter of 2020, by around 35-40% compared to pre-COVID-19, while time spent at home rose by 14%. Mobility recovered through 2021 but remained below pre-pandemic levels. By the end of 2022, retail and recreational activities and transit mobility returned to pre-pandemic levels across OECD, EU/EEA and G20 countries, yet workplace mobility remained slightly below the pre-pandemic levels in OECD and EU/EEA countries.

Figure 7.2. The COVID-19 pandemic led to a sharp shift in mobility patterns

Percentage change in mobility patterns compared to a 5-week baseline period from 3 January to 6 February 2020, OECD, EU/EEA and G20 countries, 2020-2022



Note: The figure above shows the changes in mobility patterns by place from 15 February 2020 to 15 October 2022. The Google Community Mobility Reports define the baseline date as the median value, for the corresponding day of the week, during the 5-week period Jan 3–Feb 6, 2020. Retail and recreation refers to places such as restaurants, cafes, shopping centres, theme parks, museums, libraries and movie theatres; transit stations refer to public transport hubs such as subways, bus and train stations; residential refers to places of residence and workplaces refer to places of work. Quarterly mobility patterns were calculated by aggregating daily data on the percentage change in the mobility patterns by each place category.
Source: Google Community Mobility Reports (Google LLC, 2022[9]).

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The large variation in the rollout of physical distancing measures makes it difficult to measure their precise impact. Still, there is an agreement that physical distancing helped blunt the spread of the COVID-19 outbreak, delayed the peak of the pandemic and eased the pressure on health systems. For example, one Cochrane review quantified that physical distancing measures were associated with 37-88% reduction in the basic reproduction number of the outbreak (i.e. the average number of people that an infected individual would infect in a susceptible population), 44-96% reduction in the incidence of SARS-CoV-2 and 31-76% reduction in attributable mortality (Nussbaumer-Streit et al., 2020[10]). Subsequent studies broadly confirmed these findings (Murphy et al., 2023[11]; Sun et al., 2022[12]).

While physical distancing measures seemed to have helped protect public health during the COVID-19 pandemic, they also carried steep social and economic costs. Prior OECD analysis shows that the gross domestic product (GDP) contracted sharply in 2020, by 5.5% in OECD economies and 7.5% in the Euro area, considerably higher than the average decline of 3.8% in G20 countries and the global average of around 4.2% (OECD, 2020[6]). Physical distancing measures have been suggested to play a major role in the observed shrinkage of economies (OECD, 2021[13]). Many households confronted declines in their disposable income, despite efforts in many OECD countries to shield them from the direct economic impacts of the outbreak (Ibid). Unemployment rose across the OECD, with the average unemployment rate rising from 5.4% in the first quarter of 2020 to 8.6% in the second quarter (Ibid). Mental health also deteriorated markedly, with symptoms of distress peaking during periods when physical distancing requirements were most stringent (OECD, 2021[14]; OECD, 2021[15]).

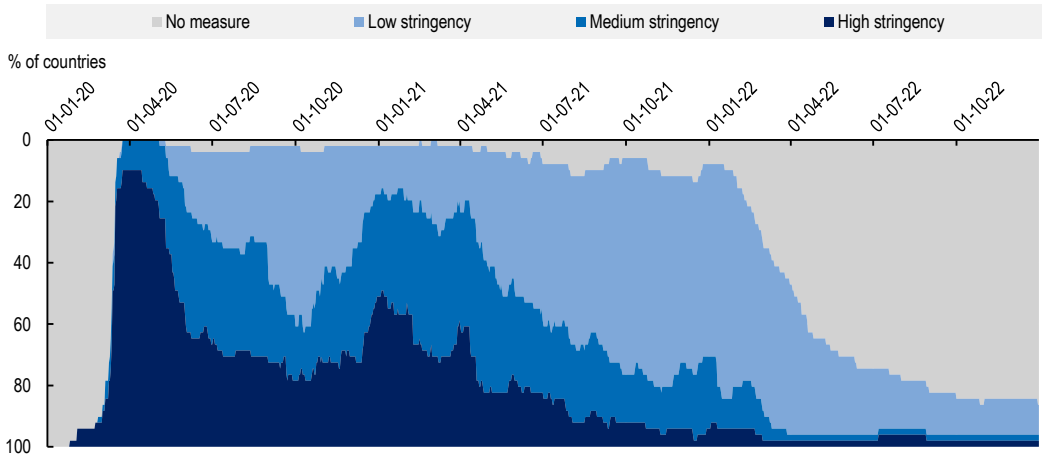
7.2.2. Temporary school closures

Classrooms bring together large groups of children who often gather closely, interact frequently and do not always follow hygiene guidelines, making schools efficient hubs for spreading infections. While closing schools, even temporarily, can interrupt the chain of transmission, this intervention is one of the most disruptive measures governments can use to curb the spread of an outbreak.

During COVID-19, temporary school closure and school-based measures were used widely across countries (Figure 7.3). Overall, OECD, EU/EEA and G20 countries followed nearly identical trajectories. In most countries included in the analysis, temporary school closures were at their strictest during the second quarter of 2020, reflecting nationwide school and university closures. Restrictions gradually eased over 2021, though intermittent tightening occurred in early 2021 as new infection waves emerged. By the last quarter of 2021, most countries shifted to partial or localised school closures and by the second quarter of 2022, schools and universities were largely open across most countries included in the analysis.

Figure 7.3. School and university closures across 51 OECD, EU/EEA and G20 countries, 2020-2022

Percentage of countries that implemented school and university closures at different levels of stringency



Note: Data captures closings of schools and universities. No measure = no recommendations/requirements for schools and university closures (grey shading); Low stringency = recommend closing or all schools open with alterations resulting in significant differences compared to non-COVID-19 operations (light blue shading); Medium stringency = require closing only some levels or categories (e.g. high schools or only public schools) (medium blue shading); High stringency = require closing all levels (dark blue shading).
Source: Data retrieved from Hale et al. (2021[7]), Oxford COVID-19 Government Response Tracker (OxCGRT).

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Studies suggest that temporary school closures can help slow the spread of infections during outbreaks. Most studies link school closures to fewer new cases and sizable drops in the basic reproduction number of the studied pathogen, with estimates showing declines from 39% to 73% (Mendez-Brito, El Bcheraoui and Pozo-Martin, 2021[16]). However, the effectiveness of these interventions depends heavily on how widespread the pathogen is already in the community and whether there are other NPIs in place. Other school-related policies such as phased re-openings, smaller classroom sizes, staggered schedules and alternating attendance days (e.g. in-person school for certain grades) have also been shown to be effective during COVID-19 in reducing the number of new cases and hospitalisations (Krishnaratne et al., 2022[17]).

Evidence on re-opening schools is more mixed. In one study from the United States, the re-opening of schools was associated with a 12.3% increase in the basic reproduction number of SARS-CoV-2 between April and May 2020 (Davies et al., 2022[18]), whereas in Finland studies found no clear link between school

re-openings and the incidence of SARS-CoV-2 (Haapanen et al., 2021[19]). Studies from Germany and Japan reported similar findings. When schools re-opened alongside other NPIs such as mask-wearing and hand washing, they did not appear to drive a wider spread (Isphording, Lipfert and Pestel, 2021[20]; Fukumoto, McClean and Nakagawa, 2021[21]).

School closures may slow the spread of outbreaks, but they disrupt education and learning. Data from the World Bank suggested that during the first phase of the crisis, on average, students lost between one-third up to a half years' worth of learning (Patrinos, Vegas and Rohan, 2022[22]). Another study estimated that the percentage of 10-year-olds who cannot read increased from 57% to 70% in low-income countries (Munoz-Najar et al., 2022[23]). OECD countries introduced several measures to limit the adverse impacts of school closures during the COVID-19 pandemic (Box 7.1).

Box 7.1. Korea's efforts to keep education resilient during COVID-19

Korea entered the COVID-19 pandemic with a well-established foundation for digital learning. The first set of Master Plans (1996-2010) focussed on building a nationwide information and communications technology (ICT) infrastructure, developing digital learning platforms and strengthening teacher capacity through formal ICT skills standards and accreditation systems (World Bank, 2022[24]). These plans were fully financed and systematically implemented, resulting in universal school connectivity. Subsequent Master Plans (2011-2018) shifted the focus toward improving equity and quality in EdTech provision and enabling more flexible and personalised learning (Ibid).

When COVID-19 struck, this long-term investment enabled Korea to pivot to online learning rapidly. Following three postponements of the 2020 school year, Korea transitioned to online learning in April 2020 and rolled out remote classes progressively by grade level (World Bank, 2022[24]). By the end of April 2020, 99% of Korea's 5.34 million students were participating in online schooling. Even after schools partially opened in May 2020, attendance remained capped at two-thirds capacity depending on local distancing requirements (Ibid). Overall, Korean students had online learning for more than half of their school days in 2020. This is far below the legally required 190 days of face-to-face instruction.

A COVID-19 Prevention Task Force, convened by the Ministry of Education in February 2020, co-ordinated a comprehensive response built around three pillars: disease control, continuity of learning and childcare. Korea's strategy included the following measures:

- Schools received clear guidance on when to close and on online teaching, along with funding to build digital infrastructure. Teachers were given time before each online semester to prepare for online teaching.
- Educators had access to extensive online teaching materials and regular emergency communication to facilitate their adjustment to online teaching.
- Students received broad support for shifting to distance learning (e.g. digital device rentals, access to an online, public learning system that aimed to resolve any technical difficulties)

Despite the shift to hybrid learning, overall student performance in Korea has been shown to remain broadly stable during the pandemic. Evidence from primary schools points to continued learning gains, whereas students in middle and upper secondary levels experienced modest learning losses alongside widening disparities in achievement (World Bank, 2022[24]).

Source: World Bank (2022[24]), *EdTech in COVID-19 Korea: Learning with Inequality*, https://thedocs.worldbank.org/en/doc/286e9d2e22dd4122f15249083ca84772-0200022022/original/EdTech-paper-4-29.pdf.

A recent systematic review of COVID-19 impact on students, teachers, parents and administrators found that in-person classes remained the most effective way to teach and learn during the pandemic (Tri Sakti et al., 2022[25]). This study highlighted that distance learning offered flexibility and innovative learning solutions but it warned that distance learning can reduce student engagement, weaken student performance, create heavier workloads for teachers and limit the opportunities for communication and socialisation (OECD, 2021[15]).

The cost of school closures extends well beyond education and learning. A growing body of evidence shows that school closures took a toll on children's and adolescents' mental health and well-being during the COVID-19 pandemic (Tri Sakti et al., 2022[25]; Ludwig-Walz et al., 2023[26]; Viner et al., 2022[27]). Families felt the strain, too, with many parents losing workdays, income or paying extra for childcare (Skarp et al., 2021[28]). These ripple effects raised questions about the broader societal cost of school closures in the long term (Vardavas et al., 2021[29]; Pasquini-Descomps, Brender and Maradan, 2017[30]).

7.2.3. Teleworking arrangements

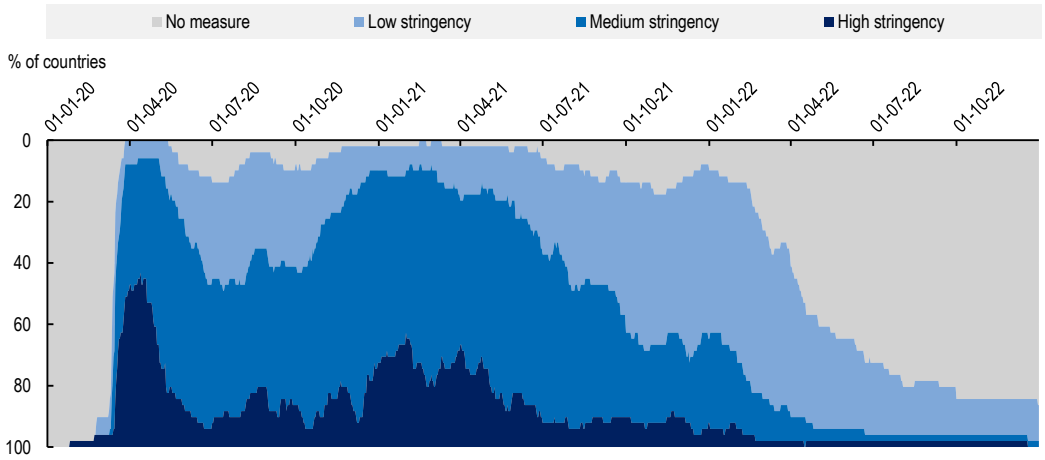
Teleworking refers to the practice of working from a location other than the traditional office setting by using information and communications technologies (ILO, 2020[31]). Teleworking can help curb the spread of an outbreak by limiting the need for employees to commute to and from the office, which in turn reduces the risk of exposure to pathogens in public transportation or through shared spaces such as elevators and offices. Teleworking can also minimise the number of people present at the office at any given time (e.g. staggered shift schedules, flexible work arrangements), limiting the opportunities for the spread of an outbreak.

The COVID-19 pandemic brought a large-scale experiment in teleworking. The share of work that shifted to teleworking varied substantially across countries, industries and types of jobs (OECD, 2021[32]). Some sectors, such as knowledge-intensive services, shifted to remote working arrangements with relative ease and have been shown to benefit from increased productivity and higher worker satisfaction (ibid). Other occupations, especially those with high levels of physical and manual proximity, had a low potential for telework.

Workplace policies were widely used across OECD, EU/EEA and G20 countries as a core measure to contain the spread of the COVID-19 pandemic (Figure 7.4). At the outset, most governments adopted moderately stringent policies which required telework or closures for selected sectors or categories of workers. As COVID-19 cases and deaths surged in early 2021, many countries escalated to the most stringent levels of workplace restrictions, mandating remote work for all but essential services (e.g. food retail and healthcare). Although restrictions gradually eased thereafter, some form of workplace policies (i.e. either recommendations or requirements for teleworking) remained in place in many countries throughout the rest of 2021. By the second quarter of 2022, most countries returned to having no teleworking requirements.

Figure 7.4. Workplace policies across 51 OECD, EU/EEA and G20 countries, 2020-2022

Percentage of countries that implemented workplace policies at different levels of stringency



Note: Data captures closure of workplaces. No measure = no recommendations/requirements for workplace closures (grey shading); Low stringency = recommend closing (or recommend work from home) or all businesses open with alterations resulting in significant differences compared to non-COVID-19 operations (light blue shading); Medium stringency = require closing (or work from home) for some sectors or categories of workers (medium blue shading); High stringency = require closing (or work from home) for all-but-essential workplaces (e.g. grocery stores, doctors) (dark blue shading).
Source: Data retrieved from the Oxford COVID-19 Government Response Tracker (OxCGRT) (Hale et al., 2021[7]).

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The precise effectiveness of teleworking policies remains uncertain. A systematic review examining measures such as extended weekends and teleworking during past influenza outbreaks in OECD countries such as Australia, Canada, Sweden and the United States found that when community transmission was low, teleworking was associated with a median reduction of about 23% in the cumulative influenza attack rate (i.e. the proportion of the population that became infected over the course of the outbreak) (Ahmed, Zviedrite and Uzicanin, 2018[33]). However, the review could not isolate the specific contribution of teleworking from other interventions rolled out at the same time. More recent evidence from COVID-19 suggests that teleworking was effective in reducing SARS-CoV-2 transmission and supported the easing of physical distancing measures without triggering a rise in new cases (Burzyński et al., 2021[34]).

Teleworking policies can have broader social and economic consequences beyond their role in reducing transmission. Recent OECD analysis shows that the capacity to work remotely varies widely across labour markets (Box 7.2), depending on job type, firm characteristics and regional factors (OECD, 2021[35]). For companies, mandatory teleworking can generate additional costs related to technology adoption and organisational restructuring, while for workers it may hinder career progression and networking opportunities (OECD, 2021[35]). Evidence from France indicates that teleworking can also disrupt workload patterns and make it more difficult for employees to set boundaries between work and personal life (Vayre et al., 2022[36]). A complementary systematic review reported that extensive teleworking was associated with reduced self-rated performance and higher employee turnover (Mutiganda et al., 2022[37]), as well as greater psychosocial strain (Antunes et al., 2023[38]).

Box 7.2. Estonia built on its digital head start to promote teleworking practices during COVID-19

Estonia is among the best performers in terms of providing key public services digitally in Europe (European Commission, 2024[39]). The country entered the COVID-19 pandemic with one of the strongest digital foundations in the OECD, which enabled a relatively smooth and rapid transition to teleworking when lockdowns and physical distancing measures were introduced.

Sustained investment in nationwide digital infrastructure, dating back to the early 1990s, had created near-universal internet access, high digital literacy and a mature ecosystem of digital public services. At the outset of the pandemic, teleworking was already widespread in digital-intensive sectors such as information and communication services, finance and professional and technical fields (Piirsalu-Kivihall et al., 2023[40]).

When COVID-19 triggered a sudden shift to telework by March 2020, more than 41% of Estonian employees were able to transition immediately (Ibid). Public sector organisations supported this shift by offering secure, well-equipped workspaces outside major urban centres and by modernising recruitment practices to remove geographic constraints. For example, the state-owned real estate company Riigi Kinnisvara AS opened decentralised, fully equipped workstations in smaller towns, reducing commuting needs (Piirsalu-Kivihall et al., 2023[40]).

Source: European Commission (2024[39]), *Estonia 2024 Digital Decade Country Report*, https://digital-strategy.ec.europa.eu/en/factpages/estonia-2024-digital-decade-country-report; Piirsalu-Kivihall et al. (2023[40]), *Acceleration of Remote Work and Coworking Practices in Estonia During the COVID-19 Pandemic*, https://doi.org/10.1007/978-3-031-26018-6_3.

7.2.4. Community-based infection prevention and control (IPC) measures

As discussed in more detail in Chapter 5, community-based IPC measures (e.g. hand hygiene, respiratory etiquette) broadly refer to the public health interventions that aim to prevent and control the spread of community-acquired infections. Most previous studies agree that community-based IPC measures are an effective tool to mitigate the spread of outbreaks, though much like other NPIs, the size of the protective effects varies depending on the study settings, the type of infection and whether people follow the recommended guidelines. High compliance by the public can make community-based IPC measures powerful enough to safeguard not only population health and the economy as a whole but also limit the need for resorting to more restrictive measures such as business closures or lockdowns.

7.2.5. Domestic and international travel restrictions

Travel restrictions aim to slow the spread of a pathogen by limiting or controlling people's movements. By reducing mobility, these measures can delay the arrival of infections in areas with little or no transmission, lower the risk of spread in crowded transport hubs such as airports and simplify contact tracing by reducing the number of potential exposures that must be identified and monitored.

The 2005 WHO International Health Regulations recognised that travel restrictions can buy valuable time for countries to prepare for outbreaks, but they also warned that unnecessary restrictions may impede the delivery of aid and technical support while imposing heavy economic and social burdens (Vaidya et al., 2020[41]). Yet, countries have increasingly relied on travel restrictions to manage their response to outbreaks. During the 2009 H1N1 influenza pandemic, some countries imposed travel advisories and entry limits (Vaidya et al., 2020[41]). The number of countries that adopted travel restrictions increased during the 2014-2016 Ebola epidemic, with nearly one-quarter of countries introducing bans on travellers from affected regions (Rhymer and Speare, 2016[42]).

This trend intensified during COVID-19. Although the International Health Regulations Emergency Committee initially discouraged travel restrictions in January 2020 (WHO, 2020[43]), mobility restrictions became widespread in the early months of the pandemic. Many countries introduced systematic approaches to inform the implementation of these policies (Box 7.3).

Box 7.3. Domestic travel restrictions as pandemic control: Italy's colour-coded system

In November 2020, during the second wave of COVID-19, Italy introduced a colour-coded system to mitigate the spread of the outbreak and avoid overwhelming regional health systems. Using 21 epidemiological and health system indicators developed by the Ministry of Health, the framework classified each of the country's 20 administrative regions into white, yellow, orange or red zones, with each colour delineating a level of risk for infections. These indicators were selected because they captured each region's disease surveillance capacity, the testing, tracking and tracing (TTT) capabilities, transmission dynamics of the outbreak and the resilience of the regional health services (Paroni et al., 2021[44]).

Each colour code was tied to specific travel rules and restrictions (Italian Ministry of Health, 2020[45]). White zones were deemed the safest regions and these zones allowed free movement across regions. Yellow zones introduced moderate restrictions while orange zones limited interregional travel only to essential reasons. Red zones imposed the strictest travel restrictions, barring entry to and exit from the region altogether (Presidency of the Council of Ministers, 2020[46]). In all zones, additional restrictions were imposed, for example, on shopping and social gatherings. Holders of a "Green Pass" (i.e. an exemption given to people with a proof of vaccination, negative test or recent recovery from a COVID-19 infection) were exempt from some restrictions (ItaliaPass, 2022[47]).

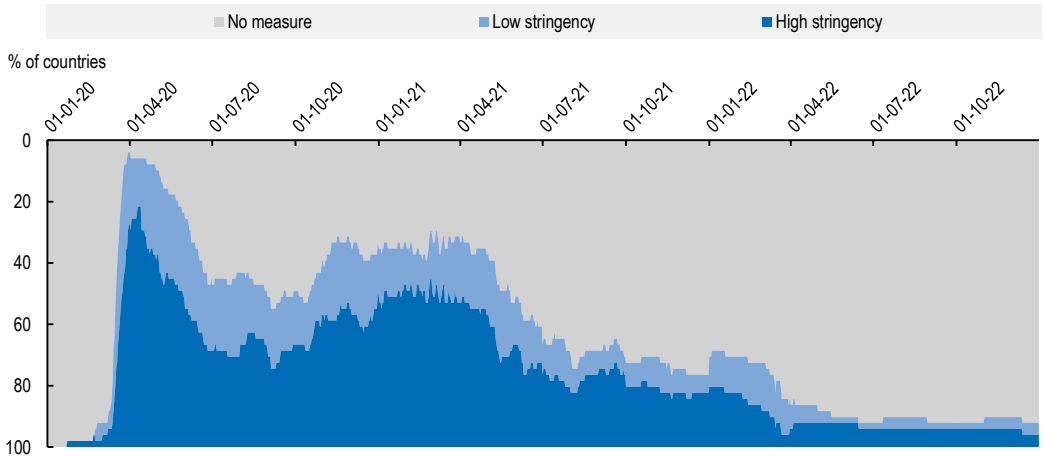
Emerging evidence suggests that stricter travel rules helped curb the transmission of disease within the community but they may have also come at a significant cost. One study estimated that red-zone restrictions, which halted most movement, were associated with a halving of new infections every 13 days, as well as reducing hospitalisations and ICU occupancy by half within 30 to 40 days (Pelagatti and Maranzano, 2021[48]). Yet, another study estimating the mental health outcomes of the general population three to four weeks into the lockdowns during the first wave of COVID-19 found high rates of symptoms related to post-traumatic stress disorder, depression, anxiety and insomnia (Rossi et al., 2020[49]).

Source: Paroni et al. (2021[44]), "*The Traffic Light Approach: Indicators and Algorithms to Identify Covid-19 Epidemic Risk Across Italian Regions*", http://doi.org/10.3389/fpubh.2021.650243; Italian Ministry of Health, (2020[45]), "*Nuovo Coronavirus*", www.salute.gov.it/portale/nuovocoronavirus/archivioNormativaNuovoCoronavirus.jsp; Presidency of the Council of Ministers (2020[46]), *Decreto del presidente del consiglio dei ministri 24 ottobre 2020*, https://www.gazzettaufficiale.it/eli/id/2020/10/25/20A05861/sg; ItaliaPass (2022[47]), "*Italy Green Pass*", https://italygreenpass.com/travel-to-italy/; Pelagatti and Maranzano (2021[48]), *"Assessing the effectiveness of the Italian risk-zones policy during the second wave of COVID-19*", https://doi.org/10.1016/j.healthpol.2021.07.011. Rossi et al. (2020[49]), "*COVID-19 Pandemic and Lockdown Measures Impact on Mental Health Among the General Population in Italy*", http://doi.org/10.3389/fpsyt.2020.00790.

Most countries shifted from no restrictions in the first quarter of 2020 to strict limitations on movement between regions and cities by the second quarter (Figure 7.5). While many of these measures eased toward the end of 2020, renewed waves in early 2021, particularly within EU/EEA countries, triggered another round of tightening. From mid-2021, domestic movement restrictions declined steadily and by 2022, nearly all countries had fully restored internal mobility.

Figure 7.5. Domestic travel restrictions across 51 OECD, EU/EEA and G20 countries, 2020-2022

Percentage of countries that implemented domestic travel restrictions at different levels of stringency



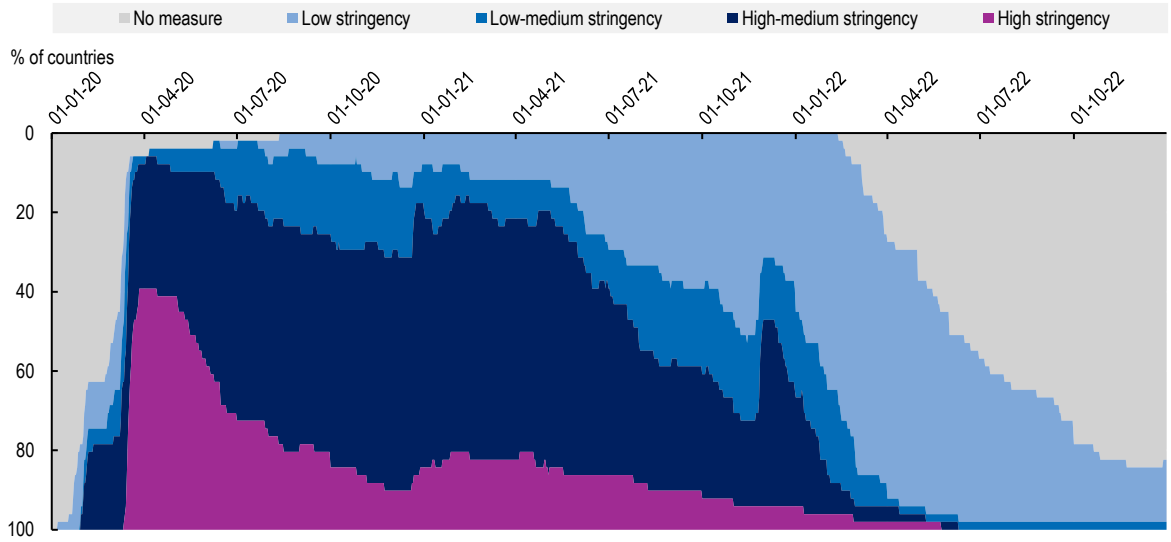
Note: Data captures domestic travel restrictions. No measures = no recommendations/requirements for domestic travel restrictions (grey shading); Low stringency = recommend not to travel between regions/cities (light blue shading); High stringency = internal movement restrictions in place (medium blue shading).
Source: Data retrieved from the Oxford COVID-19 Government Response Tracker (OxCGRT) (Hale et al., 2021[7]).

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Countries also relied on restrictions on international travel as a means to mitigate the spread of SARS-CoV-2 in their communities. They deployed a range of restrictions spanning from mild interventions such as screening arrivals to complete travel bans on all regions and total border closures (Figure 7.6). The harshest international travel restrictions (e.g. border closures) were implemented in most countries primarily in the second quarter of 2020. The second half of 2020 saw an easing of international travel restrictions, as most countries moved to restricting arrivals only from certain regions. Interventions that severely restricted international travel remained prevalent in most countries throughout the second half of 2021. Starting from the first quarter of 2022, OECD, EU/EEA and G20 countries transitioned to implementing less stringent interventions that favoured the screening and quarantine of arrivals over total border closures and by the end of 2022, most countries did not impose any restrictions on international travel.

Figure 7.6. International travel restrictions across 51 OECD, EU/EEA and G20 countries, 2020-2022

Percentage of countries that implemented international travel restrictions at different levels of stringency



Note: Data captures restrictions on international travel for foreign travellers, not citizens. No measures = no restrictions (grey shading); Low stringency = screening arrivals (light blue shading); Low-medium stringency = quarantine arrivals from some or all regions (medium blue shading); High-medium stringency = ban arrivals from some regions (dark blue shading); High stringency = ban on all regions or total border closure (purple shading).
Source: Data retrieved from the Oxford COVID-19 Government Response Tracker (OxCGRT) (Hale et al., 2021[7]).

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Travel restrictions can help slow the spread of infectious diseases. Evidence from one systematic review of past influenza outbreaks suggests that domestic travel controls delay transmission by about one week, while international restrictions can buy up to two months of additional time (Mateus et al., 2014[50]). Experiences from the COVID-19 pandemic largely reinforce this pattern. One Cochrane review estimated that international travel restrictions delayed the global spread of SARS-CoV-2 by as much as 85 days (Burns et al., 2021[51]).

However, there is no consensus on how effective travel restrictions are overall. During influenza outbreaks, their impact on new cases was small at around a 3% reduction (Mateus et al., 2014[50]), whereas for COVID-19, early international travel controls were associated with reductions ranging from 26% to 90% (Burns et al., 2020[52]). Despite this wide variation, evidence consistently shows that travel restrictions alone cannot stop an outbreak once community transmission becomes widespread (Mateus et al., 2014[50]; Bou-Karroum et al., 2021[53]; Grépin et al., 2021[54]). Important exceptions are seen in settings such as New Zealand and Australia, where island geography enabled the implementation of stringent international travel controls far more effectively than most countries, contributing to markedly delayed community transmission.

The economic toll of international travel restrictions during COVID-19 was considerable. Tourism was among the hardest-hit sectors. In OECD countries with available data, the share of GDP from tourism fell by almost half from 4.4% in 2019 to 2.5% in 2020 (OECD, 2024[55]). OECD countries with the largest tourism sectors (e.g. Greece, Iceland, Portugal, Mexico and Spain) saw some of the sharpest drops in tourism-related GDP (Rusticelli and Turner, 2021[56]). The negative impact of the outbreak went beyond the tourism sector, affecting, for example, stock markets, supply chains, businesses and commercial activities (Klinger et al., 2021[57]; OECD, 2022[58]).

7.3. Why do some people follow public health guidelines during pandemics while others ignore them?

Why people follow public health guidance during pandemics reflects a wide range of factors. These determinants do not operate in isolation; they interact in ways that can strengthen or weaken the likelihood that people will follow the public health advice. Understanding these interactions is key to designing effective public health strategies that can enhance NPI compliance and, ultimately, mitigate the spread of outbreaks. This section provides an overview of the determinants of compliance with public health guidance during pandemics (Figure 7.7), though an exhaustive review of all possible determinants is outside the scope of analysis.

Figure 7.7. The level of compliance with public health guidance during outbreaks is linked to a complex set of factors



Note: This figure presents the key factors that influence public compliance with health guidance during pandemic outbreaks, while acknowledging that it does not capture all possible determinants.
Source: Based on OECD review.

Several key factors have been shown to influence the patterns of compliance with public health guidance during outbreaks as follows:

- **Demographic factors** matter. Two recent studies that summarised evidence generated primarily in OECD countries highlighted that across many countries and settings, older adults and women generally showed higher levels of adherence to public health guidelines rolled out during the COVID-19 pandemic, which has been linked to more elevated levels of perceived risk (Moran et al., 2021[59]) and greater willingness to engage in health-protective behaviours (Cipolletta, Andreghetti and Mioni, 2022[60]).
- **Educational attainment** has also been an important determinant. People with higher educational attainment have been shown to follow public health guidelines compared to their peers with lower levels of education (Cipolletta, Andreghetti and Mioni, 2022[60]). This finding has been suggested

to be partly due to better access to information and higher levels of health literacy among people with higher educational attainment, which in turn, is associated with greater involvement in health-protective behaviours (Ibid).

- **Financial constraints** affect people's ability to comply with public health guidelines. Concerns about job insecurity or inability to work from home can make compliance with social distancing challenging. For example, in Slovenia, a national survey conducted by the National Institute of Public Health showed that a substantial proportion of the respondents perceived the COVID-19 pandemic to have a negative impact on their financial security, with this proportion reaching 36.2% by October 2021 (National Institute of Public Health Slovenia, 2021[61]). One assessment from the United Kingdom further concluded that individuals with incomes below GBP 20 000 (equivalent to around USD 26 348) or savings under GBP 100 (equivalent to around USD 132) were three times less likely to report that they could self-isolate (GOV.UK, 2020[62]). Another study from the United States showed that a gradient existed in the level of compliance with social distancing guidelines by the level of neighbourhood income (Jay et al., 2020[63]). This study showed that individuals residing in low-income neighbourhoods were more likely to have jobs that required them to work outside of home than individuals from high-income neighbourhoods. The study further highlighted that residents of low-income neighbourhoods were less likely to increase the number of days that they worked from home compared to individuals from high-income neighbourhoods.
- **Risk perception** is closely tied to compliance. Emerging evidence demonstrates that compliance with public health guidance increases with higher perceived personal or family risk (Cipolletta, Andreghetti and Mioni, 2022[60]). One recent study that collected data from 10 OECD countries between March and mid-April 2020 showed that in the early phases of the COVID-19 pandemic, risk perception was high in all countries included in the analysis (Dryhurst et al., 2020[64]). Risk perception does not remain static during outbreaks. One recent study that evaluated the global patterns in the level of compliance with pandemic guidelines concluded that pandemic fatigue was associated with reductions in compliance over time as the risks perceived by people reduced over time, even in settings where the number of cases remained high (Dryhurst et al., 2020[64]; WHO, 2020[65]).
- **Access to accurate information** also shapes compliance. While accurate knowledge and awareness can enhance adherence, exposure to disinformation, which is false information shared with the intention of causing harm, can propel non-compliance (Sontag, Rogers and Yates, 2022[66]). The COVID-19 pandemic saw an unprecedented surge in disinformation (Pool, Fatehi and Akhlaghpour, 2021[67]), including harmful messages about the effectiveness of community-based IPC measures. Emerging evidence shows that across many OECD countries, the spread of misinformation dampened people's willingness to follow the public health guidance, in part by diminishing trust in public institutions (Pavela Banai, Banai and Miklоušić, 2021[68]) and generating confusion over measures such as mask wearing (Kim et al., 2020[69]; Allington et al., 2020[70]). The effects of disinformation can be persistent. One study from the United States found that exposure to misinformation negatively influenced attitudes and intentions around mask wearing and although debunking false claims partially improved these, the gains disappeared under prolonged exposure (Mourali and Drake, 2022[71]).
- **Social and cultural norms** also come into play. Individuals often look to one another and their communities for cues on whether to follow public health guidance. One recent survey spanning 115 countries reinforced this point, demonstrating that individuals were more likely to comply with pandemic guidelines when they thought that people in their close social circle also did (Tunçgenç et al., 2021[72]). Cultural context also matters. For example, Japan entered the COVID-19 pandemic with a long-standing cultural acceptance of mask-wearing, rooted in decades of routine use during seasonal illnesses. Japan was one of the last countries to ease mask-wearing guidelines during

the COVID-19 pandemic, but even after the mask-wearing requirements were lifted in mid-March 2023, many people continued to wear them voluntarily (Suzuki et al., 2024[73]).

- **Trust in institutions and health authorities** emerged as a critical determinant of people's propensity to follow public health guidance during outbreaks. Several recent studies showed that higher levels of trust during the COVID-19 pandemic were positively correlated with the propensity to adhere to public health guidance. For example, one study showed that European countries where citizens expressed higher levels of trust in political authorities prior to the pandemic achieved higher rates of compliance with physical distancing measures (Bargain and Aminjonov, 2020[74]). Another review showed that individuals who trusted government authorities were shown to be more likely to follow COVID-19 guidelines (Moran et al., 2021[59]). By contrast, mistrust or low confidence in institutions is associated with reduced compliance (Kisa and Kisa, 2025[75]).

7.4. Estimating the health and economic consequences of NPIs

7.4.1. The OECD model aims to replicate how decision makers manage disease outbreaks in real time

The analysis in Chapter 3 suggested that, in five unmitigated potential pandemic outbreak scenarios, the 51 OECD, EU/EEA and G20 countries included in the analysis would face considerable impact on population health, as well as tremendous pressure on health systems and contraction of their GDP. Building on this analysis, this chapter examines the extent to which these deleterious impacts can be curbed by scaling up selected NPIs, using the OECD Strategic Public Health Planning (SPHeP) model for PPR (Box 7.4).

Box 7.4. The NPIs included in the OECD analysis can counter the health and economic impacts of pandemic outbreaks

The OECD analysis examines the effectiveness of eight NPIs that can help limit the negative health and economic of outbreaks

Table 1.1 outlines the main characteristics of the NPIs included in the analysis. Each intervention is incorporated into the model through a mechanism that reflects how it acts on disease transmission and these mechanisms differ across measures:

- Community-based IPC measures (e.g. hand hygiene, mask use, indoor ventilation) reduce the probability that a given physical contact results in transmission and their effectiveness estimates were extracted from literature
- Quarantine measures reduce the community contacts of symptomatic individuals, which in turn, lowers the number of secondary infections.
- Measures that reduce interactions in specific settings (e.g. teleworking policies, domestic and international travel restrictions, temporary school closure) were modelled by adjusting the social contact matrix within the OECD model (Chapter 3). For example, scaling up teleworking policies would trigger a reduction in physical interactions in the OECD model in workplace settings, whereas school closures would limit physical interactions in school settings, as well as physical interactions among parents whose occupations do not allow teleworking (Dauvin and Sampognaro, 2021[76]). For parents who can telework, productivity is assumed to decline by half.

The main advantage of this approach is that it provides a systematic and transparent way to capture how different interventions alter patterns of physical interactions (i.e. workplaces, schools, households, community spaces). In doing so, it improves comparability across interventions, ensures internal consistency in how behavioural changes are represented and enables assessments of how targeted reductions in physical contacts can influence the overall trajectory of an outbreak.

Table 7.1. Summary of key characteristics of the NPIs included in the OECD analysis

Intervention	Key characteristics	Effectiveness	Target population	How the intervention affects disease transmission in the OECD SPHeP-PPR model
Community-based IPC measures	• Community-based IPC measures are generally considered an effective tool to tackle infections • High public compliance is crucial to generate substantial benefits to population health and the economy	Hand hygiene: RR = 0.89, (95%CI: 0.83 – 0.94) based on a Cochrane review by (Jefferson et al., 2023[77]) Mask wearing: RR = 0·56, (95%CI: 0.40-0.79) based on a meta-analysis by (Chu et al., 2020[8]) Indoor ventilation: 23.5% relative reduction in infections (OECD estimates based on evidence from (Buonanno et al., 2022[78]) and (CDC, 2021[79]) The effectiveness estimates take into account considerations around pathogen type and transmission pathway of the disease	General population	• Reduces the probability of onward transmission per contact by making interactions safer • Applied directly using the effectiveness estimates from the literature
Voluntary quarantine measures	• Voluntary quarantine refers to recommendations for symptomatic individuals to limit contact with others for a specified period • Quarantines have been shown to reduce the number of infections and deaths (Nussbaumer-Streit et al., 2020[10]) • Combining quarantines with NPIs have been suggested to have a greater protective impact on population health than implementing quarantines alone (Nussbaumer-Streit et al., 2020[10])	42% of symptomatic individuals are assumed to self-quarantine, based on an OECD review of the existing literature	Symptomatic infected individuals	• Reduces the community contacts of symptomatic infectious individuals which curtails the secondary infections they generate while infectious

Teleworking policies	• Teleworking helps curb the spread of an outbreak by limiting employee commuting • Teleworking was effective in curbing the spread of SARS-CoV-2 infections and has been instrumental in lifting physical distancing measures without inducing a rise in the number of new cases (Burzyński et al., 2021[34]).	Workplace interactions are reduced using the social contact matrix of the OECD SPHeP-PPR model	Working age population who is estimated to be able to telework, by sectors of the economy	• Limits contacts in the workplace to zero by scaling the workplace cells of the social contact matrix
Domestic travel restrictions	• Domestic travel restrictions have emerged as important means to control the spread of outbreaks • They help delay the spread of pathogens from geographic areas with high transmission rates to other areas with lower transmission	Domestic travel is reduced using the social contact matrix of the OECD SPHeP-PPR model	Domestic travellers	• Limits contacts with others in other regions within the same country
Mandatory quarantine measures	• Mandatory quarantine refers to the requirements for symptomatic individuals to isolate themselves for a fixed period	93% of symptomatic individuals are assumed to self-quarantine, based on an OECD review of the existing literature	Symptomatic infected individuals	• Reduces the community contacts of symptomatic infectious individuals which curtails the secondary infections they generate while infectious
Temporary school closures	• Closing schools can prevent transmission between infected and susceptible children/school staff • School closures reduce R_0 by 39-73% (Mendez-Brito, El Bcheraoui and Pozo-Martin, 2021[16])	Interactions in school settings, and for parents, are reduced using the social contact matrix of the OECD SPHeP-PPR model	Students, teaching staff and parents	• Limits contacts in the school settings to zero by scaling the workplace cells of the social contact matrix
International travel restrictions	• International travel restrictions, including quarantines when entering a country and border closures, have been frequently used to slow the spread of the outbreak across countries	International travel is reduced using the social contact matrix of the OECD SPHeP-PPR model	International travellers	• Limits arrival of new travellers from outside of the country
Lockdowns alone	• Lockdowns refer to a set of measures aimed to maintain a physical distance between people • Physical distancing measures were associated with 37-88% reductions in R_0, 44-96% reduction in the incidence of SARS-CoV-2 and 31-76% reduction in attributable mortality (Nussbaumer-Streit et al., 2020[10])	All social interactions within countries are assumed to be limited using the social contact matrix of the OECD SPHeP-PPR model, without any change in community-based IPC practices modelled.	General population except essential workers	• Limits contacts across all settings within the country to zero by scaling the workplace cells of the social contact matrix except for essential workers

The model reflects a scenario of implementation such that the modelled NPIs maintain constant effectiveness over the simulation period. Real-life adherence to such NPIs (e.g. hand hygiene) ebbs

and flows in the course of an outbreak due a number of factors Chapter 5). These fluctuations in adherence could influence the actual effectiveness of NPIs on the ground and are not captured in the current modelling framework. Although this aspect is not explicitly modelled, the intervention simulations are based on data from real-world settings, where estimates typically reflect suboptimal adherence among the general population.

The OECD model adopts a layered approach to mitigating the spread of outbreaks

In line with country experiences during the COVID-19 pandemic and available evidence, the OECD analysis organised NPIs into four levels that represent an escalation ladder that reflects the sequence in which a policymaker would progressively introduce more restrictive measures as an outbreak intensifies as follows:

- **The "Safer contact" package (level 1)** comprises community-based IPC measures (e.g. hand hygiene, mask use, improved indoor ventilation, good respiratory etiquette) and voluntary self-quarantine
- **The "Reduced contact" package (level 2)** includes all "Safer contact" measures and introduces tighter constraints on interpersonal contact, including expanded teleworking requirements and limits on domestic travel, with quarantines now mandatory.
- **The "Targeted closures and restrictions" package (level 3)** includes all previous measures and adds NPIs with a higher level of strictness, notably school closures and international border controls.
- **The "Lockdown alone" package (level 4)** represents the highest degree of stringency and involves strict lockdowns that sharply curtail population movement except for essential workers.

This ordering reflects the degree of disruption each measure imposes, understood not only as the effect on the daily life of the average individual but as the combination of how far a measure restricts daily activities and mobility and its associated economic cost. It mirrors the sequence in which countries typically escalated NPIs during the COVID-19 pandemic (Hale et al., 2021[7]). A higher level denotes a more restrictive measure, not necessarily one with a greater impact on transmission.

The OECD model applies these interventions cumulatively such that the activation of a higher-level measure assumes that all lower-level measures are already in place. Because the measures are applied cumulatively across four levels, the effectiveness of a given level is not a single pre-specified value but the combined effect of all measures active at that level. For comparison, the analysis also estimates the additional impact of introducing lockdown measures on top of these less stringent layers.

The OECD modelling approach is designed to simulate how real-world decision makers might make decisions dynamically during an outbreak

Across OECD and partner countries, the COVID-19 crisis prompted the rapid development of alert systems that were designed to track the trajectory of the outbreak and guide decisions on when to tighten or ease NPIs. These systems varied widely in the indicators they monitored and the thresholds that triggered policy action, but most combined data on infection rates, pressure on hospital and intensive care units and COVID-19-related mortality (Yang et al., 2021[80]). Several countries such as New Zealand, South Africa and the United Kingdom established national frameworks with three to five alert levels, each with specific combinations of epidemiological and health system metrics (UK Health Security Agency, 2022[81]; Resolve to Save Lives, 2020[82]). For example, South Africa incorporated both economic and health considerations into its framework, New Zealand's model centred primarily on public health protection.

The OECD model aims to replicate the approach that real-world policymakers would use when implementing NPIs. At the beginning of each simulated day, data from the previous three days is used to forecast the expected future trajectory of the outbreak. The forecasts are assumed to be gathered based on wastewater surveillance and include several indicators including population infection rate, hospital occupancy rate and mortality rates for the next two weeks. Based on these projections, *"virtual policymakers"* may decide to implement specific NPIs ranging from milder measures like community-based IPC (the "Safer contact" package) to more stringent actions such as lockdowns (the "Lockdown alone" package). Similar to real-world experiences, the OECD model used criteria for triggering the level of intervention, as follows:

- **"Safer contact" interventions (level 1)** are implemented when at least one among the following thresholds are reached: 0.5% infection rate, 10% of hospital beds that were unused at the beginning of the simulation become occupied by patients or 1 death per 100 000 population.
- **"Reduced contact" interventions (level 2)** are implemented when at least one among the following thresholds are reached: 1% infection rate, 30% of hospital beds that were unused at the beginning of the simulation become occupied by patients or 2.5 deaths per 100 000 population.
- **"Targeted closures and restrictions" interventions (level 3)** are implemented when at least one among the following thresholds are reached: 2% infection rate, 60% of hospital beds that were unused at the beginning of the simulation become occupied by patients or 5 deaths per 100 000 population.
- **The "Lockdown alone" package (level 4)** is implemented when at least one among the following thresholds are reached: 5% infection rate, 90% of hospital beds that were unused at the beginning of the simulation become occupied by patients or 10 deaths per 100 000 population.

The thresholds used to trigger each level of intervention are illustrative modelling parameters, chosen to operationalise a consistent and escalating decision rule within the analysis. Their values draw on the indicators and alert-level frameworks used by countries during the COVID-19 pandemic (Yang et al., 2021[80]; UK Health Security Agency, 2022[81]; Resolve to Save Lives, 2020[82]; OECD, 2021[83]). The selected thresholds are applied uniformly across the modelled scenarios such that differences in outcomes reflect the characteristics of each pathogen and of the NPIs, rather than differences in the decision rule. As such, the thresholds are informed by empirical experience and policy practice but are not intended as empirically validated operational triggers. Deploying such triggers in a specific national setting would require validation against the characteristics of the pathogen, the capacity of the health system and the relevant policy objectives.

When interventions are implemented in the community, they are assumed to directly influence the spread of the infection by reducing the average number of new cases generated by each infected person. To prevent interventions from toggling on and off, once a prediction triggers an intervention, that intervention is assumed to take effect without delay and to remain in place for a minimum period, even if the underlying indicators show a slight improvement. Similarly, for the same purpose, a minimum cooldown period is maintained after an intervention is lifted. It is also important to note that, as experienced during the COVID-19 pandemic, predictions about the outbreak's progression and the implementation of related policies may not always perfectly match the actual evolution of the outbreak. All this can result in policies being either slightly more or less stringent than necessary. For instance, lockdowns might be enforced earlier than required or extended longer than needed.

The OECD modelling considers the impacts of the NPIs across different sectors of the economy

The economic impact of NPIs depends not only on the stringency of the measures but also on the sectoral structure of the economy in which they are implemented. Because most of the modelled NPIs operate by reducing physical proximity, their costs are likely to fall most heavily on contact-intensive sectors (e.g. tourism, hospitality, retail and transport), while sectors that can continue to function through teleworking are comparatively insulated. This means the same NPI would affect GDP differently across countries, depending on the relative weight of these sectors. Accounting for these sector-specific effects is an important consideration in planning the implementation of NPIs in order to allow policymakers to anticipate where the economic burden will concentrate and to design and sequence measures in ways that limit disruption. As discussed in detail in Chapter 3, the OECD model is built on a sector-level input-output structure, therefore, it takes into account the sector-specific impacts of a given NPI in each country considering that country's economic composition.

Source: Dauvin and Sampognaro (2021[76]), "*Dans les coulisses du confinement : modelisation de chocs simultanes d'offre et de demande*", http://www.ofce.sciences-po.fr/pdf/dtravail/WP2021-05.pdf; Hale et al. (2021[7]), "*A global panel database of pandemic policies (Oxford COVID-19 Government Response Tracker)*", http://doi.org/10.1038/s41562-021-01079-8; Yang et al. (2021[80]), "*Design of COVID-19 staged alert systems to ensure healthcare capacity with minimal closures*", http://doi.org/10.1038/s41467-021-23989-x; UK Health Security Agency (2022[81]); "*Living safely with respiratory infections, including COVID-19*", https://www.gov.uk/guidance/living-safely-with-respiratory-infections-including-covid-19; Resolve to Save Lives (2020[82]), "*Staying Alert: Navigating COVID-19 Risk Toward a New Normal*", https://resolvetosavelives.org/wp-content/uploads/2025/01/Staying-Alert-Navigating-COVID-19-Risk-Toward-a-New-Normal.pdf.

7.4.2. Disease surveillance and early warning systems are the cornerstone of PPR efforts

Robust disease surveillance and early warning systems are a foundational pillar of PPR. Disease surveillance systems can detect anomalous morbidity, mortality and transmission patterns (e.g. by continuous monitoring of clinical, laboratory, genomic data) before they escalate into global crises. Early detection systems can shorten the time it takes to deploy NPIs while transmission is still geographically confined. In the course of outbreaks, surveillance data can further inform decision makers on threat severity, allocation of resources and the calibration of the implementation of NPIs by signalling whether the implementation of NPIs is effective or whether they warrant escalation or relaxation.

Disease surveillance and early warning systems have advanced significantly in recent years. Even before the COVID-19 pandemic, countries were increasingly transitioning from paper-based to digital platforms for disease surveillance. Yet, the pandemic accelerated the adoption of big data and AI to forecast outbreaks and monitor population mobility (WHO, 2023[84]). A pivotal advancement is real-time genomic surveillance,[1] allowing for the tracking of virus evolution; improved sequencer accessibility and cost-performance have enabled large-scale sequencing globally (Ibid). Genomic epidemiology is increasingly used for the surveillance of influenza, antimicrobial resistance and multidrug-resistant tuberculosis (Ibid). Other advancements such as metagenomic sequencing[2] also hold great promise for strengthening PPR capacity, as they allow for more rapid detection of known and previously unidentified pathogens compared to the traditional approaches (Roca-Umbert et al., 2025[85]).

There have been efforts at the international level to support disease surveillance capacity. For example, the WHO Hub for Pandemic and Epidemic Intelligence, established in 2021, launched the International Pathogen Surveillance Network in 2023, with the aim of accelerating progress in pathogen genomics and improving public health decision making (WHO, 2026[86]). Today, this network engages 268 formal member organisations across 93 countries.

7.4.3. Wastewater surveillance has emerged during COVID-19 as a useful tool to bolster disease surveillance capacity

Many pathogens are excreted in bodily fluids before and during active infection (Larsen et al., 2021[87]), meaning that traces of viral or bacterial material can be detected in wastewater even when individuals do not seek clinical care. By analysing wastewater samples for biological and chemical markers, public authorities can monitor community-level transmission trends in a way that is independent of testing behaviour or healthcare utilisation. During the COVID-19 pandemic, these advantages prompted many countries to expand their wastewater monitoring capacity as a means of supporting efforts to mitigate the outbreak (Naughton et al., 2021[88]; Loenenbach et al., 2024[89]).

Evidence from past outbreaks illustrates several pathways through which wastewater surveillance can enhance situational awareness:

- It can detect “silent” transmission of known diseases, including infections that may not yet be captured by clinical surveillance. For instance, polio transmission in Israel was identified through sewage monitoring in 2013, which was the first evidence of re-emergence since 1988 (Bonanno Ferraro et al., 2021[90]). Similarly, in Sweden, routine sampling in the Gothenburg region revealed norovirus genetic material two to three weeks before the first clinical cases were reported (Hellmér et al., 2014[91]).
- Wastewater surveillance can also serve as an early signal for novel threats and track transmission trends across communities, though its effectiveness depends on the pathogen and the outbreak context. Retrospective analyses of wastewater samples in Italy detected SARS-CoV-2 as early as December 2019, preceding confirmed local cases by roughly two months (La Rosa et al., 2021[92]). Studies from other settings have likewise found wastewater signals 6-41 days before clinical confirmation (Bonanno Ferraro et al., 2021[90]). Another study from Germany concluded that data gathered through wastewater surveillance during COVID-19 were also useful for indicating the trends in infection waves (Loenenbach et al., 2024[89]). Prior to COVID-19, wastewater surveillance has been used to detect trends in a number of pathogens such as poliovirus and norovirus (Hellmér et al., 2014[91]; Fattal and Nishmi, 1977[93]; Hovi et al., 2001[94]).
- Another advantage is that wastewater surveillance captures contributions from both symptomatic and asymptomatic infections, thereby providing a more comprehensive picture of disease circulation. This characteristic can support more accurate technical assessments, including the identification of potential hotspots, evaluation of the effectiveness of NPIs and refinement of targeted interventions (Bonanno Ferraro et al., 2021[90]), as was seen in many OECD countries during the COVID-19 pandemic (Box 7.5). In parallel, wastewater analysis can inform genomic monitoring. For example, a study from Michigan in the United States used wastewater samples collected from late 2020 onwards to track changes in the prevalence of SARS-CoV-2 variant genes, including Alpha, Delta and Omicron (Flood et al., 2023[95]).

Box 7.5. France used wastewater surveillance to support its pandemic response capacity

During the early stages of the COVID-19 pandemic, France established Obépine, a research consortium dedicated to wastewater analysis. Drawing on advanced analytical technologies, the consortium collected samples from roughly 200 wastewater treatment plants across France between the summer of 2020 and the spring of 2022. These samples underwent systematic laboratory analysis, enabling researchers to monitor viral circulation in real time and, by January 2021, generate insights covering more than 40% of the French population (Maréchal et al., 2021[96]).

Supported by the Ministry of Higher Education, Research and Innovation, Obépine provided valuable information on both the incidence of COVID-19 and the dominant variants circulating in the population. The system provided to offer important economic benefits, with estimates suggesting savings of around EUR 1 billion per month compared with relying solely on individual diagnostic testing. It is estimated that data and analysis obtained through Obépine facilitated anticipating changes in the epidemic curve one to two weeks earlier than traditional indicators (Maréchal et al., 2021[96]). The Obépine is developing tools to detect other priority pathogens (e.g. varying forms of influenza, respiratory syncytial virus, avian influenza, monkeypox virus etc.) (Sorbonne Universite, 2024[97]).

Source: Maréchal et al. (2021[96]), "*OBEPINE : une expérience française de suivi de l'épidémie de Covid-19 à travers les eaux usées*", http://doi.org/10.3406/bavf.2021.70970; Sorbonne Universite (2024[97]),"*Anticipating future epidemics with OBEPINE+*", https://www.sorbonne-universite.fr/dossiers/sante-globale/anticiper-les-futures-epidemies-grace-obepine.

Despite these advantages, wastewater surveillance also has important limitations:

- While data gathered through wastewater surveillance can shed light on the trends of disease transmission, it is difficult to translate these trends into case numbers. The linkages between the viral signal and the true number of infections could be confounded by a number of factors (Wang et al., 2026[98]), including uncertainty around *how much* and *when* individuals shed pathogens; decay and dilution within sewer networks, for example, due to rainfall; travel time and methodological variation in sampling, extraction and qualification practices (Li et al., 2021[99]).
- Wastewater surveillance could become less reliable when a disease is rare or when the sewer network serves a large population. In these cases, the amount of pathogen that could be detected in the wastewater samples could be too small, resulting in false negatives even while the disease is still spreading (Ahmed et al., 2022[100]). More frequent sampling and more sensitive tests reduce this risk but cannot remove it.
- Comparability of data across sites and laboratories could be hindered in the absence of standardised protocols and methods, which in turn, could complicate the conversion of measures into prevalence estimates and the comparison of results between catchment areas (Davis et al., 2023[101]; Wilhelm et al., 2023[102]; Aßmann et al., 2025[103]).
- Since wastewater surveillance aggregates data across a catchment area, it cannot identify which individuals are infected nor readily disaggregate signals by age, risk group or setting (National Academies of Sciences, Engineering, and Medicine, 2023[104]). Considering this limitation, it can complement, but cannot replace, clinical-based surveillance.
- Wastewater surveillance presupposes connection to centralised sewer infrastructure. Many low- and middle-income countries rely on non-sewered sanitation (e.g. latrines, septic tanks and open drains), which in turn limits the feasibility of conventional sampling-based approaches and risks widening the global surveillance gap (Li et al., 2021[99]; Shrestha et al., 2021[105]). In high-income settings, unconnected populations may fall outside monitored catchment areas.

Considering the real-world experiences from OECD countries and the emerging evidence base, the OECD assessment integrated wastewater surveillance in its modelling framework such that it is assumed that decisions on implementing the selected NPIs are guided by wastewater-based surveillance (Box 7.6).

Box 7.6. Wastewater surveillance can serve as a valuable tool for supporting disease surveillance systems

The OECD analysed how integrating wastewater surveillance could enhance efforts to control outbreaks across 51 OECD, EU/EEA and G20 countries. The assessment compared the effectiveness of each NPI level described in Box 7.4 under two surveillance approaches:

- **Clinical surveillance-based approach**: The model relied solely on clinical data, using the previous three days of reported hospitalisation and mortality to forecast transmission and health outcomes over the subsequent two weeks. This mirrors approaches commonly used in OECD countries during the COVID-19 pandemic (Yang et al., 2021[80]).
- **Clinical surveillance coupled with wastewater-based approach**: The same forecasting framework was applied but projections were additionally informed by wastewater surveillance, providing insights into the underlying number of infections circulating in the community.

The OECD analysis indicates that integrating wastewater surveillance can enhance the effectiveness of both NPIs and lockdown policies within the first nine months of the outbreak (Figure 7.8). In a coronavirus-like outbreak, guiding the “Safer contact” package with wastewater data could prevent approximately 41% of deaths compared with relying solely on clinical surveillance. The gains increase under the “Reduced contact” package, with deaths averted rising to about 51%. Even the “Lockdown alone” package becomes more effective when supported by wastewater surveillance, reducing mortality by around 73% relative to lockdowns implemented based on clinical data alone. These improvements likely reflect several underlying mechanisms, most notably the greater ability to anticipate the course of the epidemic and deploy measures earlier. Acting before transmission accelerates enhances the impact of interventions, while more timely information also supports earlier easing of restrictions, thereby shortening the period in which populations and economies face stringent controls.

Figure 7.8. Wastewater surveillance accentuates the protective impacts of NPIs in a coronavirus-like outbreak

Share (%) of deaths averted by clinical surveillance coupled with wastewater surveillance that would have otherwise occurred using clinical-surveillance based alone, by levels of NPI package, during a coronavirus-like outbreak



Note: "Safer contact" package = community-based IPC and limited quarantine measures; "Safer contact" package &LD ("Safer contact" package with lockdown) = community-based IPC, voluntary quarantine measures and lockdowns. "Reduced contact" package = community-based IPC, mandatory quarantine measures, promoting teleworking and introducing restrictions on domestic travel; "Targeted closures and restrictions" package = community-based IPC, mandatory quarantine measures, promoting teleworking, introducing restrictions on domestic travel, school closures and international travel restrictions. "Lockdown alone" package severely limits mobility, permitting movement only for essential workers. In the coronavirus outbreak, lockdowns are not triggered once the "Reduced contact" package is in place. This is because once these interventions are activated, the simulated outbreaks never reach the threshold values listed earlier to trigger lockdowns.
Source: Analysis is based on the OECD SPHeP-PPR model.

StatLink https://stat.link/9z6ulw

As NPIs become more effective when their implementation is guided by wastewater surveillance, the need for prolonged lockdowns declines sharply

Across the three respiratory outbreak scenarios, incorporating wastewater surveillance as a complimentary monitoring tool into the "Targeted closures and restrictions" packages significantly reduces pressure on both the population and healthcare systems. Under these conditions, the additional use of lockdowns becomes largely unnecessary for maintaining control of transmission. In contrast, for Ebola-like and measles-like outbreaks, both characterised by higher severity or transmissibility, policymakers may still need to consider deploying lockdowns alongside other NPIs, depending on the specific health objectives and healthcare system capacity. Even in these situations, however, reliance on wastewater surveillance greatly reduces the duration of lockdowns, with the number of days required falling by more than 90% compared with strategies informed solely by clinical surveillance.

Source: Yang et al. (2021[80]), *"Design of COVID-19 staged alert systems to ensure healthcare capacity with minimal closures"*, http://doi.org/10.1038/s41467-021-23989-x.

7.5. Results

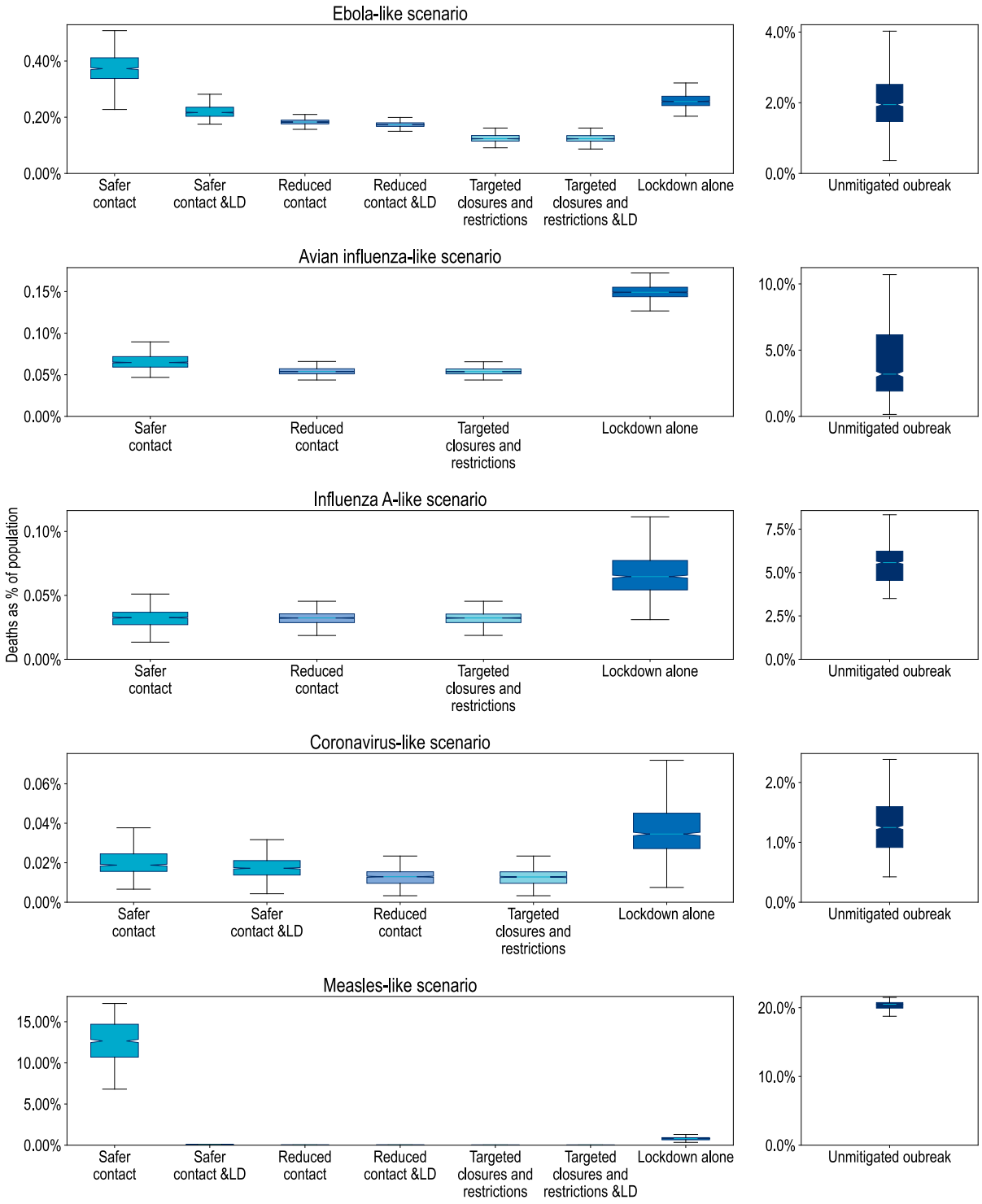
7.5.1. Impact on population health

Early and well-implemented community-based IPC measures form the foundation of an effective PPR response

The OECD analysis suggests that across all outbreak scenarios, early and well-implemented NPIs would markedly reduce the mortality burden of the pandemic (Figure 7.9). The least stringent package, “Safer contact”, which involves community-based IPC measures and voluntary quarantines, could reduce deaths substantially, with the proportion of the population losing their lives falling to 0.4% of the population on average in an Ebola-like outbreak across the 51 countries included in the analysis. This corresponds to preventing around 80% of deaths that would have occurred in an unchecked Ebola-like pandemic (see Annex Figure 7.A.1). In outbreaks caused by agents similar to avian influenza, influenza A and coronavirus, the “Safer contact” package on its own would considerably ease the pressure on healthcare systems and in many cases, the potential health gains from escalating to stricter NPIs would be minimal. In contrast, the “Safer contact” package alone would have limited impact on preventing mortality in the case of a highly infectious agent such as measles, where they would avert only around 40% of deaths that would have occurred in an unmitigated outbreak.

Figure 7.9. Early and well-implemented NPIs save lives

Percentage of the population that lost their lives in 51 countries included in the analysis, by scenario



Note: “Safer contact” package = community-based IPC and limited quarantine measures; “Safer contact” package &LD (“Safer contact” package with lockdown) = community-based IPC, voluntary quarantine measures and lockdowns. “Reduced contact” package = community-based IPC, mandatory quarantine measures, promoting teleworking and introducing restrictions on domestic travel; “Reduced contact” package &LD (“Reduced contact” package with lockdown) = community-based IPC, mandatory quarantine measures, promoting teleworking and introducing restrictions on domestic travel and lockdowns; “Targeted closures and restrictions” package = community-based IPC, mandatory quarantine measures, promoting teleworking, introducing restrictions on domestic travel, school closures and international travel restrictions. “Targeted closures and restrictions” package &LD (“Targeted closures and restrictions” package with lockdown) = community-based IPC, mandatory quarantine measures, promoting teleworking, introducing restrictions on domestic travel, school closures and international travel restrictions and lockdowns. “Lockdown alone” package severely limits mobility, permitting movement only for essential workers. In the OECD analysis, the lockdowns were not triggered in avian influenza-like and influenza A-like outbreak scenarios once the “Safer contact” package is implemented and in the coronavirus outbreak once the “Reduced contact” package is in place. This is because once these interventions are activated, the simulated outbreaks never reach the threshold values listed earlier to trigger lockdowns.
Source: Analysis is based on the OECD SPHeP-PPR model.

As discussed earlier, the estimated effectiveness of the “Safer contact” package, which consists primarily of behavioural actions such as community-based IPC interventions (e.g. hand washing) and voluntary quarantine, depends heavily on the level of buy-in from the community. Although the OECD model does not explicitly simulate variations in compliance, the OECD analysis incorporates evidence from real-world settings, where adherence to these measures is shown to be often suboptimal. A more detailed examination of the determinants of compliance with community-based IPC interventions, along with policy options to strengthen community engagement, is presented in Chapter 5.

The results from the OECD model suggest that in avian influenza-like and influenza A-like outbreaks, lockdowns would not be triggered in most countries if the “Safer contact” package is already being implemented (Figure 7.9). This reflects the finding that adding lockdowns on top of the “Safer contact” package offers limited additional measurable benefit to population health and to healthcare systems, indicating that once transmission is substantially reduced through the “Safer contact” package, lockdowns yield minimal returns. Lockdowns would be triggered in Ebola-like and coronavirus-like outbreaks, and the additional health gains they bring on top of those delivered by the “Safer contact” package would be around 7 percentage points (p.p.) gain in deaths averted in the Ebola-like outbreak and less than 1 p.p. gain in the coronavirus-like outbreak. This pattern would differ sharply in the measles-like outbreak where the extremely high transmission of the pathogen means that lockdowns could produce large additional health gains when they are combined with the “Safer contact” package. Still, even in these settings, greater reductions in mortality could be achieved by escalating to the “Reduced contact” package, rather than by adding lockdowns to the “Safer contact” package.

Layering community-based IPC measures with teleworking, ensuring essential travel and stricter quarantine requirements delivers notable health gains in many cases

Supplementing community-based IPC measures with teleworking promotion, domestic travel restrictions and mandatory quarantine requirements could bring notable gains in specific outbreak contexts, particularly in Ebola-like and measles-like pandemics. In the Ebola-like scenario, escalating to the “Reduced contact” package would help curb the remaining chain of transmission that the “Safer contact” package alone could not mitigate (Figure 7.9). Under the “Reduced contact” package, an average of 90% of deaths that would have occurred in an unchecked pandemic could be avoided, compared to around 80% of deaths that would be averted under the “Safer contact” package alone. In the measles-like scenario, escalating to the “Reduced contact” package would substantially strengthen pandemic response efforts and would help avoid nearly all deaths that would have occurred in an unmitigated outbreak.

The OECD analysis suggests that adding lockdowns once the “Reduced contact” package is activated would provide little additional measurable benefit to population health and the healthcare systems in outbreaks resembling avian-influenza, influenza-A and coronavirus. As a result, lockdowns would not be triggered in most countries included in the OECD analysis in these scenarios. Even in scenarios where lockdowns are triggered such as the Ebola-like and measles-like outbreaks, their added value would

remain marginal. In these two scenarios, adding lockdowns to the "Reduced contact" package would generate less than 1% additional reduction in the number of deaths averted.

As an additional analysis, the OECD model evaluated the potential impact of using TTT strategies as part of the "Reduced contact" package (Box 7.7).

Box 7.7. Testing, tracing and tracking efforts are a core tool in the pandemic response toolbox

Testing, tracing and tracking form a core pillar of public health strategies to mitigate the spread of outbreaks. The objective of TTT systems is to detect infections as early as possible, break chains of transmission and target public health interventions where they can have the greatest impact. Variations of the TTT approach have been deployed in nearly every recent major outbreak, including the 2002-2003 SARS-CoV outbreak, the 2009 H1N1 influenza pandemic, the 2012 MERS-CoV outbreak, the 2014-2016 Ebola epidemic, the 2015-2016 Zika outbreak and, most recently, COVID-19 (Nussbaumer-Streit et al., 2020[10]). While the design of TTT systems differs across countries and pathogens, the overall strategy typically consists of three components as follows:

- **Testing** serves as the foundation for all TTT activities, because it enables public health authorities to identify infections early, including among individuals with mild or no symptoms. During COVID-19, for example, widespread PCR and antigen testing supported county efforts to isolate and treat infected individuals (WHO, 2020[106]). Data gathered through testing provide essential information on transmission intensity, which can help determine the level and timing of NPIs (OECD, 2020[107]). Diagnostic results typically feed into laboratory-based genomic sequencing which helps track the circulation of variants of the pathogen in the community.
- **Tracing** refers to identifying and contacting individuals who have been exposed to confirmed cases so they can be rapidly isolated, tested or monitored. When implemented promptly and systematically, contact tracing can substantially reduce onward transmission. During the early phases of COVID-19, Korea, for instance, developed a crowd-source contact tracing technology which entailed the use of mobile phone data, security camera records and credit and debit card (OECD, 2020[107]). Free smartphone apps indicated the location of cases and text message updates were sent to provide updates on the new local cases.
- **Tracking** and surveillance systems, whether clinical, laboratory-based, syndromic or environmental, provide essential information on how disease activity evolves over time. During COVID-19, many countries expanded their tracking and surveillance systems (e.g. combining clinical and wastewater monitoring) to gather data from complementary data systems in order to get a more complete picture of transmission dynamics.

Despite their important benefits, TTT strategies have limitations. Previous studies suggest that the TTT strategies are most effective in the early phases of an outbreak when case numbers remain manageable and transmission chains can still be identified and followed (Kwok et al., 2019[108]; Juneau et al., 2023[109]; Nussbaumer-Streit et al., 2020[10]). Their effectiveness diminishes when a large proportion of transmission occurs asymptomatically (Pozo-Martin et al., 2023[110]) or when testing capacity is constrained (Guy et al., 2025[111]). Diagnostic testing is also less informative for pathogens with very short incubation periods or those requiring specialised laboratory procedures such as Ebola or Nipah virus (Nussbaumer-Streit et al., 2020[10]). Delays in obtaining test results further undermine the ability to act quickly and unequal access to testing can lead to systematic under-detection in certain population groups (Guy et al., 2025[111]). Evidence from modelling studies shows that once an outbreak grows unchecked for more than two to three days, it becomes extremely difficult to stop it through contact tracing alone (Juneau et al., 2023[109]).

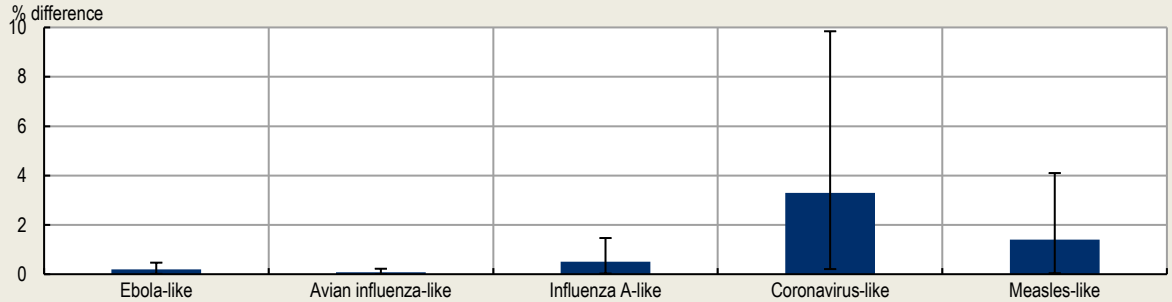
The OECD assessed the effectiveness of TTT strategies in supporting efforts to mitigate the spread of outbreaks

To assess the potential of TTT in the context of future pandemics, a nationwide TTT programme was modelled in which 10% of the population is tested each week, including those that do not show any symptoms and all positive cases are immediately isolated without exception. This represents a strong assumption given the real-world experiences and should be regarded as an upper-bound estimate of the potential of TTT strategies when fully scaled and unconstrained. For example, during the COVID-19 pandemic, Singapore, one of the countries that relied most heavily on a large-scale TTT strategy in the early days of the outbreak, conducted approximately 2 200 molecular diagnostic tests each day, equivalent to testing approximately 0.27% of the population per week (OECD, 2020[107]). The modelled TTT programme is also assumed to include integrated tracing and tracking functions whereby trained contact tracers were available at the outset of the pandemic and surveillance systems were in place to inform public health action in a timely manner. The TTT strategy is assumed to be triggered concurrently with the "Safer contact" package. The thresholds for activating the NPI packages remained the same as those highlighted in Box 7.4.

Figure 7.10 quantifies the incremental impact of TTT by showing the percentage difference in daily infections with and without TTT integrated into the "Safer contact" package. It shows that the reductions in daily infections attributable to TTT would range, on average, from 0.08% in the avian influenza-like scenario to 3.3% for the coronavirus-like outbreak. This result suggests that while TTT can enhance mitigation efforts, it should be viewed as a complementary rather than primary mitigation strategy once community transmission has become widespread. The relatively modest protective estimated impact of TTT is in part because "Safer contact" measures (e.g. community-based IPC and voluntary quarantines) already act on many of the transmission pathways that TTT is designed to interrupt. For instance, when some of the symptomatic individuals voluntarily limit their physical contacts, as was modelled in the OECD analysis as one of the "Safer contact" measures, the number of secondary infections that TTT would otherwise need to identify and manage would already be reduced. Similarly, greater adherence to community-based IPC measures would lower the probability of onward transmission, which in turn would leave fewer infections for TTT to identify. At the same time, once widespread community transmission is established, many physical contacts with infected individuals are likely to occur before individuals would be detected through testing or identified through tracing. The time lag between infection, the onset of symptoms, testing, tracing and tracking would limit the marginal effect of TTT when the "Safer contact" package is already in place and actively reducing contact opportunities.

Figure 7.10. TTT strategy is beneficial, but its impact on the trajectory of the modelled outbreaks would be modest when NPIs are already in place

Percentage difference in daily infections with and without TTT integrated into the "Safer contact" package



Note: "Safer contact" package = community-based IPC and voluntary quarantine measures; TTT = testing, tracing and tracking; Whiskers represent the 5th and 95th quantiles in all simulations across countries.
Source: Analysis is based on the OECD SPHeP-PPR model.

StatLink https://stat.link/v4sy90

While the TTT strategy may offer limited population-wide protective effects once community transmission becomes widespread, it can still generate important benefits as a targeted risk mitigation tool by focussing on infections among vulnerable populations (e.g. the older adults, immunocompromised individuals) and in high-risk settings. For example, one recent literature review concluded that during the COVID-19 pandemic, universal testing of residents and staff in long-term care facilities at regular intervals proved critical for early detection of presymptomatic and asymptomatic cases, especially when community prevalence was high (Dykgraaf et al., 2021[112]). Similar evidence from hospitals shows that maintaining TTT strategies during periods of high community transmission can help prevent nosocomial transmission (Velen et al., 2021[113]; Pozo-Martin et al., 2023[110]).

Source: Nussbaumer-Streit et al. (2020[10]), *"Quarantine alone or in combination with other public health measures to control COVID-19: a rapid review"*, http://doi.org/10.1002/14651858.cd013574.pub2; WHO (2020[106]), *"Laboratory testing for 2019 novel coronavirus (2019-nVOC) in suspected human cases. Interim guidance"*, https://iris.who.int/server/api/core/bitstreams/223676aa-d552-4a61-9a69-ba84f48babd6/content; OECD (2020[107]), *"Testing for COVID-19: A way to lift confinement restrictions"*, http://doi.org/10.1787/89756248-en; Kwok et al. (2019[108]); *"Epidemic Models of Contact Tracing: Systematic Review of Transmission Studies of Severe Acute Respiratory Syndrome and Middle East Respiratory Syndrome*", http://doi.org/10.1016/j.csbj.2019.01.003; Juneau et al. (2023[109]), *"Effective contact tracing for COVID-19: A systematic review"*, http://doi.org/10.1016/j.gloepi.2023.100103; Guy et al. (2025[111]), "*Contact tracing strategies for infectious diseases: A systematic literature review*", http://doi.org/10.1371/journal.pgph.0004579; Juneau et al. (2023[109]), *"Effective contact tracing for COVID-19: A systematic review"*, http://doi.org/10.1016/j.gloepi.2023.100103; Velen et al. (2021[113]), *"The effectiveness of contact investigation among contacts of tuberculosis patients: a systematic review and meta-analysis*", http://doi.org/10.1183/13993003.00266-2021; Pozo-Martin (2023[110]), *"Comparative effectiveness of contact tracing interventions in the context of the COVID-19 pandemic: a systematic review"*, http://doi.org/10.1007/s10654-023-00963-z.

Closing schools and restricting international travel provides marginal health benefits if less stringent NPIs are already well-implemented

Adding even stricter controls such as school closures and international travel restrictions (i.e. the "Targeted closures and restrictions" package) while the "Reduced contact" package is already implemented would bring incremental health gains in all pandemic scenarios except the Ebola-like outbreak, with the additional reduction in deaths averted remaining well below 1% in most cases (Figure 7.9). In the Ebola-like outbreak, the estimated gains would be modest, with the proportion of the population dying declining, on average, from 0.2% to 0.1% of the population.

Much like with less stringent interventions, in most cases, adding lockdowns on top of the "Targeted closures and restrictions" package would offer modest health gains only in the Ebola-like and measles-like outbreaks and little measurable health gains in the other outbreak scenarios. This finding suggests that while progressively layering interventions strengthens outbreak response, the additional health benefits would start tapering off once local transmission has already been curbed through the "Reduced contact" package. This means that more stringent measures continue to save lives, but with declining returns.

Lockdowns alone produce the least protection for population health

The OECD model suggests that in most scenarios, the "Lockdown alone" package would produce the smallest reduction in mortality. In all scenarios, escalating to the "Reduced contact" package could reduce more deaths compared with the "Lockdown alone" package. In an Ebola-like outbreak, the share of the population dying would fall from 0.3% on average under lockdowns to 0.18% under the "Reduced contact" package. The difference would be modest in a coronavirus-like (0.04% vs. 0.01%) scenario and more pronounced in avian influenza-like (0.15% vs. 0.07%) and influenza A-like (0.07% vs. 0.03%) outbreaks and measles-like (0.8% vs. 0.03%) scenarios. These findings suggest that lockdowns should be considered in certain situations, for example when compliance with community-based IPC interventions is low, to achieve the health-related goals.

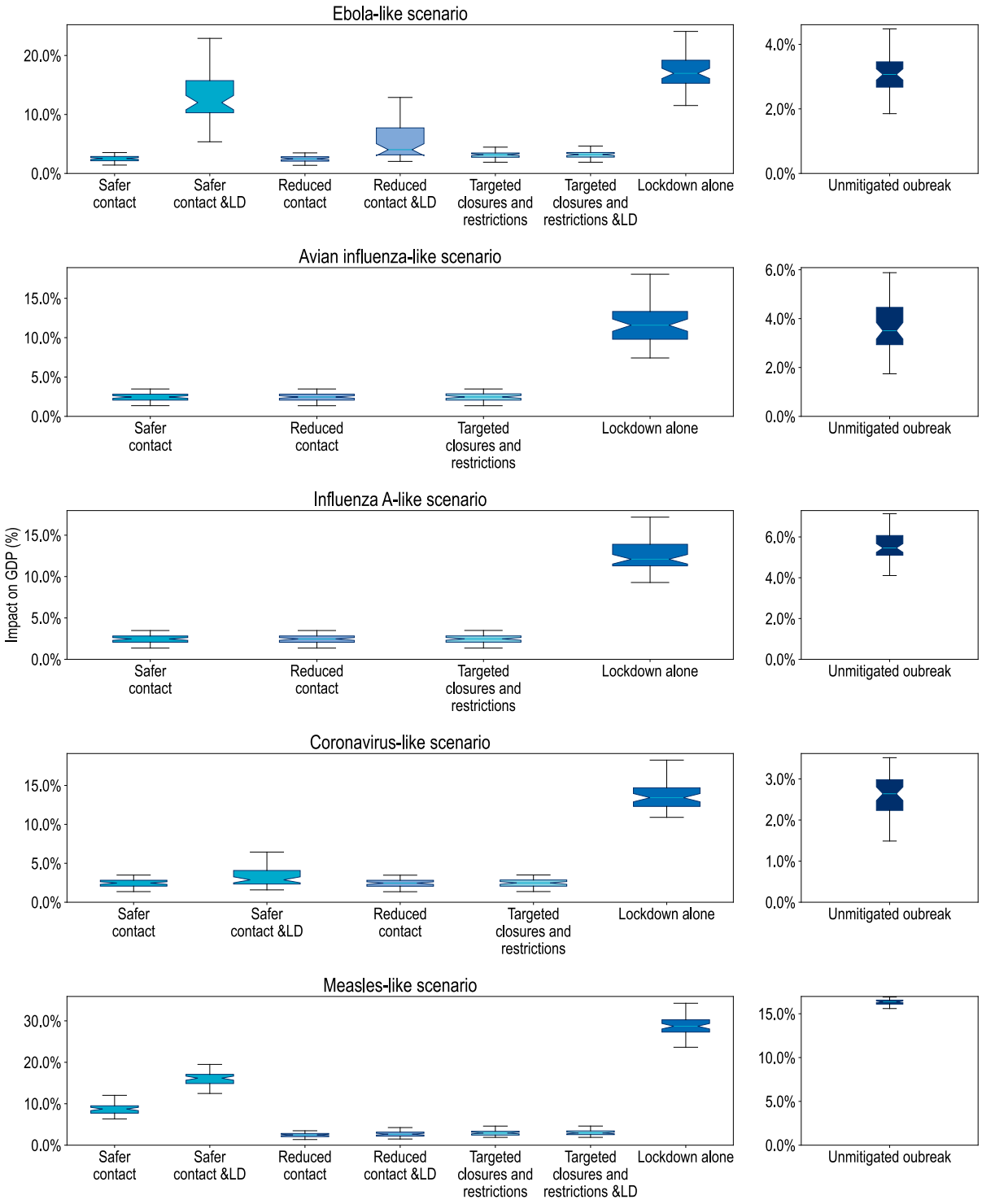
7.5.2. Impact on the economy

Community-based IPC measures and limited quarantines result in moderate losses in economic output

The OECD analysis suggests that implementing the “Safer contact” package alone would result in modest contractions in GDP in most cases (Figure 7.11). In outbreaks caused by agents similar to avian influenza, influenza A and coronavirus, GDP losses would average around 2.5%. In more severe scenarios such as the Ebola-like and measles-like outbreaks, the economic contraction could average 2.6% and 8.6% of GDP respectively, smaller than the economic losses associated with unmitigated outbreaks (i.e. 3.4% and 16.2% loss in GDP respectively).

Figure 7.11. NPIs reduce the steep economic impact of outbreaks

Percentage drop in GDP, by scenario for 50 countries included in the analysis



Note: “Safer contact” package = community-based IPC and limited quarantine measures; “Safer contact” package &LD (“Safer contact” package with lockdown) = community-based IPC, voluntary quarantine measures and lockdowns. “Reduced contact” package = community-based IPC, mandatory quarantine measures, promoting teleworking and introducing restrictions on domestic travel; “Reduced contact” package &LD (“Reduced contact” package with lockdown) = community-based IPC, mandatory quarantine measures, promoting teleworking and introducing restrictions on domestic travel and lockdowns; “Targeted closures and restrictions” package = community-based IPC, mandatory quarantine measures, promoting teleworking, introducing restrictions on domestic travel, school closures and international travel restrictions. “Targeted closures and restrictions” package &LD (“Targeted closures and restrictions” package with lockdown) = community-based IPC, mandatory quarantine measures, promoting teleworking, introducing restrictions on domestic travel, school closures and international travel restrictions and lockdowns. “Lockdown alone” package severely limits mobility, permitting movement only for essential workers. In the OECD analysis, the lockdowns were not triggered in avian influenza-like and influenza A-like outbreak scenarios once the “Safer contact” package is implemented and in the coronavirus outbreak once the “Reduced contact” package is in place. This is because once these interventions are activated, the simulated outbreaks never reach the threshold values listed earlier to trigger lockdowns.
Source: Analysis is based on the OECD SPHeP-PPR model.

Layering teleworking policies, essential travel and stronger quarantines on top of community-based IPC measures helps cushion the economic shock in many cases

In most cases, adding teleworking, domestic travel restrictions and stricter quarantine measures (the “Reduced contact” package) would lead to minor reductions in the overall average contraction in GDP compared with the “Safer contact” package alone. In Ebola-like and coronavirus-like outbreaks, the average GDP losses would fall slightly from 2.6% to 2.5% and from just over 2.5% to just below 2.5% respectively, once the “Reduced contact” package is introduced. In the measles-like outbreak, the reduction in the GDP loss would be higher, from 8.6% to 2.5%. In comparison, in the avian-influenza and influenza A-like outbreaks, the change in the average GDP loss would remain well below 1%.

This finding reflects the crucial role of promoting teleworking policies and maintaining domestic travel for essential workers while quarantining the sick during outbreaks. By enabling businesses that rely less on physical contact to continue operations through teleworking arrangements and maintaining controlled domestic travel for essential sectors, introducing the “Reduced contact” package could potentially prevent the abrupt halts in production and promote continuity of work, especially in service-oriented economies where digital connectivity allows activity to shift online. This finding aligns with lessons from the COVID-19 pandemic when in European economies, sectors in which teleworking was easier to scale up (e.g. finance and insurance) were hit less severely than those relying more heavily on personal contact (e.g. construction) (European Commission, 2021[114]).

Temporarily closing schools and limiting international travel deepens the economic impact of outbreaks if less stringent NPIs are already in place

Introducing school closures and limitations on international travel (i.e. the “Targeted closures and restrictions” package) would deepen the economic contraction compared to implementing the less stringent interventions (i.e. the “Reduced contact” package). This pattern is consistent across all outbreak types, including those resembling Ebola and measles where the average decline in GDP is estimated to rise from 2.5% to 3.1% and from 2.5% to 2.9% respectively. Introducing the “Targeted closures and restrictions” package could also deepen economic contraction in other outbreak scenarios though the adverse impact would be relatively smaller.

The OECD analysis suggests that the widening economic cost associated with the “Targeted closures and restrictions” package reflects the broader disruption caused by closing schools and limiting cross-border travel. As discussed in Box 7.4, closing schools, even temporarily, cuts the available labour supply and reduce the productivity of those who telework by shifting the childcare burden to parents, disrupting in-person education and related services. School closures would also have long-term negative consequences for human capital formation but these additional effects are not considered in this chapter given the time frame of the analysis focussing on the first nine months of outbreaks. In other words, any potential effects

in this area are expected to be minimal, if present at all. On the other hand, international travel limitations suppress high-value activities such as tourism, business travel, higher education inflows, affecting internationally exposed sectors of the economy.

Using lockdowns as a last resort comes with steep economic costs

Using lockdowns alone as a last resort could impose a significant economic penalty. The results from the OECD analysis suggest that when added to the "Safer contact" package, GDP contractions could deepen sharply from 2.6% to 12.5% in an Ebola-like outbreak and from 8.6% to 16.0% in a measles-like outbreak. Implemented alone, the economic fallout could be even more severe, with losses reaching 17.4% in Ebola-like and 12.7% in influenza A-like outbreaks. In the measles-like scenario, the average contraction in GDP would be 28.9%, though it should be noted that introducing lockdowns on top of the "Safer contact" package could considerably reduce the mortality impact of the outbreak in most cases as discussed earlier.

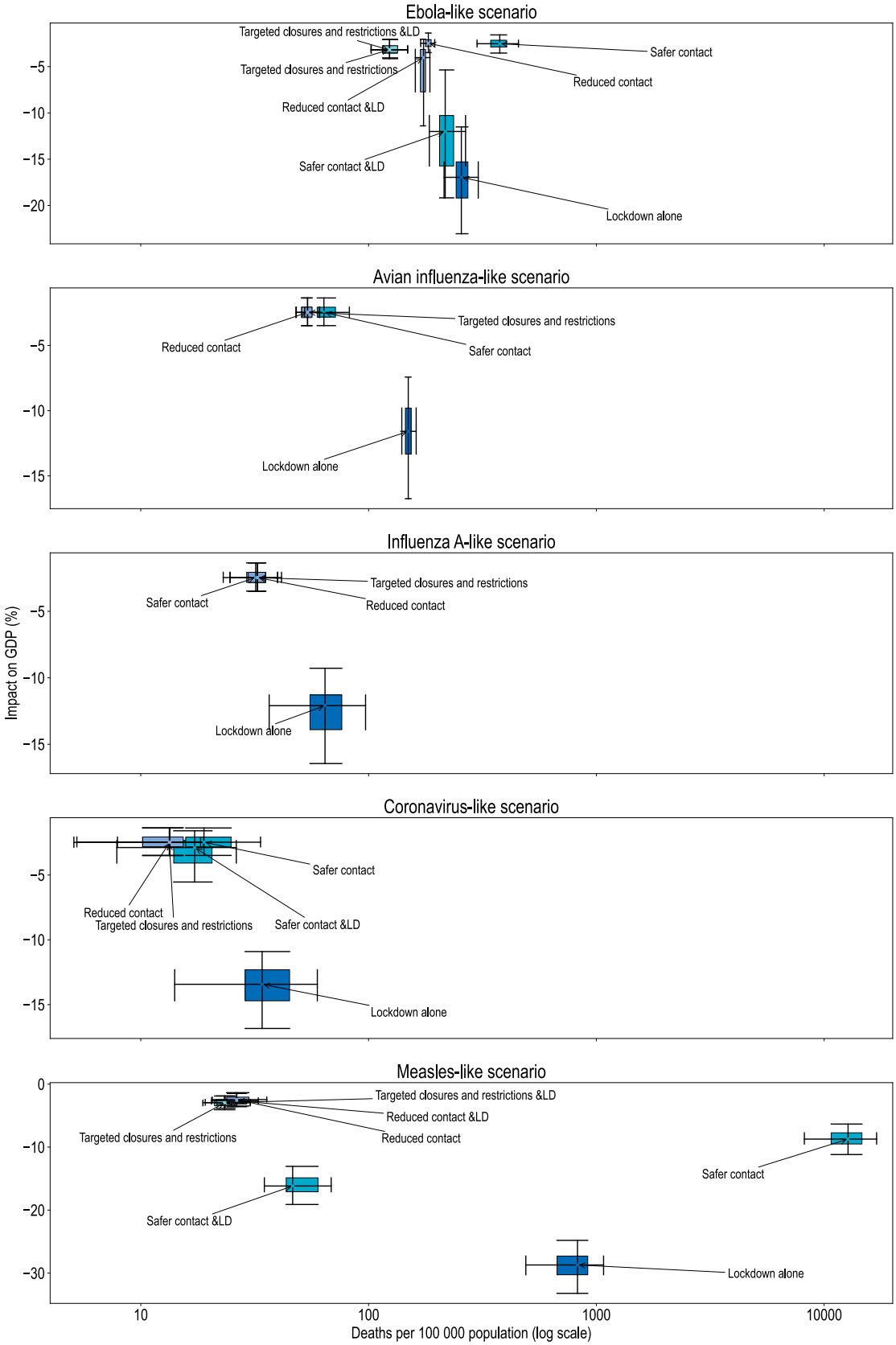
If lockdowns are implemented alone as a last resort measure and without implementing NPIs, the economic fallout would be more severe, with the contraction in GDP reaching 17.4% in Ebola-like, 11.7% in avian influenza-like, 12.7% in influenza A-like, 13.7% in coronavirus-like and 28.9% in measles-like outbreaks. In all outbreak scenarios, the average contraction of GDP under the "Lockdown alone" package is estimated to exceed that of unmitigated outbreaks, sometimes by a wide margin.

7.5.3. Health and economic co-benefits

In most cases, a layered approach involving community-based IPC, quarantines, promotion of teleworking and domestic travel restrictions offers a practical strategy to balance health and economic gains

Figure 7.12 shows the health and economic impact for the modelled NPI packages and across the five outbreak scenarios. Impact on population health (deaths per 100 000 population) is shown on the horizontal axis, while impact on GDP (% of GDP contracted) is reported on the vertical axis. The findings presented on the graph can be used to help prioritise interventions under the various scenarios, considering that interventions in the bottom left corner of each panel are those that, according to the simulation, would allow the lowest negative impact on population health and GDP. For example, if two NPI packages show a similar level of mortality, the one with lower impact on GDP would be the preferable option. Extending this concept further, the graph allows efficient frontiers to be designed for packages of interventions.

Figure 7.12. Distribution of impact on the economy compared to the number of deaths, by modelled NPI package, OECD, EU/EEA and G20 countries



Note: “Safer contact” package = community-based IPC and limited quarantine measures; “Safer contact” package &LD (“Safer contact” package with lockdown) = community-based IPC, voluntary quarantine measures and lockdowns. “Reduced contact” package = community-based IPC, mandatory quarantine measures, promoting teleworking and introducing restrictions on domestic travel; “Reduced contact” package &LD (“Reduced contact” package with lockdown) = community-based IPC, mandatory quarantine measures, promoting teleworking and introducing restrictions on domestic travel and lockdowns; “Targeted closures and restrictions” package = community-based IPC, mandatory quarantine measures, promoting teleworking, introducing restrictions on domestic travel, school closures and international travel restrictions. “Targeted closures and restrictions” package &LD (“Targeted closures and restrictions” package with lockdown) = community-based IPC, mandatory quarantine measures, promoting teleworking, introducing restrictions on domestic travel, school closures and international travel restrictions and lockdowns. “Lockdown alone” package severely limits mobility, permitting movement only for essential workers. In the OECD analysis, the lockdowns were not triggered in avian influenza-like and influenza A-like outbreak scenarios once the “Safer contact” package is implemented and in the coronavirus outbreak once the “Reduced contact” package is in place. This is because once these interventions are activated, the simulated outbreaks never reach the threshold values listed earlier to trigger lockdowns.
Source: Analysis is based on the OECD SPHeP-PPR model.

Some of the main take-aways from this analysis include:

- In all outbreak scenarios, introducing lockdowns alone would fall short of the health gains that could be achieved through the timely implementation of the “Reduced contact” package, while causing the highest levels of damage to the economy. Considering the detrimental impact that lockdowns have on society, the OECD analysis suggests that lockdowns can be avoided if other, less stringent but effective NPIs are implemented early and with high levels of buy-in from the general public.
- In most outbreak scenarios, adding lockdowns on top of the NPI packages offers limited health gains with considerably higher strain on economic performance. However, it is recognised that, in some cases, this may be the only viable solution to limit the health burden caused by an outbreak. For example, implementing the “Safer contact” package alone would lead to the highest level of average mortality in the case of an outbreak caused by a highly infectious measles-like pathogen. In an Ebola-like outbreak, adding lockdowns to the “Safer contact” package could also avert a considerable portion of deaths but at a substantially higher economic cost.
- In most scenarios, the model suggests that escalating to the “Targeted closures and restrictions” package would show limited gains for population health but higher economic costs compared with the “Reduced contact” package alone. Therefore, the introduction of the “Targeted closures and restrictions” package would become particularly appropriate in those circumstances where the primary focus is on minimising the health burden.

7.6. Conclusion

NPIs remain essential tools for protecting population health and the economy during outbreaks, when pharmaceutical interventions are not available. They were widely used during the COVID-19 pandemic across OECD, EU/EEA and G20 countries, though countries differed in how they designed and applied them. While NPIs offer clear health benefits, they can also generate unintended social and economic consequences, underscoring the need for policymakers to select measures that best balance health and economic objectives.

The OECD analysis shows that early and well-implemented NPIs can safeguard population health while also protecting the economy, with their effectiveness varying by outbreak scenario. In most cases, the least stringent NPIs (i.e. community-based IPC measures), layered with domestic travel restrictions and quarantines are sufficient to prevent the majority of deaths without imposing major economic costs. By contrast, relying on lockdowns alone, without the support of NPIs, is generally less effective and more damaging to the economy. The analysis also highlights the value of strengthening surveillance systems by integrating wastewater data with clinical indicators, which enhances the effectiveness of NPIs and reduces the likelihood and duration of lockdowns.

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Annex 7.A. Impact of non-pharmaceutical interventions

Annex Figure 7.A.1. Health impact of non-pharmaceutical interventions

Share of deaths (%) that would have otherwise occurred in unmitigated outbreaks, 51 OECD, EU/EEA and G20 countries



Note: “Safer contact” package = community-based IPC and limited quarantine measures; “Safer contact” package &LD (“Safer contact” package with lockdown) = community-based IPC, voluntary quarantine measures and lockdowns. “Reduced contact” package = community-based IPC, mandatory quarantine measures, promoting teleworking and introducing restrictions on domestic travel; “Reduced contact” package &LD (“Reduced contact” package with lockdown) = community-based IPC, mandatory quarantine measures, promoting teleworking and introducing restrictions on domestic travel and lockdowns; “Targeted closures and restrictions” package = community-based IPC, mandatory quarantine measures, promoting teleworking, introducing restrictions on domestic travel, school closures and international travel restrictions. “Targeted closures and restrictions” package &LD (“Targeted closures and restrictions” package with lockdown) = community-based IPC, mandatory quarantine measures, promoting teleworking, introducing restrictions on domestic travel, school closures and international travel restrictions and lockdowns. “Lockdown alone” package severely limits mobility, permitting movement only for essential workers. In the OECD analysis, the lockdowns were not triggered in avian influenza-like and influenza A-like outbreak scenarios once the “Safer contact” package is implemented and in the coronavirus outbreak once the “Reduced contact” package is in place. This is because once these interventions are activated, the simulated outbreaks never reach the threshold values listed earlier to trigger lockdowns.
Source: Analysis is based on the OECD SPHeP-PPR model.

Notes

[1] Genomic surveillance refers to the systematic sequencing and analysis of pathogen genomes to track how they spread, evolve and diversify over time.

[2] Metagenomic sequencing is the untargeted sequencing of all genetic material in a sample (e.g. host, bacterial, viral and fungal etc.) allowing the organisms present to be identified and characterised without prior isolation or assumption about what the sample contains, which makes it particularly valuable for detecting novel or unexpected pathogens.

8 Investing in pandemic preparedness and response capacities delivers dividends far beyond moments of crisis

This chapter provides an overview of the cost of investing in pandemic preparedness and response across 51 OECD, European Union/European Economic Area and Group of 20 countries, using the OECD Strategic Public Health Planning Costing Tool.

In Brief

Key messages

Investments in pandemic preparedness and response (PPR) pay twice: By reducing the cost of health emergencies and by strengthening the foundations of routine health systems

- When pandemics strike, countries with stronger PPR systems are better able to respond. While investments in PPR can appear costly, failing to make them simply shifts, and often amplifies, expenses during health emergencies.
- Many PPR investments also deliver "dual-use" benefits: the infrastructure, surveillance systems and co-ordination mechanisms built for emergencies strengthen routine care, improve detection of everyday health threats and bolster public trust.

The OECD Strategic Public Health Planning (SPHeP) Costing Tool was used to estimate the cost of scaling up a comprehensive PPR package across 51 OECD, EU/EEA and G20 countries:

- The OECD analysis included investments that can help safeguard population health and the economy when reliable medicines and vaccines are unavailable at scale:
  - building a national stockpile for personal protective equipment (PPE) and hygiene supplies,
  - physical contact-reducing non-pharmaceutical interventions (NPIs) including those that aim at ensuring greater compliance with physical distancing measures, ensuring educational continuity, facilitating innovative workplace arrangements and ensuring safe international and domestic travel and
  - improving wastewater surveillance capacity.

The OECD estimates suggest that:

- In the OECD, the average annual cost of PPR is estimated at almost USD PPP 7.1 billion (USD PPP 5.9 per capita). The annual cost averages around USD 2.6 billion across the EU/EEA countries (USD PPP 6.3 per capita) and it exceeds USD PPP 18 billion (USD PPP 4.7 per capita) per year in G20 countries.
- Of the estimated USD PPP 5.9 per capita needed each year to strengthen PPR capacity across OECD countries, around USD PPP 2.1 per person reflects start-up investments to establish core systems, institutions and infrastructure. An additional USD PPP 2.1 per capita would be required on an ongoing basis to cover operational costs once these foundational elements are in place. The remaining investment, about USD PPP 1.7 per capita, would only be required in the event of an outbreak to scale up activities and support the response.
- Building and maintaining national PPE and hygiene stockpiles is the most expensive component of the PPR package, with an average annual cost of USD PPP 4.4 billion (USD PPP 3.2 per capita) in the OECD to almost USD PPP 1.5 billion (USD PPP 3.2 per capita) in the EU/EEA and nearly USD PPP 14 billion (USD PPP 3.1 per capita) across G20 countries. The average yearly cost of implementing NPIs that aim to reduce physical contact is slightly lower, ranging from USD PPP 1.6 per capita in the G20 to USD PPP 2.5 per capita in the OECD and USD PPP 2.8 per capita in the EU/EEA. The scaling up of wastewater surveillance remains below USD PPP 1 per year in nearly all countries.

- The cost estimates presented in this chapter assume that countries start with relatively limited PPR capacities. Countries that already have some core PPR systems, institutions and infrastructure in place would need lower overall investments due to lower initial investment needs, although recurrent spending would still be required to sustain preparedness and ensure timely and effective responses to future outbreaks.

8.1. When pandemics strike, countries with stronger PPR systems are better positioned to respond and safeguard population health and the economy

The COVID-19 pandemic showed how outbreaks can disrupt healthcare systems and economies. As highlighted in Chapter 2, the health and economic shocks of potential outbreaks can be vast and as shown in Chapter 6, a number of non-pharmaceutical interventions (NPIs) remain a vital first line of defence when reliable medical treatments or vaccines are not yet available. As OECD, EU/EEA and G20 countries continue to work towards enhancing their resilience against future pandemics, a growing body of evidence shows that disease outbreaks are becoming more frequent and severe (Jones et al., 2008[1]; Meadows et al., 2023[2]), with projections suggesting substantially higher death tolls than previous outbreaks without stronger action (Meadows et al., 2023[2]; Madhav et al., 2023[3]).

When pandemics strike, countries with stronger PPR systems are better positioned to respond quickly and avoid the steep health and economic toll of uncontrolled outbreaks. Although PPR spending may appear costly upfront, neglecting it simply shifts, and ultimately magnifies, the expenses incurred during the response phase. Importantly, PPR investments generate important “dual-use” benefits that extend well beyond crisis moments. The same infrastructure, surveillance systems and co-ordination mechanisms that safeguard populations during outbreaks also strengthen routine care, accelerate detection of other health threats and reinforce public trust in institutions. Wastewater surveillance, for instance, can track seasonal influenza and other endemic diseases, while robust stockpiles can be mobilised for a range of health emergencies. In this sense, preparedness is not simply an insurance policy, but a long-term investment in the resilience of health systems.

The COVID-19 pandemic spurred a comprehensive re-evaluation of financing needs to strengthen PPR capacity at the country and global levels (Box 8.1). Two landmark reviews were particularly influential. The first review, which was done by the Independent Panel for Pandemic Preparedness and Response (2021[4]), showed that prior to COVID-19, efforts to bolster national PPR capacities were vastly underfunded and only two-thirds of countries reported having in place mechanisms that would fully enable legislation and financing to support PPR capacities. The second review, by the G20 High Level Independent Panel (2021[5]), similarly concluded that countries must substantially increase domestic investment in core PPR capacities to prevent and contain future outbreaks. In 2025, the COVID-19 Global Evaluation Coalition, led by the OECD, brought together evaluation units from countries, multilateral institutions and United Nations organisations to generate evidence-based lessons and good practices for future global crises, including those pertaining to financing efforts to strengthen PPR capacities (OECD, 2025[6]).

Box 8.1. The global community has been taking steps to shift the paradigm on PPR financing

The COVID-19 pandemic spurred a comprehensive re-evaluation of global PPR financing

At the international level, the Independent Panel for Pandemic Preparedness and Response (2021[4]) review showed that the pre-COVID-19 global health financing mechanisms were not able to facilitate

rapid access to financial resources. The G20 High Level Independent Panel review underlined that countries should commit to scaling up international financing for PPR to support global PPR capacity across the globe (G20 High Level Independent Panel, 2021[5]). It highlighted that the additional international PPR funding must add to, and not substitute for, existing financial resources to advance other global public health and development goals.

Both reviews called for a massive scale-up in multilateral financing to prevent and respond to future disease outbreaks (OECD, 2020[7]). They spurred the global health community to shift the paradigm on pandemic financing, with a transition towards proactive and sustainable long-term investments in PPR capacities.

The Pandemic Fund is the first multilateral financing mechanism dedicated to ensuring sustainable PPR funding

Launched in November 2022, the Pandemic Fund was developed under Italy and Indonesia's respective G20 presidencies, with broad support from other G20 members and beyond, to address the lack of a global funding body aiming to strengthen global capacity to prevent, detect and respond to future pandemics (The Pandemic Fund, 2024[8]). It is the first multilateral financing mechanism dedicated to ensuring sustainable funding for strengthening PPR capacities in low- and middle-income countries, with three core objectives: 1) strengthening national health systems, 2) supporting regional and global surveillance mechanisms and 3) ensuring rapid response capabilities.

The Pandemic Fund is structured as a financial intermediary fund, pooling contributions from governments, philanthropic organisations and private entities. Its governance framework includes representatives from donor and recipient countries, as well as technical experts and civil society organisations. Hosted by the World Bank, the Pandemic Fund completed two funding rounds by October 2024, which amounted to USD 885 million to finance 47 projects across 75 countries in all geographic regions (The Pandemic Fund, 2024[8]; World Bank, 2024[9]).

Source: G20 High Level Independent Panel (2021[5]), *"A Global Deal for Our Pandemic Age: Financing the Global Commons for Pandemic Preparedness and Response"*, https://pandemic-financing.org/report/foreword/; OECD (2020[7]), "*Multilateral Development Finance 2020"*, http://doi.org/10.1787/e61fdf00-en; The Pandemic Fund (2024[8]), *"Building Pandemic Resilience: The Time is Now"*, https://www.thepandemicfund.org/sites/default/files/2024-08/UK01_0005700_03_ThePandemicFund_InvestmentCase_Singles.pdf; World Bank (2024[9]), *"Pandemic Fund Allocates Second Round of Grants to Boost Pandemic Preparedness in 50 Countries"*, https://www.worldbank.org/en/news/press-release/2024/10/19/pandemic-fund-allocates-second-round-of-grants-to-boost-pandemic-preparedness-in-50-countries.

This chapter seeks to estimate the cost of investing in a comprehensive policy package for strengthening PPR capacity which involves: 1) building a national stockpile for personal protective equipment (PPE) and hygiene supplies, 2) strengthening the implementation of physical contact-reducing NPIs including ensuring greater compliance with physical distancing measures, ensuring educational continuity, facilitating innovative workplace solutions and ensuring safe domestic and international travel and 3) enhancing wastewater surveillance capacity. The estimates focus on country-level resource needs, although regional initiatives remain essential to complement and reinforce national efforts (Box 8.2). The results presented in this chapter were generated using the OECD Strategic Public Health Planning (SPHeP) Costing Tool in 51 OECD, EU/EEA and G20 countries. The chapter begins with a concise overview of the OECD SPHeP Costing Tool, followed by the presentation of results and concludes by synthesising the key findings and discussing their implications for resource allocation and policy design.

Box 8.2. The EU/EEA countries set a new precedent for strengthening regional strategies to strengthen PPR capacities

The COVID-19 pandemic underscored the importance of building resilience not only at the national level but also across regions. In response, the EU/EEA countries have intensified efforts to strengthen regional co-operation, launching several major initiatives in recent years. A key example is the launch of the European Health Emergency Preparedness and Response Authority (HERA) in 2021. HERA is responsible for implementing the European Commission's policies on health preparedness, crisis response and strengthening the resilience of healthcare systems (HERA, 2024[10]). During health emergencies, it oversees the development, production and distribution of medicines, vaccines and other medical countermeasures. To date, HERA channelled funding through multiple instruments:

- **EU4Health Programme:** Established by Regulation (EU) 2021/522, the EU4Health Programme aims to improve health system resilience across EU member states by 1) strengthening national health systems to cope with future public health crises, 2) enhancing access to medicines and medical devices, 3) promoting digital health solutions to improve efficiency and cross-border co-operation and 4) supporting disease prevention and addressing inequities (European Commission, 2024[11]).
- **Horizon Europe:** Horizon Europe is the EU's key funding programme to promote research and innovation. To support the EU-level effort to strengthen PPR and health security, Horizon Europe aims to advance 1) research projects focussing on better assessing pathogen characteristics and behaviours, 2) the development of novel vaccines, therapeutics and diagnostics and 3) research on climate change-related health threats and antimicrobial resistance (European Commission, 2024[12]).
- **rescEU:** RescEU was created in 2019 as part of the EU Civil Protection Mechanism to safeguard EU citizens from disasters and to manage emerging risks. Today, RescEU capacity includes field hospitals and a stockpile of medical items (e.g. ventilators) for health emergency response, as well as shelters, transport and logistics assets and energy supply items.
- **HERA invest:** With a budget of EUR 100 million, HERA invest is the first European health investment instrument that specialises in promoting advanced research and development (R&D) for medical countermeasures and relevant technologies for tackling priority cross-border health threats including pathogens of epidemic/pandemic potential, antimicrobial resistance and chemical, biological, radiological and nuclear threats (European Commission, 2024[12]).

In addition to HERA, there have been other developments at the EU-level as follows:

- **Introduction of Regulation (EU) 2022/2371:** At the regional level, the EU has established a structured framework for assessing and strengthening PPR capacity. Under Article 7 of Regulation (EU) 2022/2371 on serious cross-border threats to health, EU Member States report to the European Commission every three years on their national prevention, preparedness and response planning, using a common template set out in Commission Implementing Regulation (EU) 2023/1808 (European Commission, 2023[13]). The template is organised around 16 capacities in two groups. The first 11 correspond to the core capacities of the International Health Regulations (2005), spanning, among others, surveillance, laboratory capacity, the health workforce, health emergency management and logistics, health-service provision, risk communication, points of entry and border health, and zoonotic and environmental threats. The remaining capacities reflect additional EU-specific elements, including antimicrobial resistance and healthcare-associated infections, and Union-level co-ordination. These self-assessments are subsequently reviewed by the European Centre for Disease Prevention and Control

(ECDC), which conducts country assessments and issues tailored recommendations, creating a recurring cycle of reporting, assessment and improvement designed to identify and close preparedness gaps. The first cycle was run between 2024 and 2026 (ECDC, 2026[14]).

- **Expansion of the ECDC mandate:** In 2022, Regulation (EU) 2022/2370 reinforced the ECDC mandate, granting the institution a much stronger role in EU-wide disease surveillance and prevention. Among many new capacities, the ECDC is now tasked with co-ordinating the EU Health Task Force, which is responsible for outbreak investigation and crisis support.
- **Expansion of the European Medicines Agency (EMA) mandate:** The expansion of the EMA's mandate in 2022 reaffirmed the institution's critical role in the EU's crisis preparedness and management of medicinal products and medical devices. Most importantly, the new mandate gave rise to the Executive Steering Group on Shortages and Safety of Medicinal Products, which is the leading body tasked with responding to and preventing medicine supply issues caused by public health emergencies such as pandemics (European Medicines Agency, 2023[15]).

In addition, the EU has recently strengthened its crisis preparedness framework through a set of strategies and policy initiatives that emphasise surveillance, prevention and effective response to major threats across both civilian and military domains as follows:

- The EU Preparedness Union Strategy, the EU Stockpiling Strategy and the Niinistö report collectively highlight the need to build robust protection capabilities, improve resilience and ensure the availability of critical resources in times of crisis (Niinistö, 2024[16]; European Commission, 2025[17]; European Commission, 2025[18]).
- These efforts align with the EU priorities for 2024-2029, which identifies a "strong and secure Europe" as a core priority, including enhanced preparedness, prevention and response capacities (European Union, 2024[19]).
- The 2025 EU Medical Countermeasures Strategy reinforces these objectives by accelerating innovation and securing the supply of medical countermeasures, further contributing to the EU's overall resilience architecture (European Commission, 2025[20]).

Source: HERA (2024[10]), *"Health Emergency Preparedness and Response Authority"*, https://commission.europa.eu/about/departments-and-executive-agencies/health-emergency-preparedness-and-response-authority_en; European Commission (2024[11]), *"EU4Health programme 2021-2027 – a vision for a healthier European Union"*, https://health.ec.europa.eu/funding/eu4health-programme-2021-2027-vision-healthier-european-union_en; European Commission (2024[12]); "*Funding and opportunities*", https://health.ec.europa.eu/health-emergency-preparedness-and-response-hera/funding-and-opportunities_en; European Commission (2023[13]), *"Commission Implementing Regulation (EU) 2023/1808"*, https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32023R1808; ECDC (2026[14]), *"Public Health Emergency Preparedness Assessments"*, https://www.ecdc.europa.eu/en/about-us/what-we-do/public-health-emergency-preparedness-assessments; European Medicines Agency (2023[15]), *"EMA's extended mandate"*, https://www.ema.europa.eu/assets/en/annual-report/2022/emas-extended-mandate.html; Niinistö (2024[16]), *"Safer Together – Strengthening Europe's Civilian and Military Preparedness and Readiness*", https://commission.europa.eu/document/download/5bb2881f-9e29-42f2-8b77-8739b19d047c_en?filename=2024_Niinisto-report_Book_VF.pdf; European Commission (2025[17]), *"EU stockpiling strategy: Boosting the EU's material preparedness for crises*", https://civil-protection-humanitarian-aid.ec.europa.eu/document/download/c57d4067-1900-4616-9239-ca4598b55d69_en?filename=COM_2025_528_1_EN_ACT_combined.pdf; European Commission (2025[18]), *"EU preparedness union strategy"*, https://commission.europa.eu/topics/preparedness_en; European Union (2024[19]), *"European Union priorities 2024-2029"*, https://european-union.europa.eu/priorities-and-actions/eu-priorities/european-union-priorities-2024-2029_en; European Commission (2025[20]), *"Medical Countermeasures Strategy*", https://health.ec.europa.eu/health-emergency-preparedness-and-response-hera/preparedness/medical-countermeasures-strategy_en.

8.2. The OECD SPHeP Costing Tool is used to quantify the investment requirements for strengthening PPR capacities

The OECD SPHeP Costing Tool aims to provide accurate estimates for a wide range of interventions that can help safeguard population health (Box 8.3). The tool balances the need for a consistent methodology to estimate the country-level cost of interventions with flexibility required to consider the diversity in country context by:

- adopting an ingredients-based approach (i.e. a systematic methodology for estimating the total costs of implementing an intervention) which entails exhaustively specifying all inputs required to implement an intervention regardless of how they are financed.
- offering flexibility to modify parameters such as demographic characteristics, time horizon of analysis, target population and intervention coverage to reflect a country's circumstances.

Box 8.3. Estimating the cost of investing in interventions that bolster country-level PPR capacities

The OECD SPHeP Costing Tool was used to estimate the investment requirements to bolster PPR capacity across 51 OECD, EU/EEA and G20 countries. Similar to the WHO Choosing Interventions that are Cost-Effective Tool (Bertram et al., 2021[21]),the OECD SPHeP Costing Tool uses a standardised ingredient-based approach, whereby quantities of all inputs were multiplied by their corresponding unit prices. Total intervention costs were calculated as the sum of two components:

- **Programme-level costs**, covering resources needed for implementation including personnel, administration, training, co-ordination and materials; and
- **Individual-level expenditures**, capturing personal use of goods and services such as PPE.

Costs were estimated for two phases of a pandemic: 1) preparedness and 2) response. The preparedness phase, spanning ten years, is assumed to comprise a two-year start-up period followed by eight years of steady-state operations. Costs incurred in the preparedness phase reflect the set of activities required to establish and maintain each intervention:

- **Start-up costs** which include one-off investments needed to establish the interventions, including developing standard operating procedures (SOPs) and guidelines, building co-ordination mechanisms across sectors, putting in place digital infrastructure (e.g. public health hotlines, wastewater surveillance dashboards etc.), initial recruitment and training of staff, as well as the procurement of capital goods such as laboratory equipment.
- **Operational costs** represent recurrent expenditures required to sustain the implementation of the interventions beyond the start-up period, including replenishment of stockpiles, maintenance of warehouses and subscriptions to digital learning platforms, ongoing guideline revisions, routine training and staff salaries.

Given that consistent cross-country data on current capacity is difficult to obtain, analyses for the preparedness phase assume that countries do not have any pre-existing capacity for these interventions. This approach allows estimation of the full investment required and can be considered as an upper-bound indicator of the resources required. Additional analysis is also provided for scenarios where 30% and 50% initial capacity is assumed to be available at the start-up period.

The response phase covers the first nine months of an outbreak caused by a respiratory pathogen, similar to those discussed in Chapters 3 and 7, during which the capacities established during the preparedness phase are assumed to expand to meet emergency needs. Costs incurred in the response

phase capture surge requirements during an outbreak such as temporary workforce expansion, increased sampling and testing for more frequent wastewater surveillance and enhanced communication campaigns.

Inputs and data sources

The analysis incorporated all commodities, supplies and human resources required to implement each intervention across preparedness and response phases. Commodities included, for example, PPE (e.g. N95 respirators), hand hygiene supplies (e.g. hand sanitisers, liquid soap), wastewater testing kits and other laboratory consumables, laptops, barcode readers for warehouse staff, subscriptions to learning management systems and communication materials (e.g. posters). Full-time equivalent (FTE) estimates were mapped to salary levels from the International Labour Organization (ILO) wage database.

Whenever possible, quantities were parameterised using international guidelines and evidence gathered from comprehensive literature reviews that aimed to identify the operational aspects of real-world programmes and best practice examples for each intervention. To adapt inputs across the 51 countries, the quantities identified were scaled to population size. Internationally traded goods (e.g. computers) were assigned harmonised PPP-adjusted prices. The costing analysis was conducted from a governmental perspective. All costs are expressed in 2022 PPP-adjusted USD.

All inputs were parameterised using publicly available data sources. Population estimates were taken from the United Nations World Population Prospects. Macroeconomic indicators, including PPP conversion factors, market exchange rates, consumer price indices and level price indices, were extracted from the World Bank World Development Indicators, OECD and Eurostat. Unit costs for PPE and medical consumables were obtained from Eurostat's medical supplies dataset and salary estimates for relevant personnel were sourced from the ILO wage database reflecting the level of educational attainment.

Source: Bertram et al. (2021[21]), *"Methods for the Economic Evaluation of Health Care Interventions for Priority Setting in the Health System: An Update from WHO CHOICE"*, http://doi.org/10.34172/ijhpm.2020.244.

Table 8.1 summarises the key design features of each intervention that was costed as part of the PPR package and the remainder of the section provides more details. The designs of the costed interventions were informed by reviews of the scientific and grey literature, government reports and documents on real-world programmes and international guidelines. The interventions presented in the rest of the chapter should be interpreted as illustrative benchmarks that provide a consistent and comparable basis for estimating investment needs. While they reflect evidence-based approaches to implementing interventions to prepare for and respond to pandemic outbreaks, they are not intended to imply that countries should implement identical activities or organisational arrangements.

Table 8.1. Key design features of components of the PPR package

Intervention		Key activities	Key cost items in preparedness phase	Key cost items in response phase
Building a national stockpile for PPE and hygiene supplies		Establishing the national stockpile	• Procurement of essential PPE and hygiene items (e.g. respiratory masks, hand sanitisers etc.) in quantities to cover 20% of the population aged >12 years for 3-months (WHO, 2020[22])	• Additional procurement of PPE and hygiene supplies to meet increased demand during an outbreak (10% of the supply procured in preparedness phase; OECD assumption)
		Stockpile management	• Development, regular updating and implementation of SOPs and best practice guidelines • 10% of the stockpile is assumed to be distributed every year within the health system and replenished (OECD assumption) • Recruitment and salaries of staff responsible for stockpile management and logistics (e.g. managers, administrative staff, procurement specialists, warehouse workers etc.) • Putting in place and maintaining an inventory management information technology (IT) system • Purchase of operational equipment (e.g. laptops, barcode scanners etc.) • Planning and operating transportation and distribution arrangements	• Temporary expansion of staff capacity to support higher distribution volumes (+30% of preparedness phase; OECD assumption) • Purchase of additional equipment to support increased staffing levels • Higher transportation activity associated with expanded distribution (+10% of preparedness phase; OECD assumption)
		Warehouse management	• Leasing, maintenance and operation of warehouse facilities	• Same as preparedness phase
		Monitoring and evaluation (M&E)	• Annual external audits to verity stock levels and compliance with procedures	Not applicable
Physical contact-reducing NPIs	**Ensuring greater compliance with physical distancing measures**	Developing and implementing operational guidance	• Development, regular updating and implementation of SOPs and best practice guidelines, informed by expert consultations • Identification and assignment of staff responsible for co-ordinating the development and rollout of operational guidance	• Temporary expansion of staff capacity to manage intensified implementation and oversight (+30% of preparedness phase
		Improving public access to accurate information	• Development and ongoing maintenance of a public information website • Establishment and routine operation of a public health hotline including staff, basic equipment (e.g. laptops, headsets) and initial training	• Large-scale public communication campaigns, including design and placement of weekly television and radio public announcements, placement of poster and signage in public spaces • Temporary expansion of hotline workforce (+30% of preparedness phase), with additional equipment and training sessions

Intervention		Key activities	Key cost items in preparedness phase	Key cost items in response phase
		Enforcement	Not applicable	• Salaries of civil security officer salaries to support enforcement of physical distancing requirements
		Monitoring and evaluation	• Assigning staff to monitor implementation, compliance and performance of physical distancing measures	• Increased M&E capacity to increase compliance levels in the public
	Ensuring educational continuity	Developing and implementing operational guidance	• Development, regular updating and implementation of SOPs and best practice guidelines, informed by expert consultations • Identification and assignment of staff responsible for co-ordinating the development and rollout of operational guidance	• Temporary expansion of staff capacity to manage intensified implementation and oversight (+30% of preparedness phase)
		Strengthening readiness for online education	• Set-up subscription of learning management systems (LMS) in schools • Offer online training sessions for teaching staff on best practices in remote learning	• Procurement of laptops for primary and secondary school students from disadvantaged backgrounds • Additional teacher training sessions to support remote teaching during school closures • Continued LMS subscription and use throughout the response period
	Facilitating innovative workplace solutions	Developing and implementing operational guidance	• Development, regular updating and implementation of SOPs and best practice guidelines, informed by expert consultations • Identification and assignment of staff responsible for co-ordinating the development and rollout of operational guidance	• Temporary expansion of staff capacity to manage intensified implementation and oversight (+30% of preparedness phase)
	Ensuring safe domestic and international travel	Developing and implementing operational guidance	• Developing, revising and implementing standard operating procedures and best practice guidelines, based on expert consultations • Identifying staff who would co-ordinate the development and implementation of SOPs and best practice guidelines	• Temporary expansion of staff capacity to manage intensified implementation and oversight (+30% of preparedness phase)
		Improving public access to accurate information	• Development and ongoing maintenance of a public information website to disseminate up-to-date information on guidelines to travelling high risk areas in terms of disease outbreaks	• Large-scale public communication campaigns, including placement of poster and signage in major travel hubs, regular updates of travel advisory on the dedicated public website and placement of weekly television and radio public announcements
		Enforcement	Not applicable	• Salaries of civil security officer salaries to support enforcement of travel requirements in major travel hubs
Enhancing wastewater surveillance		Developing and implementing operational guidance	• Developing, revising and implementing standard operating procedures and best practice guidelines, based on expert consultations • Identifying staff who would co-ordinate the development and implementation of SOPs and best practice guidelines	• Temporary expansion of staff capacity to manage intensified implementation and oversight (+30% of preparedness phase)

Intervention	Key activities	Key cost items in preparedness phase	Key cost items in response phase
	Strengthening laboratory capacities	• Procurement of sampling kits and transport materials for wastewater treatment plants • Laboratory equipment and consumables (e.g. RT-qPCR kits)	• Sampling frequency to increase from two to three per week • Procurement of additional laboratory consumables to support expanded testing capacity
	Strengthening research and data sharing capacities	• Development and maintenance of an online dashboard to facilitate data sharing	• Expanded dashboard maintenance and support

Note: LMS = learning management systems; M&E = monitoring and evaluation; PPE = personal protective equipment, RT-qPCR = reverse transcription-quantitative polymerase chain reaction; SOP = standard operating procedures.
Source: Based on OECD review of the available literature.

8.2.1. Building a national stockpile for PPE and hygiene supplies

Investing in a national PPE stockpile is an essential strategy that can rapidly safeguard population health during disease outbreaks while ensuring preparedness for future health emergencies. A well-maintained stockpile guarantees the availability of critical PPE for rapid distribution, benefiting not only healthcare workers but also the general population. Adequate PPE reserves also enable essential workers to return to their jobs more quickly, mitigating the economic distress caused by outbreaks. Building a national stockpile can also stimulate domestic production of medical supplies, reducing reliance on global supply chains in the event of a disease outbreak.

Maintaining a national stockpile also offers significant cost advantages. Procuring PPE in advance at standard market prices can help avoid the inflated costs observed during disease outbreaks. For example, one earlier study showed that in Israel, pre-pandemic stockpiling to protect against a future influenza pandemic remained a cost-saving option as long as the estimated risk of a pandemic remained greater than 1 every 80 years (Balicer et al., 2005[23]). Another study from the United States found that establishing an adequate PPE stockpile beforehand would cost only 17% of the amount required to purchase the same supplies during a crisis (Dow, Lee and Lucia, 2020[24]).

This intervention was conceptualised as a national stockpile for PPE and hygiene supplies (Table 8.1), with the aim of supporting the needs of the public during a health emergency. (See Chapter 9 for a deeper discussion of various types of stockpiling arrangements). During the preparedness phase, the stockpile is assumed to be built through the procurement of goods such as respiratory masks and essential hygiene and protective supplies in quantities sufficient to cover 20% of the population aged over 12 years for a three-month period (WHO, 2020[22]). Other activities include managing the stockpile (e.g. staff for procurement and warehouse management), warehouse management (e.g. putting in place inventory management IT systems and basic operational equipment) and annual external audits to verify stock levels and compliance with guidelines. Assumptions used to parameterise warehousing requirements (e.g. physical space and staffing levels) are based on the stockpiling experiences from Australia (Premier of Victoria, 2020[25]) and scaled by population size for each country. During the response phase, it is assumed that a temporary scale-up of operations would be necessary to meet increased demand, with additional procurement of goods equivalent to 10% of the preparedness-phase stock; a 30% increase in staffing capacity in the warehouses to support higher distribution volumes and a 10% increase in transport activity to reflect intensified logistics and delivery requirements.

8.2.2. Strengthening the implementation of physical contact-reducing NPIs

Physical contact-reducing NPIs refer to interventions aimed at reducing close interpersonal contacts across various settings (i.e. ensuring greater compliance with physical distancing measures, ensuring educational continuity, facilitating innovative workplace solutions and ensuring safe domestic and international travel). During the preparedness phase, all these interventions are assumed to rely on similar foundational activities to support operational readiness in case of outbreaks (Table 8.1). These include developing and implementing SOPs and best practice guidelines, reviewing and updating them every five years and assigning dedicated staff to co-ordinate implementation. During the response phase, implementation is assumed to be temporarily scaled up, which would involve a 30% expansion in staff capacity to manage the additional operational demand due to the outbreak.

Each physical contact-reducing NPI also includes setting-specific activities as discussed below.

Ensuring greater compliance with physical distancing measures

Physical distancing is a highly effective strategy to limit disease transmission by reducing the number of close contacts between individuals, but its effectiveness depends on the level of compliance in the general

population. Previous studies suggest that physical distancing measures are most effective when clear and well-designed guidelines that consider social, cultural and economic contexts are in place (Bausch, 2020[26]). This is particularly important during rapidly evolving disease outbreaks when timely communication of key public health messaging is key.

This intervention is modelled as a novel programme that aims to increase compliance with physical distancing during an outbreak (Table 8.1). During the preparedness phase, the main activities are assumed to centre around building operational capacity and improving the public's access to accurate public health information (e.g. building a public health hotline to increase awareness of best public health practices, for example, in peak influenza seasons.) The parameters used to cost the public health hotline are scaled by population size, referencing an emergency programme from the United Kingdom (NHS, 2023[27]). It is also assumed that public compliance with public health best practices would be monitored and evaluated to identify bottlenecks in implementation (see Chapter 5 for more detailed discussion.) During the response phase, a temporary intensification of implementation activities is assumed, including the launch of large-scale public communication campaign (e.g. weekly television and radio announcements, widespread use of posters and signage in public spaces), as well as a 30% increase in public health hotline staff. It is also assumed that civil security personnel would assist with enforcement of physical distancing requirements, using the staffing levels consistent with the assumptions in the WHO-CHOICE mode (Bertram et al., 2021[21])l.

Ensuring educational continuity

As discussed in more detail in Chapter 7, temporary school closures can reduce the adverse health impacts of disease outbreaks, but they also have significant negative consequences such as disruptions to learning and mental health challenges for students. One effective strategy to mitigate the negative effects of school closures is scaling up the use of alternative education systems such as virtual learning platforms. These measures can help counter the adverse impacts of school closures by lowering the need for physical interactions while helping to maintain educational continuity. They can also facilitate social interactions with peers and teachers, which, in turn, may help support the mental health of students. They can be particularly valuable for vulnerable students who may lack access to adequate learning materials and resources at home. Beyond students, alternative education systems can enable parents to continue working during outbreaks (Sadique, M.Z., Adams and Edmunds, 2008[28]), while helping to avoid large scale job losses among teachers and support staff.

This intervention is costed as a nationwide programme to support virtual learning during disease outbreaks (Table 8.1). During the preparedness phase, this intervention is assumed to involve developing and implementing operational guidance to ensure a smooth transition from face-to-face teaching to remote learning and strengthening readiness for online education (e.g. obtaining and maintaining subscriptions to online teaching platforms and providing training opportunities at regular intervals for teaching staff to promote best practices in remote learning). During the response phase, a temporary intensification of implementation is assumed to support large-scale remote education such as procurement of laptops for primary and secondary school students from lower-income families to reduce digital access gaps; monthly teacher training sessions, as well as the continued use and subscription of LMS platforms throughout the response period.

Facilitating innovative workplace solutions

Facilitating innovative workplace solutions can be crucial in case of outbreaks to ensure business continuity and operational resilience. Well-designed guidelines, for example, can address occupational health and safety concerns arising from teleworking such as work-life balance and mental health (OECD, 2022[29]). They can help mitigate risks associated with prolonged teleworking such as social isolation and detachment from colleagues.

This intervention is conceptualised as a nationwide programme to support businesses in their efforts to transition to teleworking-based work in an emergency context (Table 8.1). During the preparedness phase, activities would focus on establishing the institutional and operational foundations that would support higher use of teleworking arrangements during health emergencies, whereas during the response phase, a 30% expansion is assumed in the staff capacity to provide technology support and guidance for businesses on the skillset and organisational changes that would help facilitate timely implementation of innovative workplace solutions. The design of this intervention reflects examples from many initiatives undertaken by the OECD countries prior to and during the COVID-19 pandemic (OECD, 2021[30]). For example, it has been reported that Germany supported small and medium enterprises by facilitating their access to consultancy firms that assist them in the digitisation of business processes, whereas Australia was shown to offer advisory and mentoring services, involving an initial review of business needs and granting access to webinars, workshops and one-to-one mentoring (OECD, 2021[30]).

Ensuring safe domestic and international travel

Ensuring safe travel during a pandemic is essential for preserving global connectivity, facilitating trade and promoting economic recovery while safeguarding public health. During the COVID-19 pandemic, countries scaled up the implementation of various types of safe travel protocols such as testing requirements at entry and exit points, establishing “travel bubbles” between countries with similar levels of SARS-CoV-2 incidence rates etc. to help prevent the cross-border importation of the virus and subsequent infection waves, protecting both travellers and local populations.

This intervention is conceptualised as a nationwide programme implemented in major travel hubs such as domestic and international airports (Table 8.1). During the preparedness phase, efforts are assumed to focus on developing and implementing SOPs and best practice guidelines. During the response phase, this intervention would be further supported by launching a communication campaign to disseminate timely and accurate information on the most up-to-date travel requirements through broadcast and digital platforms (e.g. weekly travel advisories in radio, television and real-time online updates of public advisory on travel guidelines). Resources would also be allocated to validate the compliance of travellers with the travel-related health regulations in major travel hubs based on experiences from France where approximately 6 000 civil security service members were deployed each week to support travel-related validations (Ministre de l'Intérieur, nd[31]), adjusting for population size.

8.2.3. Enhancing wastewater surveillance

As discussed in more detail in Chapter 7, improving disease surveillance through enhanced wastewater surveillance is key to strengthen PPR capacity. Wastewater surveillance does not depend on individual testing or healthcare access, making it a highly desirable approach to population-based monitoring. It captures the presence of pathogens shed by both symptomatic and asymptomatic individuals, offering a more comprehensive view of population health. Multi-pathogen detection capabilities further enhance the utility of wastewater surveillance.

This intervention is conceptualised as a national programme to enhance wastewater surveillance as an early warning system for disease outbreaks (Table 8.1). During the preparedness phase, activities are assumed to include developing and implementing operational guidance (e.g. updating and implementing SOPs and best practice guidelines), strengthening laboratory capacity (e.g. procuring wastewater sampling kits, laboratory equipment and consumables such as RT-qPCR kits) and strengthening research and data sharing capacities to enable timely data sharing and analysis (e.g. developing and maintaining of an online data dashboard). In line with the French experience during the COVID-19 pandemic, wastewater surveillance is assumed to cover 40% of the population (Maréchal et al., 2023[32]). During the response phase, it is assumed that a temporary scale-up activities will take place, including an increase in sampling frequency from twice per week in line with international guidelines during “normal times”

(European Commission, 2021[33]) to three times a week to reflect the rise in the circulation of pathogens in the community (Jourdain et al., 2025[34]) and expanded technical support for the data sharing.

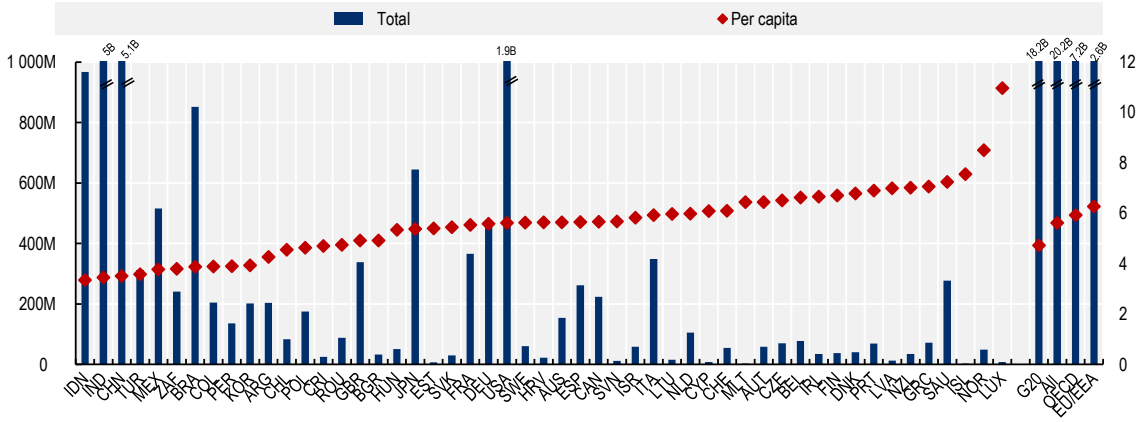
8.3. Results

8.3.1. Strengthening PPR capacity in the OECD will cost nearly USD PPP 6 per capita each year

The annual cost of strengthening pandemic preparedness and response capacity is estimated to average around USD PPP 20.2 billion across the 51 countries included in the analysis, corresponding to USD PPP 5.6 per capita (Figure 1.10). In the OECD, the cost of PPR is estimated to average at almost USD PPP 7.2 billion. This is around USD PPP 5.9 per capita whereas the estimated cost per year is estimated to reach around USD 2.6 billion across the EU/EEA countries, which is around USD PPP 6.3 per capita. The same cost is estimated to be around USD PPP 18.2 billion (USD PPP 4.7 per capita) per year in G20 countries.

Figure 8.1. Strengthening PPR capacity in the OECD would require nearly USD PPP 6 per person per year

Annual average cost of investing in PPR, USD PPP



Note: PPP = purchasing power parity; B = billions; M = millions.
Source: OECD analysis based on the OECD SPHeP Costing Tool.

StatLink https://stat.link/vph8lf

The OECD analysis reveals significant cross-country variation in the investments required to strengthen PPR capacity, with the per capita annual cost of PPR ranging from USD PPP 3.3 in Indonesia to USD PPP 11 in Luxembourg (Figure 1.10). More populous countries incur the highest costs in absolute terms, even when their per capita annual cost remains relatively low. For example, the annual cost of PPR averages around USD PPP 5 billion in China and India, more than double the cost in the United States at less than USD PPP 1.9 billion, even though the per capita cost in China and India is roughly 40% lower (about USD PPP 3.5 per capita in both countries compared to USD PPP 5.6 per capita in the United States). This finding partly reflects that the PPR systems (e.g. the quantities of PPE purchased) need to be scaled to the population size.

8.3.2. Investments made during the preparedness phase can help reduce costs incurred during the response phase

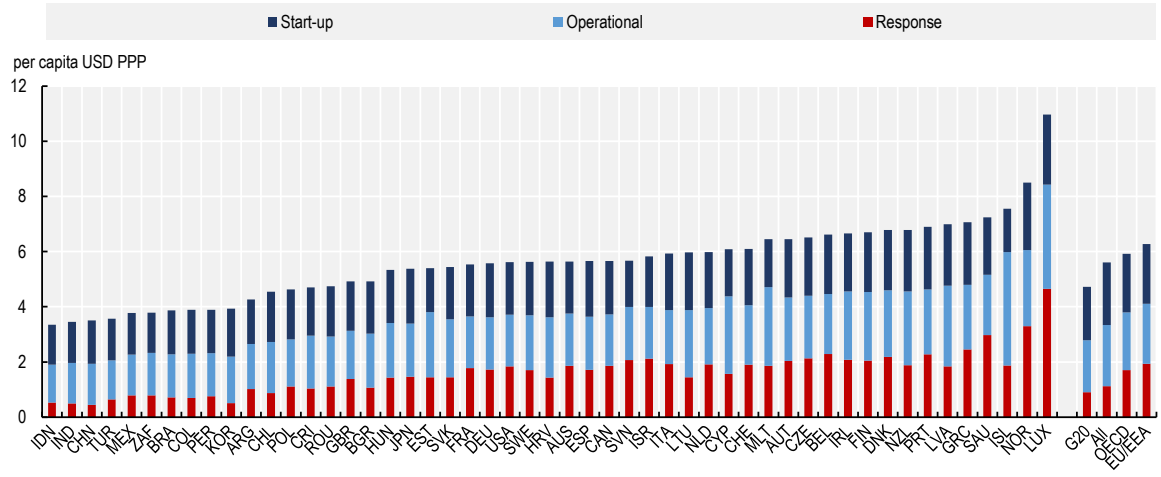
It is critical to adopt a proactive approach to investing in PPR. Without prior investments in strengthening PPR capacity, countries would still incur the estimated preparedness costs during an outbreak as part of the response expenses but likely at a higher price. Proactive investments can yield significant benefits. For instance, establishing wastewater surveillance systems can enable early detection of emerging threats, potentially curbing widespread transmission and reducing the need for costly large-scale interventions. Similarly, building and maintaining a national stockpile of PPE and hygiene supplies can eliminate the need for emergency procurements during a crisis, thereby lowering costs associated with urgent capacity expansion and resource mobilisation. Furthermore, pre-established emergency response plans and protocols developed as part of preparedness initiatives can facilitate a more co-ordinated and efficient response by streamlining decision-making processes and resource allocation, reducing potential delays in the response phase and inefficiencies that could otherwise inflate response costs.

Figure 8.2 represents the annual average cost of PPR across different phases of the outbreak. The OECD analysis shows that of the USD PPP 5.9 per person required each year to bolster PPR capacity in the OECD countries, around USD PPP 2.1 per person per year would be spent on start-up costs incurred for building the core PPR systems, institutions and infrastructure (e.g. national PPE and hygiene stockpile, strengthening operational readiness for implementing physical contact-reducing NPIs and disease surveillance capacity) needed, whereas USD PPP 2.1 per capita would be needed annually to cover the cost of operations following the start-up years. In comparison, the cost that would be incurred in the response phase would average at around USD PPP 1.7 per capita per year, which would entail expanding the PPR capacity established during the preparedness phase rather than building these systems from scratch in an emergency context.

It is crucial to note that the costs associated with the preparedness phase represent expenses that countries would have incurred during the response phase if they had not made any prior investments in preparation for a pandemic. In this light, the preparedness estimates (i.e. a combination of start-up and operational costs) presented in Figure 8.2 should be viewed as conservative, as actual costs incurred during an outbreak would likely be higher, especially for activities such as expanding the national stockpiles, considering that the expected peak in demand is likely to drive up costs.

Figure 8.2. Investment required for strengthening core PPR systems would represent around one-third of the total PPR investment in the OECD

Annual average cost of PPR by the phase of outbreak



Note: Preparedness phase involves a 10-year period when investments in NPIs are made before a disease outbreak occurs. The first 2 years of the preparedness phase are considered to be the start-up period, whereas the remainder is considered as the operational period. Response phase focusses on the scale-up of NPIs during the initial 9 months of an ongoing outbreak. EU/EEA = European Union/European Economic Area; G20 = Group of 20; NPIs = non-pharmaceutical interventions; PPP = purchasing power parity.
Source: OECD analysis based on the OECD SPHeP Costing Tool.

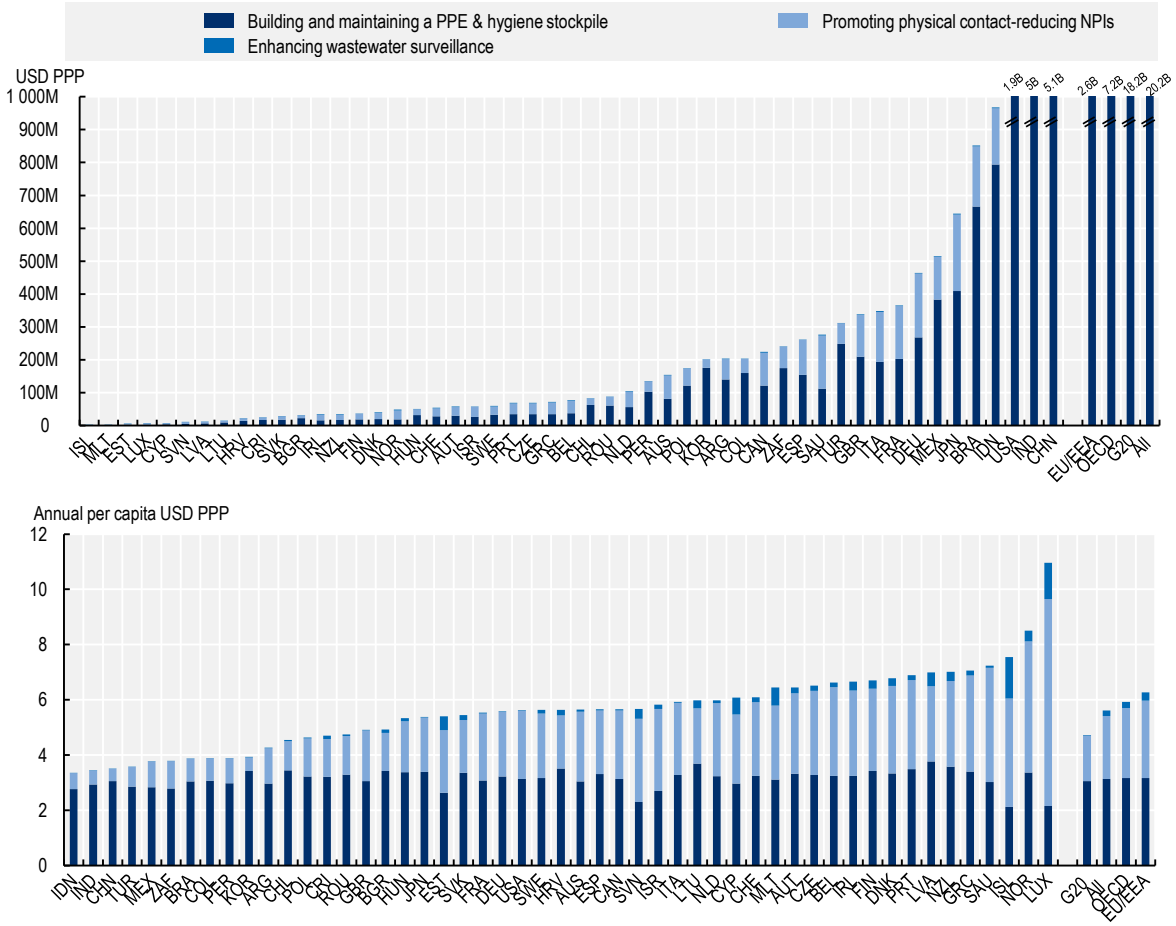
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8.3.3. Building a national stockpile is the costliest component of the PPR package

The OECD analysis suggests that building and maintaining a national PPE and hygiene stockpile is consistently the costliest component of the PPR package (Figure 8.3). It is estimated that the annual average cost of this intervention ranges from almost USD PPP 1.5 billion (USD PPP 3.2 per capita) in the EU/EEA, almost USD PPP 4.4 billion (USD PPP 3.2 per capita) in the OECD and nearly USD PPP 14 billion (USD PPP 3.1 per capita) across G20 countries (Figure 8.3). Across countries, Iceland would bear the lowest annual cost of building and maintaining a national stockpile (USD PPP 2.1 per capita) whereas Latvia would face the highest annual cost at almost USD PPP 3.8 per capita.

Figure 8.3. Building and maintaining a national PPE and hygiene stockpile is consistently the costliest component of the PPR package

Annual average cost of PPR by component



Notes: Physical contact-reducing NPIs include 1) promoting higher compliance with physical distancing measures, 2) ensuring innovative workplace solutions, 3) ensuring educational continuity and 4) encouraging safe international and domestic travel. EU/EEA = European Union/European Economic Area, G20 = Group of 20; B = billions; M = millions; NPIs = non-pharmaceutical interventions; PPE = personal protective equipment; PPP = purchasing power parity.
Source: OECD analysis based on the OECD SPHeP Costing Tool.

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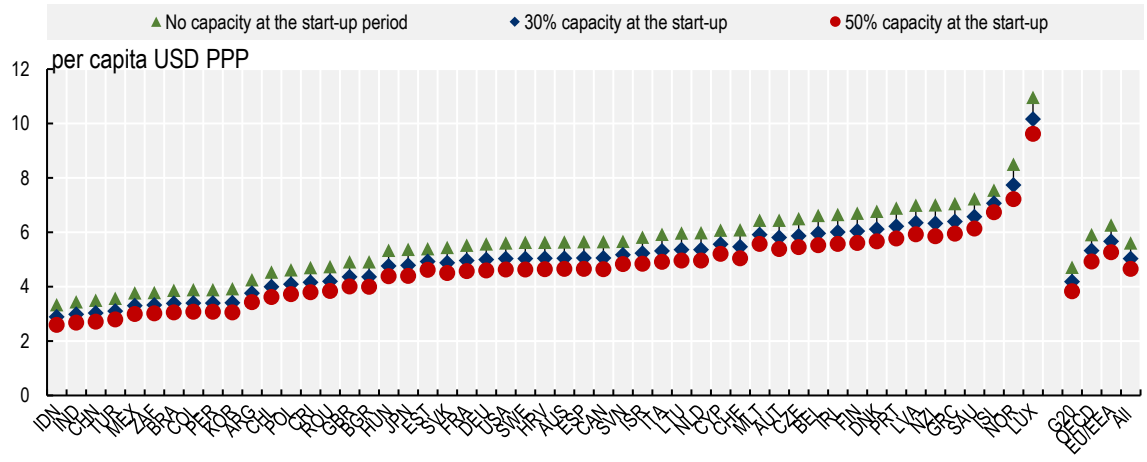
The average yearly cost of activities to strengthen the implementation of NPIs that aim to reduce physical contact is slightly lower than supporting national stockpiling efforts (Figure 8.3), ranging from around USD PPP 1.1 billion (USD PPP 2.8 per capita) in the EU/EEA to almost USD PPP 2.8 billion (USD PPP 2.5 per capita) in the OECD and nearly USD PPP 4.2 billion (USD PPP 1.6 per capita) across the G20 countries. Efforts to scale up wastewater surveillance are cheaper, with the estimated per capita cost of facilitating enhanced wastewater surveillance remaining below USD PPP 1 per year in all countries included in the analysis except in Luxembourg where the average cost is estimated to be around USD PPP 1.3 per year.

8.3.4. How do OECD estimates change depending on the PPR capacity at the start-up period?

The cost estimates provided in this chapter reflect an upper bound, under the assumption that countries start from relatively limited PPR capacity for the interventions assessed. Countries that already have some of these systems in place would require lower overall investments. As illustrated in Figure 8.4, if countries begin with even 30% of the necessary PPR capacity at the start-up period, average annual cost would fall markedly to USD PPP 6.4 billion (USD PPP 5.3 per capita) for the OECD, to USD PPP 2.4 billion (USD PPP 5.7 per capita) for the EU/EEA and to USD PPP 17.7 billion (USD PPP 4.2 per capita) across the G20 (See Annex Figure 8.A.1 and Annex Figure 8.A.2). These results reinforce that early and sustained investments in PPR capacities can reduce long-term investment needs.

Figure 8.4.The cost of strengthening PPR capacity hinges on where countries start

Annual average PPR cost per capita



Note: Start-up period refers to the first two years of the preparedness phase in which countries establish mechanisms to bolster PPR capacity.
Source: OECD analysis based on the OECD SPHeP Costing Tool.

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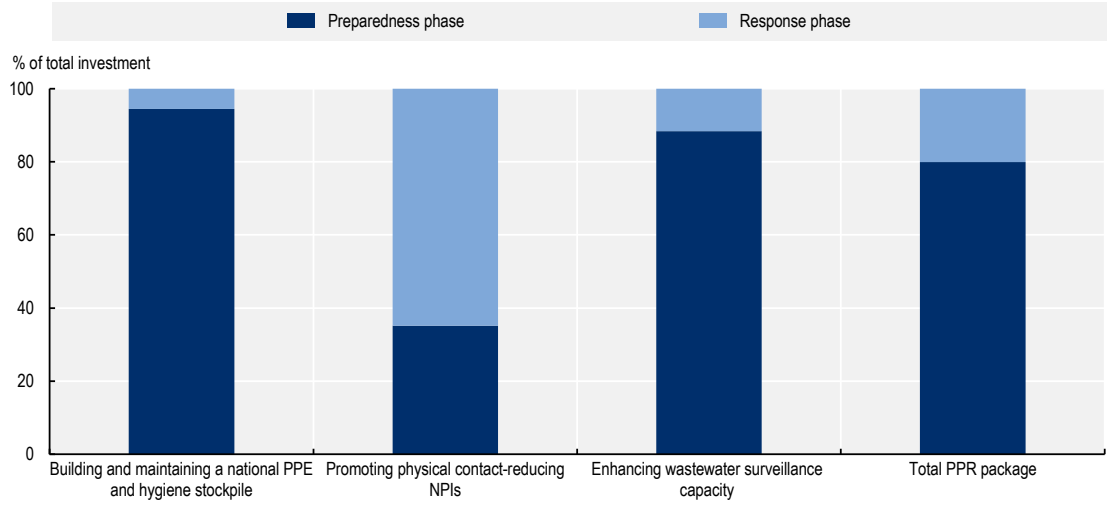
The relatively modest decline in long-term costs at higher initial levels of PPR capacity reflects the structure of the cost components. Countries with pre-existing PPR capacity can expect to reduce certain programme-level expenditures (e.g. developing SOPs and best practice guidelines, costs associated with the initial recruitment and training of staff, procurement of certain goods such as PPE and wastewater sampling kits etc.). However, even in countries with higher start-up PPR capacity, there is limited scope for reducing the operational costs, because many recurrent expenditures (e.g. staff salaries, routine staff training, warehouse costs etc.) are largely driven by the overall scale of the PPR systems in the country, which depends heavily on the population size rather than the initial level of preparedness. In other words, while early investments would reduce the need for accelerated building of PPR capacities during health emergencies, they do not eliminate the recurring costs of sustaining readiness for future outbreaks and for effective response.

Figure 8.5 shows the total PPR investment by the phase of outbreak. Nearly 80% of the total cost of the PPR package is estimated to be incurred in the preparedness phase. Investments in building and maintaining national PPE and hygiene stockpiles and in strengthening wastewater surveillance are highly concentrated on this phase, with close to 95% and 90% respectively of their total costs allocated to

preparedness activities. This reflects the need for upfront investments, such as for the procurement of goods (e.g. purchase of PPE, sampling kits etc.). By contrast, spending during the response phase would mainly involve scaling up capacities that have already been put in place. Physical contact-reducing NPIs follow a different pattern. Most of these measures are response-driven, largely reflecting their reliance on activities that would only be introduced in case of an active outbreak (e.g. enforcement of public health guidelines). For example, investments made in the preparedness phase account for approximately 20% of total cost associated with efforts to encourage safe international and domestic travel, which reflects the greater resource requirements due to enforcement related activities carried out during the response phase. Similarly, the majority of costs incurred due to the NPIs for ensuring innovative workplace solutions and for ensuring educational continuity would take place during the response phase. In comparison, costs incurred during the response phase represent only around 20% of the total cost of efforts to ensure innovative workplace solutions, as the core investments associated with this intervention are made upfront during the preparedness phase.

Figure 8.5. Nearly 80% of the total investment estimated by the OECD analysis is dedicated to supporting the preparedness phase

Percentage of total PPR investment by the phase of outbreak



Notes: Preparedness phase involves a 10-year period when investments in NPIs are made before a disease outbreak occurs. Response phase focusses on the scale-up of NPIs during the initial 9 months of an ongoing outbreak. Physical contact-reducing NPIs include 1) promoting higher compliance with physical distancing measures, 2) ensuring innovative workplace solutions, 3) ensuring educational continuity and 4) encouraging safe international and domestic travel.
Source: OECD analysis based on the OECD SPHeP Costing Tool.

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8.4. The OECD analysis broadly aligns with cost estimates generated by previous works

Costing the investment requirements for strengthening PPR capacity is a complex endeavour. The existing estimates for the magnitude of PPR investment requirements vary considerably, reflecting the variation in terms of their assumption related to what activities should be costed as part of efforts to strengthen PPR capacity, diversity in the data sources and costing methods used. This high level of variation in

methodological approaches makes direct comparison of cost estimates challenging. Despite these challenges, the cost estimates presented in this chapter are well aligned with estimates generated by previous works on global PPR investment requirements (Box 8.4).

Box 8.4. The OECD analysis broadly aligns with previous works that estimated the investment requirements for strengthening PPR capacities

The OECD analysis suggested that the annual per capita cost of PPR ranges from USD PPP 4.7 in G20 countries to USD PPP 5.9 in the OECD and USD PPP 6.3 across the EU/EEA. These estimates are aligned with the range of per capita annual global cost estimates generated by previous works, varying from USD 1.4 to USD 5.4 per capita (Craven et al., 2021[35]; World Bank, 2022[36]). The (G20 High Level Independent Panel[5]) and the (WHO and World Bank[37]) estimates, at USD 4.3 and USD 3.9 respectively, sit near the midpoint of this range. More recently, the WHO, OECD and the World Bank (2025[38]) also estimated that the cost of improving PPR within the health sector alone to full capacity in low- and lower-middle-income countries. The OECD estimates presented in this chapter are slightly higher than previous estimates, reflecting the more comprehensive coverage of cross-sectoral investments spanning health, education and transportation sectors and labour markets and higher costs for non-tradable goods (e.g. wages) in many OECD countries compared to many low- and middle-income countries included in the global analyses. Unlike previous estimates, the OECD analysis goes beyond quantifying the cost of preparedness alone by including the cost of responding to a COVID-19-like pandemic as explored in Chapters 3 and 7.

The OECD analysis estimated that strengthening disease monitoring through wastewater surveillance would cost, on average, USD PPP 0.2 per capita each year across OECD countries. As discussed below in this box, this figure is broadly aligned with France's investment to develop its wastewater surveillance system, which served as a model for this analysis, but remains below earlier estimates (Sorbonne Universite, 2024[39]), which range from the global estimates of USD 0.9 to 1.4 (Craven et al., 2021[35]) and to USD 1.9 (G20 High Level Independent Panel, 2021[5]). The difference largely reflects the scope of the investment. Enhancing wastewater surveillance capacity primarily requires building on existing surveillance systems, whereas (Craven et al.[35]) estimated the cost of closing gaps in pathogen surveillance and sequencing, building notifiable disease surveillance systems globally and developing population-representative surveillance foundations in countries. In comparison, the G20 High Level Independent Panel (2021[5]) calculated the cost of expanding the global surveillance capacity more broadly, often from ground up in many countries, including upgrading laboratory infrastructure and investing in research and development capabilities on future and emerging communicable diseases.

The OECD estimates of the annual investment needed to build national stockpiles of PPE and hygiene supplies are higher than those from earlier analyses, averaging USD PPP 3.1 per person per year across OECD countries, versus the global estimates of USD 0.6-0.9 in Craven et al. (2021[35]) and USD 1.6 in the G20 High Level Independent Panel (2021[5]). The differences likely reflect methodological approaches. For example, estimates generated by Craven et al. (2021[35]) focus on the cost of maintaining stockpiles of medical supplies and emergency supply-chain mechanisms at different administrative levels (i.e. subnational, national or regional).

The estimates presented in this chapter are also consistent with emerging evidence from OECD countries and recent regional efforts:

- The United States allocated about USD 905 million to its national stockpile in 2022 through the Public Health and Social Services Emergency Fund (HHS, 2022[40]). This investment helped secure critical medical supplies, expand storage and distribution capacity and reinforce the

broader PPR infrastructure, closely aligning with the OECD's estimate of roughly USD 1 billion annually to maintain a robust national stockpiling system.

- In France, the OBEPINE network, a consortium of 22 public, private and academic partners, received approximately EUR 10 million over five years to scale up wastewater surveillance and integrate it into the national health monitoring system (Sorbonne Universite, 2024[39]). This translates to about EUR 2 million per year, broadly in line with the OECD's estimate of EUR 2.3 million annually for building and sustaining wastewater surveillance capacity in France.
- In the EU/EEA, HERA allocated EUR 2.8 billion (USD 3.2 billion) under the EU4Health programme to reinforce PPR capacities and additional EUR 1.2 billion (USD 1.24 billion) to expand rescEU's shared EU-level reserves for 2022-2027 (HERA, 2023[41]; DG Sante, 2023[42]). This corresponds to roughly USD 900 million per year, lower than the OECD estimate of nearly USD 1.5 billion. The differences in the HERA resource allocation and the OECD estimates reflect both methodological assumptions and HERA's policy focus. The OECD analysis found that if national stockpiles across the EU/EEA countries already cover around half of the capacity needed, the OECD estimate would fall to around USD PPP 1.1 billion annually. Whereas HERA's funding is designed to *supplement* existing national stockpiles, providing a strategic shared reserve to be deployed in times of crises. Taken together, these figures indicate an alignment, showing that EU-level and national efforts are mutually reinforcing part of a broader strategy to bolster PPR capacity.

Source: Craven et al. (2021[35]); "*Not the last pandemic: Investing now to reimagine public health systems*", https://www.mckinsey.com/industries/public-sector/our-insights/not-the-last-pandemic-investing-now-to-reimagine-public-health-systems#/; World Bank (2022[36]), "*Putting Pandemics Behind Us: Investing in One Health to Reduce Risks of Emerging Infectious Diseases*", https://openknowledge.worldbank.org/server/api/core/bitstreams/956a58be-ddd8-572f-8aac-df5ab453d7b2/content; G20 High Level Independent Panel (2021[5]), *"A Global Deal for Our Pandemic Age: Financing the Global Commons for Pandemic Preparedness and Response"*, https://pandemic-financing.org/report/foreword/; WHO and World Bank (2022[37]), "*Analysis of Pandemic Preparedness and Response (PPR) architecture, financing needs, gaps and mechanisms: Prepared for the G20 Joint Finance & Health Task Force*", https://thedocs.worldbank.org/en/doc/5760109c4db174ff90a8dfa7d025644a-0290032022/original/G20-Gaps-in-PPR-Financing-Mechanisms-WHO-and-WB-pdf.pdf; WHO, OECD, World Bank (2025[38]), *"Report on Financing Pandemic Preparedness: Ensuring Sustainable and Efficient Financing. Report for G20 South Africa Presidency"*, https://www.g20.utoronto.ca/2025/G20-JFHTF_Report-on-financing-for-pandemic-preparedness-1.pdf; HHS (2022[40]), *"Department of Health and Human Services Public Health and Social Services Emergency Fund Fiscal Year 2022: Justification of Estimates for Appropriations Committee"*, https://www.hhs.gov/sites/default/files/fy-2022-phssef-cj.pdf; Sorbonne Universite (2024[39]), "*Anticipating future epidemics with OBEPINE+"*, https://www.sorbonne-universite.fr/dossiers/sante-globale/anticiper-les-futures-epidemies-grace-obepine; HERA (2023[41]), "*HERA 2024 Work Plan"*, https://health.ec.europa.eu/publications/hera-2024-work-plan_en; DG Sante (2023[42]), *"State of Health Preparedness Report 2023"*, https://health.ec.europa.eu/publications/state-health-preparedness-report-2023_en.

The OECD analysis has some limitations. The interventions included in this chapter were selected to capture non-pharmaceutical measures that protect health and the economy in the early phase of an outbreak, consistent with the scenarios modelled in Chapter 7 and other measures that have been shown to bolster PPR foundations including strategic stockpiling arrangements (Chapter 9) and wastewater surveillance. They do not, however, encompass every measure that strengthens PPR capacity. Others such as improving ventilation and air hygiene, as well as targeted initiatives in healthcare and other high-risk settings can also play an important role in reducing transmission. Countries undertaking their own costing analyses could weigh these alongside the interventions assessed here, drawing on the factors most relevant to their context.

The OECD analysis focusses exclusively on the investments required to strengthen PPR capacity at the country level. But because pandemics can emerge anywhere and spread rapidly, a global-goods perspective is critical. Investments in cross-border priorities (e.g. R&D for new therapeutics, diagnostics and vaccines) are indispensable for a resilient global health architecture. The analysis does not account

for country-specific institutional arrangements that may substantially affect investment needs. Decentralised systems, for instance, may face higher costs due to additional co-ordination demands and potential duplication across administrative levels. Differences in regulatory environments, procurement practices and public-private partnership models may further shape investment requirements. Countries with streamlined emergency approval pathways may be able to implement certain PPR measures more quickly and at lower cost.

Despite these limitations, the OECD cost estimates should be considered conservative. Many of the investments examined in this chapter have the potential to yield benefits beyond PPR, contributing to other health system priorities. For instance, improving disease surveillance capacity through enhanced wastewater monitoring can effectively address the rising threat of antimicrobial resistance. Expanding stockpiles of PPE and hygiene supplies increases resilience against seasonal surges, natural disasters and other health emergencies. Together, these dual-use benefits underscore that spending on PPR capacities is not only a safeguard against future pandemics but also a strategic investment in the resilience of health systems.

8.5. Conclusions

Findings from this chapter showed that the annual cost of bolstering PPR capacity involving multisectoral action averages almost USD PPP 7.2 billion across the OECD, with substantial cross-country variation in investment needs. Crucially, findings from the chapter showed that failing to invest in the preparedness efforts before a disease outbreak occurs does not eliminate the need for these expenses. Instead, it shifts them to the response phase where they are likely to be more costly. In the response phase, it will be crucial to provide funding quickly to support the rapid scale up of the implementation of physical contact-reducing NPIs and other measures that can help limit the adverse health and economic impacts of the outbreak.

The economic rationale for prioritising PPR is compelling. It not only saves lives but shields economies from the devastating economic consequences of inadequate pandemic responses. As discussed earlier, the cumulative probability of experiencing another pandemic on the scale of COVID-19 within the next 25 years is estimated at roughly 50% (Madhav et al., 2023[3]). Set against the potential health and economic toll documented in Chapters 3 and 7, the investment required to strengthen PPR capacity is modest. In the absence of timely non-pharmaceutical interventions, an uncontrolled outbreak could reduce GDP by between 11.7% and 28.9% in its first nine months and, in the most severe scenarios, could claim the lives of up to one in five people. Against losses of this magnitude and an increasing risk of facing them within a generation, investing in bolstering PPR capacity emerges as a sound economic proposition.

As OECD countries weigh their options for strengthening PPR capacity, it will be essential to emphasise international co-operation, establish sustainable funding models and adopt integrated approaches that account for the complex interplay between human, animal and environmental health.

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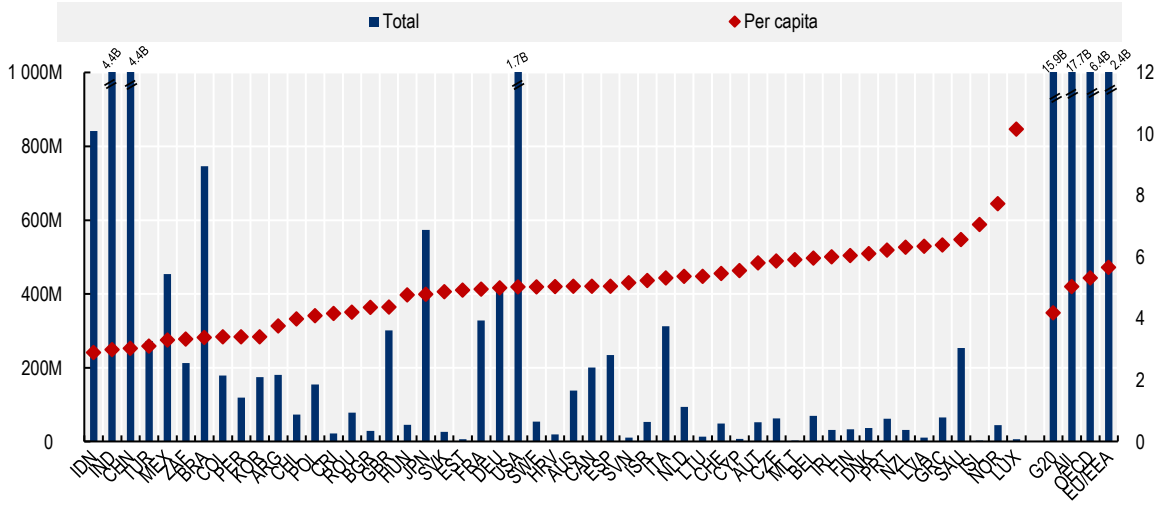
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Annex 8.A. PPR investment estimates under different assumptions of start-up PPR capacities

Annex Figure 8.A.1. Annual average cost of investing in PPR, 30% capacity at the start-up

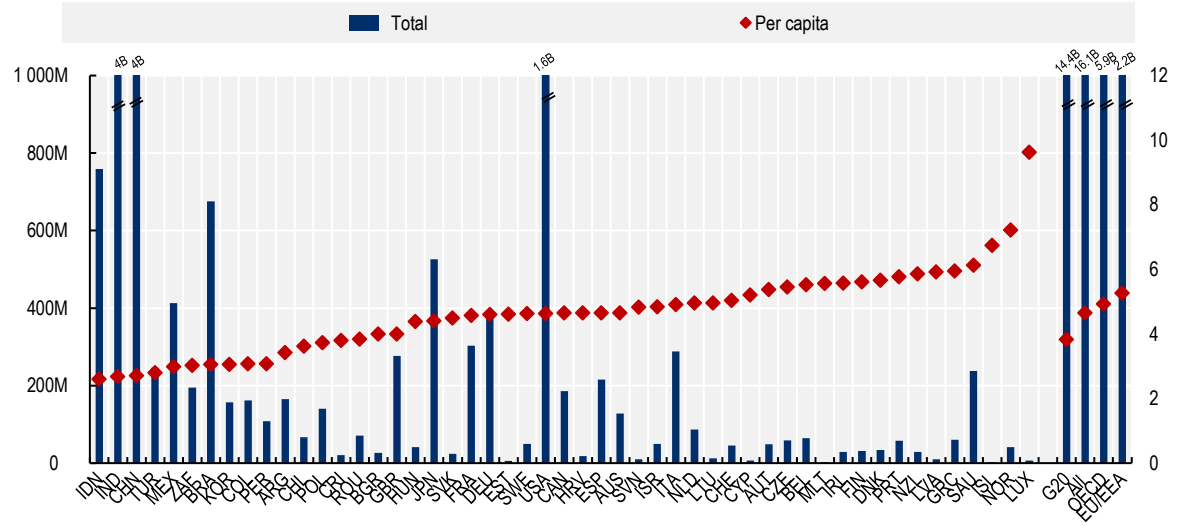
Total and per capita cost of investing in PPR, USD PPP



Note: Start-up period refers to the first two years of the preparedness phase in which countries establish mechanisms to bolster PPR capacity. PPP = purchasing power parity; B = billions; M = millions.
Source: OECD analysis based on the OECD SPHeP Costing Tool.

Annex Figure 8.A.2. Annual average cost of investing in PPR, 50% capacity at the start-up

Total and per capita cost of investing in PPR, USD PPP



Note: Start-up period refers to the first two years of the preparedness phase in which countries establish mechanisms to bolster PPR capacity. PPP = purchasing power parity; B = billions; M = millions.
Source: OECD analysis based on the OECD SPHeP Costing Tool.

Annex 8.B. The scope of previous works estimating the investment requirements for strengthening PPR capacities

Annex Table 8.B.1. Previous works that quantified the cost of PPR

Study	Geographic coverage	Period	Aim of the PPR package	Components of the PPR package
(WHO and World Bank, 2022[37])	Global	Not specified	Bolster PPR capacity at the country, region and regional levels	• Surveillance, collaborative intelligence and early warning • Prioritised research and equitable access to medical countermeasures and essential supplies • Public health and social measures and engaged, resilient communities • Lifesaving, safe and scalable health interventions and resilient health systems • PPR strategy, co-ordination and emergency operations
(World Bank, 2022[36])	Global	Over 5 years	Scaling up One Health approach to reduce the likelihood or consequences of large outbreaks or pandemics	• Strengthen animal health and veterinary services • Improve on-farm biosecurity • Reduce de-forestation and/pr forest degradation, improve conservations • Improve urban planning
(Eaneff et al., 2022[43])	Global	Over 5 years	Strengthening country level health security capacity in the International Health Regulations to progress towards the criteria identified by the Joint External Evaluation	• Skilled healthcare workforce to support prevention activities, including animal health and AMR detection • Food safety inspectors • Public health workforce to develop and implement prevention plans
(G20 High Level Independent Panel, 2021[5])	Global	Over 5 years	Strengthening international and national PPR and investments in global public goods	• Building robust surveillance and detection networks • Building resilience in health systems • Strengthening supply capacity for medical counter measures
(Craven et al., 2021[35])	Global	Over 10 years	Bolster PPR capacity at the country, region and regional levels	• Building “always on” response systems and partnerships that can scale rapidly during epidemics (e.g. maintain robust medical supply stockpiles etc.) • Strengthen global, national and local mechanisms for detecting infectious diseases • Integrated epidemic-prevention agenda (e.g. increasing vaccination coverage etc.) • Systems ready to survey while maintaining essential services • Investing in infectious-disease research and development
(Dobson et al., 2020[44])	Global	2020	Reduce zoonosis outbreaks due deforestation in tropical forests	• Support wildlife trade monitoring program; • Efforts to end wild meat trade in China; • Reduce deforestation by 40%; • Programmes for early detection and control • Programmes to reduce spillovers from wildlife and livestock from emerging disease hotspots

9 Strategic stockpiling is key for timely and effective pandemic preparedness and response strategy

This special focus chapter provides an overview of policies for stockpiling medical goods as a first short-term buffer layer for pandemic preparedness and response. It draws on insights from several OECD countries and the European Union, describing some of the practical considerations, implications and challenges of strategic and co-ordinated stockpiling.

In Brief

Key messages

Stockpiling of relevant medical goods, such as medical countermeasures, is important for timely and effective pandemic preparedness and response capacity

- Strategic stockpiling is the proactive accumulation and maintenance of a critical supply of relevant medical goods, such as medical countermeasures used to diagnose, prevent, protect from, or treat conditions during a public health emergency. The rapid deployment of these supplies serves as an important first-layer response during the initial stages of a public health emergency and forms an important part of pandemic preparedness and response. In preparation for severe crises, stockpiling offers a short-term solution while manufacturing and production capacity of relevant goods are ramped up.
- During COVID-19, sudden large increases in demand, coupled with supply disruptions due to imposed restrictions and supply chain bottlenecks saw critical shortages in basic supplies of personal protective equipment (PPE) and essential medicines such as anaesthetics.

Stockpiling systems have variable scope, objectives, governance, and financing arrangements

- National and regional stockpiling strategies have differing and multiple objectives, including various types of products for different crisis events, such as pandemics, natural disasters, chemical, biological, radiological and nuclear (CBRN) threats, and the threat of antimicrobial resistance.
- Prior to the COVID-19 pandemic, 16 of 23 surveyed OECD countries stated in 2022 that their preparedness plans included provisions for stockpiles of vaccines and medicines, and 11 of 23 countries included provisions for PPE procurement and logistics.
- Effective stockpiling policies require strategic planning and risk assessment, clear governance structures, sustainable funding and reimbursement arrangements, as well as effective inventory management and logistics. The responsibility of national physical emergency stockpiles often lies with government authorities (e.g. in Canada, France and the United States), although there are some cases where companies may also be under obligation to increase their own inventories to a defined level with or without compensation.

Regional EU stockpiles are an example of co-ordinated strategic stockpiling

- One challenge with national stockpiling policies is that accumulating larger quantities of essential medical supplies at national or subnational levels may lead to unintended consequences, such as shortages for regular use, price increases, and wastage of unused stock.
- Regional stockpiling and pooled procurement can be considered a pragmatic option in some circumstances for certain goods, provided that allocation of products during times of crises are well defined. Under the EU Civil Protection Mechanism's rescEU initiative, the European Commission established a regional strategic stockpiling mechanism in 2020 aimed at preparing and responding to health crises and large-scale disasters. Here, 22 stockpiles are strategically hosted across 16 EU Member States, with stock covering three priority threats (pathogens of pandemic potential, antimicrobial resistance and CBRN) and to be used as a last-resort option. Building on the lessons from rescEU, the 2025 *EU Strategic Plan for Stockpiling Medical*

Countermeasures aims to enhance preparedness and response for priority threats through efficient, effective EU-level stockpiling that complements national and global initiatives in a cost-effective manner.

Designing stockpiling policies should consider several challenges

- Assessing the costs and benefits of stockpiling policies is challenging as evidence on costs and cost-effectiveness of stockpiling are sparse. Nevertheless, previous evidence points to the importance of considering the financial sustainability of the stockpile, the high uncertainty and predictability in the virulence and infectiousness of future pathogens of pandemic potential, the value of robust logistics and inventory management systems for stock management, and effective co-ordination, communication and information-sharing among relevant stakeholders (e.g. national and local authorities, healthcare providers, industry partners, the public).
- Finally, it should be recognised that while stockpiling is an immediate response capacity that provides only a finite supply and offers limited effectiveness during prolonged disruptions. Ensuring ongoing supply of critical goods to populations goes beyond stockpiling initiatives.

9.1. Introduction

Strategic stockpiling is the proactive accumulation and maintenance of a critical supply of relevant goods, such as medical countermeasures (MCMs),[1] the rapid deployment of which serves as a first buffer layer in public health emergencies by providing critical supplies during the initial stages when market supply may be unable to meet high demand (OECD, 2023[1]; OECD, 2024[2]). As was the case with the COVID-19 pandemic, the onset of a large-scale event can result in shortages of basic supplies of PPE, including face masks, gowns, and gloves, as well as essential medicines such as anaesthetics. These shortages are amplified by sudden large increases in demand coupled with disruptions in supply, for example due to imposed restrictions and supply chain bottlenecks. Companies generally manage seasonal or unexpected volatility in demand on a small or medium scale to ensure reliable supply of their product. However, in preparation for an event such as a pandemic, national or regional stockpiling of basic critical supplies and essential medicines may be needed to offer a short-term solution while manufacturing and production capacity is ramped up to meet unprecedented demand.

A recent OECD report, *Securing Medical Supply Chains in a Post-Pandemic World*, identified appropriate inventory strategies and co-ordinated strategic stockpiling as part of the basket of policy measures to enhance the resilience of medical supply chains, both under routine circumstances as well as in preparation for a severe crisis (OECD, 2024[2]). However, it also recognised that some stockpiling techniques could have a negative impact on supply. For example, increasing volumes of (national or local) stockholdings of supplies, particularly amid a crisis, can lead to counteractive outcomes, such as causing product shortages elsewhere, driving up prices, or resulting in wastage from unused stock. This report further underlined that stockpiling cannot serve as a long-term solution for strengthening the resilience of supply chains more broadly, as it provides only a finite supply and offers limited effectiveness during prolonged disruptions (OECD, 2024[2]).

Building on insights from the recent OECD report (2024[2]), as well as those found in the literature, this special focus chapter aims to focus on practical implications of stockpiling specifically for pandemic preparedness and response. This is challenging, however, as national and regional stockpiling strategies often have differing and multiple objectives and include various types of products for different crisis events, and not only limited to medical products like PPE and medicines, but also other inventory including back-up personnel and hospital beds. The analysis is also limited by a lack of transparency regarding stockpiling

strategies, which may be due to national security reasons, risk of market disruptions etc. Consequently, to the extent possible, the current analysis benefits from understanding stockpiles developed for various purposes, though it is not exhaustive. The special focus chapter is organised as follows: Section 9.2 describes the context of medical supply chains and why strategic stockpiling might be necessary as a first-layer buffer for pandemic preparedness and response. Sections 9.3 and 9.4 describe some examples of different stockpiling policies implemented by countries and in the European Union (EU), respectively. Section 9.5 discusses some of the limitations of stockpiling and practical implementation issues. Annex 9.A contains an overview of some specific stockpiling initiatives.

9.2. Strategic stockpiling is an important short-term buffer for pandemic preparedness and response

In today's interconnected world, governments need to be ready to address potential supply chain disruptions in preparation for public health emergencies. As seen with COVID-19, lockdowns, travel bans or restrictions imposed during pandemics have resulted in disruptions to transport, freight, logistics and customs activities, adversely affecting the movement of goods across borders (OECD, 2024[2]). This is pertinent to medicines and medical devices, as their production from raw materials, intermediate inputs, or components to finished products involves complex, increasingly transnational, supply chains, with multiple stakeholders across different facilities and countries.

As described in the recent OECD medical supply chain report, over the last 30 years, global trade in pharmaceuticals has increased 10-fold, amounting to USD 900 billion in 2022, half of which is attributed to intermediate inputs such as active pharmaceutical ingredients (OECD, 2024[2]). Over the same period, global trade in medical devices has increased seven-fold, reaching USD 700 billion in 2022. More than a third of trade in medical devices by value is attributed to medical equipment (34%), followed by PPE (30%) and other medical supplies (25%). In Europe, parallel trade also allows the free movement of goods within the European Economic Area (ibid.). While trade is important to ensure the continuity of supply chains and has played an important role to address pandemic-related disruptions and shortages, strategic stockpiling policies are used by countries as interim buffer solutions to allow for rapid deployment of medical goods during the initial stages of a large-scale emergency event (OECD, 2024[2]).

9.3. National stockpiling policies vary, but common practical considerations apply

Stockpiling has been widely recognised as a risk management strategy for national response efforts to public health emergencies. Prior to the COVID-19 pandemic, 16 of 23 countries that responded to the OECD Resilience of Health Systems Questionnaire 2022 stated that their preparedness plans included provisions for stockpiles of vaccines and medicines, and 11 of 23 countries included provisions for PPE procurement and logistics (Figure 4.1, (OECD, 2023[1])).

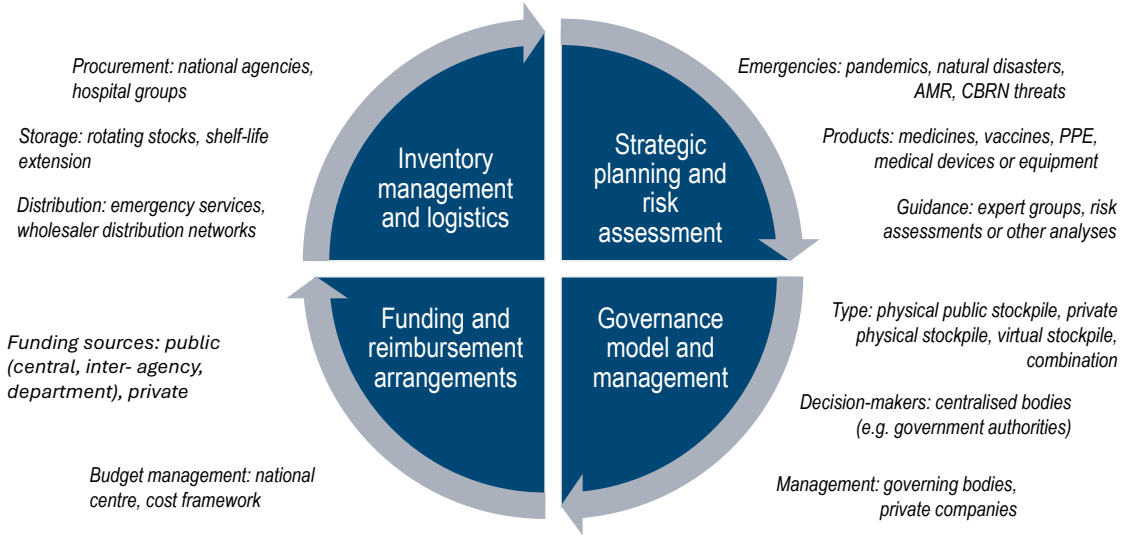
In its 2021 guidance, the World Health Organization (WHO) identified strategic health stockpiles as one of the resources that countries may deploy as part of their national response to a variety of health emergencies and disasters (WHO, 2021[3]). For example, the WHO also defined a list of products specific to radiological and nuclear emergencies that it recommends for national stockpiling (WHO, 2023[4]). However, the WHO Pandemic Agreement formally adopted on 20 May 2025 calls on countries to "avoid maintaining national stockpiles of pandemic-related health products that unnecessarily exceeds the quantities anticipated to be needed for domestic preparedness and response" during a pandemic emergency (WHO, 2025[5]).

At the EU level, the European Commission's Health Emergency and Response Authority (HERA) was created in 2021 to better prepare for and respond to cross-border threats, including 1) pathogens with high pandemic potential, 2) chemical, biological, radiological and nuclear (CBRN) threats, and 3) threats from antimicrobial resistance (EC, 2021[6]; EC, 2022[7]). HERA's mandate includes enhancing MCM stockpiling capacity at EU level to secure ready availability and accessibility of MCMs and also recommends the creation and management of national stockpiling strategies (HERA, 2023[8]).

The sections below describe some of the practical considerations for stockpiling of medical goods or countermeasures, which covers strategic planning and risk assessment, governance model and management, funding and reimbursement arrangements, and inventory management and logistics (Figure 9.1.). This is not intended to be exhaustive but draws on lessons learned from several country experiences.

As previously highlighted in the OECD report (2024[2]), OECD countries have implemented national stockpiling systems with variable scope, objectives, governance, and financing arrangements (see Annex Table 9.A.1. , Annex 9.A, for some examples in **Australia, Canada, Colombia, Korea, Spain, Switzerland** and the **United States)**. Among others, the current analysis draws on insights gained from a recent report by the Health Information and Quality Authority (HIQA), an independent statutory authority in Ireland, which overviewed national MCM stockpiling in five countries (**France**, **Latvia**, **Lithuania**, the **Netherlands**, and **Norway),** based on expert interviews, to inform the development of a national MCM stockpiling strategy for Ireland (HIQA, 2023[9]). A HERA commissioned report on the feasibility of stockpiling against antimicrobial resistance (AMR) threats in EU countries also informed the analysis (European Commission, 2022[10]). Box 9.1 describes the specific situation in the United States, with further information on some countries available in Annex 9.A.

Figure 9.1. Practical considerations for stockpiling: Examples



Note: AMR: antimicrobial resistance. CRBN: chemical, biological, radiological, nuclear. PPE: personal protective equipment. This list is not intended to be exhaustive.

Box 9.1. United States' Strategic National Stockpile

The U.S. Department of Health and Human Services Administration for Strategic Preparedness and Response oversees the United States' Strategic National Stockpile (SNS) (ASPR, n.d.[11]). The federally-managed SNS contains large quantities of medicines and other medical supplies to be deployed to States and local health jurisdictions as a last resort to respond to a public health emergency, including bioterrorist attack, outbreak, earthquake etc, or any severe event in which local supplies are insufficient for the response (Congressional Research Service, 2023[12]). More than 250 civil servants, the U.S. Public Health Service officers, and contractors are organised to support the SNS – staff include those with backgrounds in pharmacy, clinical care, emergency management, medical logistics and operations, quality control, public health, procurement, financial management, information technology, strategic planning, training, policy and communications (ASPR, n.d.[11]). Each State has plans for rapid distribution of the SNS.

The contents of the stockpile are not public but generally include a broad range of medications such as antibiotics, antidotes and antitoxins, as well as vaccines and other biological products, medical devices such as ventilators and other equipment and ancillary supplies including PPE and surgical items (ASPR, n.d.[11]; Congressional Research Service, 2023[12]). The SNS also includes pre-determined deployable packages such as CHEMPACKs[1], Federal Medical Stations [2], and other combination packs that contain pre-identified supplies to address specific needs such as Push-Packages[3]. The types and quantities of stockpiled products are determined by the Department of Health and Human Services Secretary who, with the assistance of an interagency group, reviews the stockpile annually to ensure that contents are consistent with current health threats (Congressional Research Service, 2023[12]).

The annual allocation of federal funds to the SNS pre-COVID was USD 610 million in 2019, increasing to USD 705 million in 2020 and 2021, USD 845 million in 2022, and USD 965 million in 2023, 2024 and 2025 (HHS, 2021[13]; HHS, 2022[14]; HHS, 2023[15]; HHS, 2024[16]; HHS, 2025[17]). Over the COVID-19 period, the budget prioritised targeted investments in critical medical supplies as well as the development and sustainment of capabilities to prepare for and respond to pandemics, and to support expanded storage and distribution needs in light of COVID-19 (HHS, 2022[14]). According to the budget request in 2025, of a total USD 965 million funds allocated to the SNS, around USD 791 million is projected to be allocated to products, including around USD 564 million for procurement of additional quantities and replenishment, around USD 227 million for sustainment (i.e. storage, transportation, maintenance and disposal), and USD 157 million for warehousing costs. The remaining allocation of around USD 174 million is to be allocated to SNS operational costs (e.g. costs to develop and provide guidance, training, security and other resources) (HHS, 2025[17]).

More recently, the SNS received supplemental funding to expand its pandemic preparedness portfolio, with the value of SNS inventory on medical countermeasures growing by more than 50% to around USD 13 billion in 2024, up from USD 8 billion in 2019. In the same period, the inventory volume increased by more than 400% (HHS, 2021[13]; HHS, 2024[16]). By 15 December 2022, the SNS had obligated more than USD 11 billion in supplemental funds for the COVID-19 response, put towards increasing SNS inventories of essential medical supplies (e.g. ventilators, PPE, and pharmaceuticals), supporting COVID-19 vaccination, boosting domestic manufacturing, transporting materials and modernising its operations (HHS, 2025[17]). Of USD 6.1 billion in COVID-19 relief funds in 2020 and 2021, USD 3 billion went to purchasing ventilators, USD 2.4 billion to PPE, USD 494 million to vaccination supplies, USD 149 million to medications, and USD 25 million to other products (US Government Accountability Office, 2022[18]). As a comparison, nearly USD 5 billion in non-COVID-19 funds in the fiscal years 2015-2021 were committed to buying medical countermeasures for the SNS, with approximately 75% directed towards smallpox (USD 1.1 billion) and anthrax (USD 2.3 billion) and

the rest to viral haemorrhagic fever (USD 477 million), pandemic influenza (USD 191 million), ancillary and intravenous supplies (USD 124 million) and other threats such as CBRN (USD 403 million) (Congressional Research Service, 2023[12]; US Government Accountability Office, 2022[18]).

Most supplies in the SNS are in physical warehouse facilities strategically distributed across the country. For example, Push Packages[3], which make up around 5% of SNS inventory, can be deployed anywhere within the country from physical stockpiles within 12 hours. Vendor-managed stockpiles are also used for around 10% of current SNS contracts. Here, the SNS pays the vendor to store and manage defined quantities of a product for SNS deployment. This type of stockpile allows the vendor to rotate product to the commercial market and the SNS and government does not need to pay for replacement of expired stock. However, delivery time from these systems usually takes around 24 to 36 hours and this arrangement is only suitable for products in which the commercial market is viable enough to sell expiring products. The SNS also uses user-managed stockpiles, whereby products for emergency scenarios (e.g. chemical warfare and antidotes) are stored at selected local medical, emergency management and public health facilities across the country for quick deployment (i.e. less than 12 hours) (Congressional Research Service, 2023[12]). The SNS maintains contracts with commercial transportation partners who can meet the most challenging delivery timelines. Effectiveness of transportation capabilities are also tested through live, no-notice deployment drills (HHS, 2022[14]).

The Inventory Management and Tracking System (ITMAS), which was released in September 2011 following lessons learned during the 2009 H1N1 influenza pandemic, helps state and local responders to manage inventory they receive from the SNS stockpile (Congressional Research Service, 2023[12]; ASPR, n.d.[19]). It allows tracking of inventory to local levels, monitoring of re-order thresholds and supports warehouse operations (ASPR, n.d.[19]). For example, The Countermeasure Inventory Tracking Dashboard allows a graphical visualisation of the supply chains and key information on countermeasure availability (Congressional Research Service, 2023[12]). The SNS provides the Inventory Management and Tracking System and appropriate training to authorised jurisdictions at no cost.

Sustaining the stockpile requires management of the lifecycle of stockpiled products, including stock rotation to avoid expiry, quality assurance and inspections. To support with this, the Shelf-Life Extension Program applies to federal stockpiles and allows the extension of expiration dates for certain products (e.g. some medicines, vaccines and other medical products). Here, the U.S. Food and Drug Administration agency conducts periodic stability testing and the programme can extend expiry dates up to around 12 to 24 months beyond their original expiries (ASPR, n.d.[20]). Stability testing refers to assessing whether properly stored products retain their stability beyond their labelled expiration date (i.e. assessing degradation of the active ingredients, integrity of product appearance etc). Current testing in the SNS prioritises medications procured in large quantities (e.g. doxycycline, ciprofloxacin), and products with limited commercial demand (e.g. nerve agent antidotes such as atropine and diazepam), among others (FDA, 2024[21]).

Since the establishment of the SNS, the stockpile has been deployed in a variety of emergency situations including the 2011 11 September and anthrax attacks, H1N1 influenza pandemic, Ebola outbreak, Zika virus crisis, various hurricane and flooding response, and the COVID-19 crisis (Congressional Research Service, 2023[12]). As part of the COVID-19 response, the SNS distributed PPE (including N95 respirators, surgical and face masks, face shields, gloves, and disposable gowns) across all 50 states, the country's four largest cities, as well as eight U.S. territories and islands. The distribution strategy was based on a pro rata allocation proportion to the population size of each jurisdiction (HHS, 2022[14]; HHS, 2023[15]). Over the more than 3-year COVID-19 response period, the SNS distributed 25 000 ventilators to areas in need and all 32 of the SNS's Federal Medical Stations (ASPR, n.d.[11]; HHS, 2022[14]), 5 000 high-flow nasal cannula for respiratory support and ancillary kits that supported upwards of 1.3 billion COVID-19 vaccinations (HHS, 2025[17]). By 18 March 2021 alone,

the SNS COVID-19 support included engagement with over 180 private industry partners for medical supply chain and delivery, more than 4 380 trucks and transporting supplies, more than 640 flights, more than 16 800 tons of cargo shipped, and with more than 200 staff working on the response (HHS, 2022[14]).

The COVID-19 pandemic did, however, reveal vulnerabilities in global supply chains and the SNS faced several challenges early on. For example, the SNS did not hold sufficient PPE to meet demand, and the storage and distribution needs were expanded and modified in light of COVID-19 using supplemental funds appropriated by Congress. Efforts were put in place to build the SNS's inventory of PPE and ventilators to ensure that the SNS could meet 90 days of need for pandemic response, with progress towards meeting these goals up until December 2022 shown in Table 9.1. These goals remain lower than previous estimates of what might be needed to protect healthcare personnel in the event of a severe influenza pandemic – for example, stockpiles of 3.5 billion N95 respirators and 500 million surgical masks at federal level, and additional stock at state and local levels (Mehrotra, Malani and Yadav, 2020[22]; Carias et al., 2015[23]). The SNS greatly expanded its PPE and ventilator stockpile using temporary COVID-19 funds, but after the Fiscal Responsibility Act of 2023 rescinded remaining balances and those funds were exhausted, it will lose this capacity as existing supplies expire (HHS, 2025[17]). The main text outlines some additional challenges faced by the SNS stockpile during COVID-19, such as management and co-ordination issues, areas that have subsequently been strengthened.

Table 9.1. Progress towards enhancing SNS capacity to meet 90 days of need for pandemic response

Item	Stockpiling goal	Deployable quantity		
		As of 9 April 2021 (HHS, 2022[14])	As of 16 December 2021 (HHS, 2023[15])	As of 15 December 2022 (HHS, 2024[16])[1]
N95 respirators	300 million	**358 million (+)**	**747 million (+)**	**537 million (+)**
Masks (surgical / procedural)	400 million	273 million (↑)	274 million (↑)	244 million (↑)
Eye / face shields	18 million	**19.5 million (+)**	**19.6 million (+)**	**18.9 million (+)**
Gowns / coveralls	265 million	2.9 million (–)	59.6 million (↑)	51.5 million (↑)
Gloves	4 500 million	311 million (↑)	4 055 million (↑)	4 486 million (↑)
Ventilators	152 000	**154 000 (+)**	**158 000 (+)**	**158 000 (+)**

Note: (+) stockpiling goal met; (↑) stockpiling goal not met, but holdings have been increased from pre-pandemic; (–) stockpiling goal not met.
1. Some PPE from the COVID-19 response is expiring so the table shows the upper limit of what is available to use as of 15 December 2022.
Source: Adapted from sources as cited in row two of the table.

1. CHEMPACKs are containers of nerve agent antidotes placed in around 1 330 locations across the country, generally in hospitals or fire stations; most of the population is within 1 hour distance of a CHEMPACK location.
2. Federal Medical Stations (FMS) allow first responders to rapidly set up temporary medical shelters that can each treat 50-250 patients, and contain a 3-day supply of pharmaceuticals, medical equipment and other supplies.
3. "Push packages" are read-made containers with supplies covering a range of public health emergencies (including antibiotics, intravenous fluids, bandages, and other medical supplies).
Source: As cited. Further details on ASPR budget and funding for recent fiscal years can be found at https://aspr.hhs.gov/AboutASPR/BudgetandFunding/Pages/default.aspx, last accessed 06 November 2025. Some years have been archived but are still accessible.

9.3.1. Strategic planning and risk assessment

One of the main challenges with stockpiling is deciding what to stockpile and in what quantities to prepare for what types of crises. Emergencies that are stockpiled against include pandemics, natural disasters, as well as CBRN threats. Generally, national stockpiles include products such as medicines (including intravenous antibiotics, antivirals), vaccines, PPE, and medical devices, among other medical countermeasures against CBRN threats. Stockpiles vary in size, for example from six week to six-month supply, and stock must be actively rotated to ensure it can be used before expiry. Stockpiles can also vary in location (e.g. held centrally, locally, in multiple locations etc), reflecting concerns around security of supply, ability to deploy quickly, and potential for wide geographic coverage. HIQA reports that while France, Latvia, Lithuania, the Netherlands and Norway all had pre-existing MCM stockpiles, they made significant adjustments post-COVID-19, such as adding general medicines and PPE and a review of sources of medical countermeasures (HIQA, 2023[9]). All these countries reported relying on risk assessments or various forms of analysis to identify risks that justify stockpiling. They sought guidance from expert groups to pinpoint threats, evaluate risks and determine which products to include in what quantities (HIQA, 2023[9]). A recommendation from HIQA's review suggested that future stockpiling approaches should involve a national independent expert group or a national security board to assess risks and make decisions about what items to stockpile (HIQA, 2023[9]).

Strategic planning and risk assessment shape how countries determine what to stockpile. In Australia, the key decision-making committee for health emergencies advises on managing the stockpile (Australian Department of Health and Aged Care, 2023[24]), while in the United States an interagency group helps determine stockpiled contents, which get reviewed annually (see Box 9.1 for more details on the U.S. stockpiling system). In Korea, the Ministry of Food and Drug Safety develops a list of essential products which must be stockpiled, and other stockpiled products are informed by priority diseases identified by Korea's Centers for Disease Control and Prevention (Ministry of Food and Drug Safety, 2019[25]). Several countries and regional authorities are also identifying "critical" medical products towards which to best direct their supply chain resilience efforts; in some cases these lists may be used to guide stockpiling (OECD, 2024[2]).

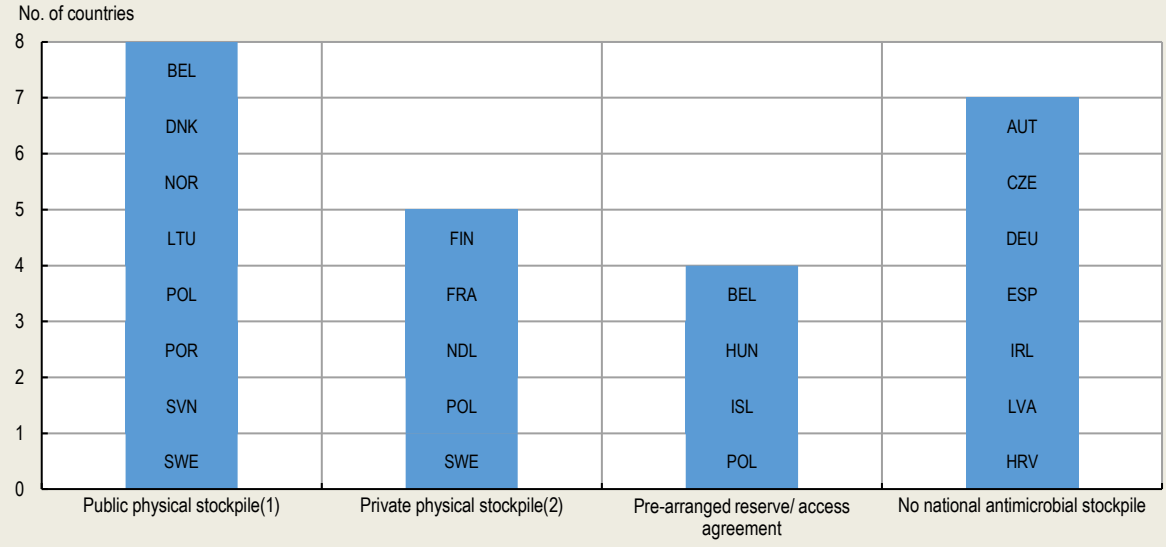
9.3.2. Governance model and management

Stockpiling strategies require a defined governance structure to ensure effective management and oversight. Common elements may include centralised decision-making bodies, collaboration between various government agencies and clear regulatory frameworks. A recent HERA-commissioned report mapping organisations and structures involved in preparedness and response to health crises related to MCMs found that most OECD countries have entities involved in stockpiling and distribution capacities for MCMs (European Commission et al., 2025[26]). The report identified a trend towards the centralisation of strategic stockpiling at the national level, although some countries, particularly in Europe, also maintain decentralised approaches that complement national reserves (ibid). Responsibility of national emergency stockpiles often lies with government authorities (e.g. in Australia, Canada, Colombia, Korea, the United States – see Annex 9.A), although different types of arrangements are possible such as when private companies are required to maintain publicly mandated stockpiles. Several countries use mixed models, whereby the presence of nationally financed and managed public physical stockpiles may be complemented by private stockpiles or pre-arranged access agreements. Box 9.2, for example, overviews existing or planned stockpiling systems for antimicrobials, while Annex 9.A explains Switzerland's compulsory rolling stockpiling system.

Box 9.2. Assessment of stockpiling systems in the EU, in the context of antimicrobial resistance

While not directly related to pandemic preparedness and response, a review by HERA found that 13 of 20 EU and European Free Trade Agreement countries reported having a national stockpile that included antimicrobials, either as finished products and/or active pharmaceutical ingredients (European Commission, 2022[10]). As shown in Figure 9.2, countries use different governance models for these stockpiles, with 8 countries reporting a physical stockpile managed by public authorities and fully financed by national (public) funds. Other countries such as Finland and France make use of privately owned stockpiles whereby companies and wholesalers are obligated to keep certain levels of stock. In France, companies are not compensated for this obligatory stockpiling and compliance is exercised through fines for non-compliance, while in Finland companies are compensated for this stockholding by payers through higher prices. Several countries including Belgium, Sweden and Poland use a mix of governance systems. In most countries, stockpiles are managed by national authorities. The presence of regional-level stockpiles (Denmark and Sweden) and hospital-level stockpiles (Austria, Finland, Norway) were also reported.

Figure 9.2. Existence and governance of national antimicrobial stockpile in 20 EU/EFTA countries



Note: 1. Physical stockpile managed by public authorities and fully financed by national funds.
2. Companies or wholesalers are under obligations to increase their inventories to a defined level.
Source: (OECD, 2024[2]), originally adapted from European Commission (2022[10]), *HERA AMR feasibility study on stockpiling*, https://op.europa.eu/en/publication-detail/-/publication/712bbfff-801e-11ed-9887-01aa75ed71a1.

In HIQA's review, France, Latvia, Lithuania, the Netherlands and Norway all reported physical[2] stockpiles of MCMs, which were mainly held by governments and designed for national and cross-border threats (HIQA, 2023[9]). Government ministries were ultimately responsible for national stockpile governance, with stockpile management the responsibility of the associated governing body. Stockpiling practices in these countries are governed by national legislation, with three of the countries requiring maintenance of general medicines by wholesalers, and two other countries regulating government- or public body-held stockpiles. Medical institutions such as hospitals and other healthcare institutions reportedly held their own stockpiles in four countries. One country reported involvement of a national stockpile management group, which oversees reviewing the stockpile, ensuring minimised stock wastage and that appropriate product quantities are maintained in the stockpiles (HIQA, 2023[9]). A recommendation emerging from the HIQA report was that future stockpiling approaches should consider an active stockpile management group to manage the day-to-day of the stockpile, while also considering decentralised stockpiles distributed geographically across the country to ensure access albeit remaining under centralised co-ordination (HIQA, 2023[9]). The United States and Australia both have centrally co-ordinated decentralised stockpiles strategically distributed in undisclosed locations to facilitate timely deployment (see Box 9.1 and Annex 9.A).

9.3.3. Funding/reimbursement arrangements

Funding arrangements also differ across countries, depending on the stockpile approach. According to the HIQA report**,** public sector stockpiles in the five reviewed countries were fully funded by public funds from national budgets, however in three of the countries, stockpiles for general medicines were privately owned in industry stockpiles – either held by wholesalers or companies (HIQA, 2023[9]). Out of the five countries, only three disclosed their funding sources: one relies on central government funding, another on inter-ministerial funding, and the third on the Department of Health. In one country, a national centre managed the budget, while another had a cost framework which outlined the maximum amount to be spent on the stockpile. The other countries mentioned that their stockpile budget depended on government approval (HIQA, 2023[9]). In the United States, federal funds are allocated annually towards the Strategic National Stockpile (Box 9.1). In systems whereby companies are obligated to hold certain stock, such as in France and Finland, different compensation mechanisms exist (Box 9.2).

9.3.4. Inventory management and logistics

Stringent inventory management and sound distribution practices are paramount to the effective functioning and deployment of stockpiles. National agencies with experience in stockpiling and preparedness typically oversee procurement, although hospital procurement groups may also be involved. Stockpile procurement is, however, reportedly affected by global supply shortages, as well as long lead times with the production of some products (e.g. vaccines), and issues around supplier reliability (HIQA, 2023[9]). To prevent waste and ensure efficient stockpile management, most countries report using rotating stocks (European Commission, 2022[10]). Medicines approaching their expiry dates can be reintroduced to the market via wholesalers or directly transferred to hospitals. Publicly owned stockpiles have also reported donating medicines to other countries. Privately-owned stockpiles typically rotate their inventory back into the commercial supply chain, with each country imposing different requirements on stockpile volumes (European Commission, 2022[10]). The United States also has an interesting programme that can extend the shelf-life of some federally stockpiled products (see Box 9.1). Further to stock management, operational delivery, such as stockpile distribution, generally takes place through defined mechanisms guided by the ministry of health and in some cases inter-ministerial collaboration, as well as through wholesaler distribution networks and national emergency medical service (HIQA, 2023[9]).

9.4. Regional EU stockpiles are an example of co-ordinated strategic stockpiling

Enhancing cross-country co-operation could improve the sustainability and efficiency of stockpiling schemes. One challenge with national stockpiling policies is that accumulating larger quantities of essential medical supplies at national or subnational levels may lead to unintended consequences, such as shortages for regular use, price increases, and wastage of unused stock. Collaboration on stockpiling both during and outside of pandemic emergencies is one of the aims of the WHO Pandemic Agreement, which establishes a Global Supply Chain and Logistics Network to co-ordinate international efforts in ensuring timely and efficient access to pandemic-related health products (WHO, 2025[5]).

Regional stockpiling and pooled procurement can be considered a more pragmatic option in some cases, provided that allocation of products during times of crises are well defined (OECD, 2024[2]). For example, under the EU Civil Protection Mechanism's rescEU initiative, the European Commission established a regional strategic stockpiling mechanism in 2020 aimed at preparing and responding to health crises and large-scale disasters (EC, 2024[27]) – see Box 9.3 for further details. The rescEU stockpile reserves of medical countermeasures serve as stockpiles of last resort against priority threats including pathogens with pandemic potential, antimicrobial resistance and CBRN hosted geographically across several Member States, from which Member States and associated countries can request assistance in the event of an emergency to which they do not have sufficient capacity to respond. The European Commission fully fund the rescEU stockpiles in part through the Health Emergency Preparedness and Response Authority (HERA) and maintains control of their operation through DG ECHO, in close co-operation with the hosting states that manage the physical stockpiles and handle logistics and procurement. EU Member States and the 10 Participating States of the European Civil Protection Mechanism can request assistance from the EU Civil Protection Mechanism through the Emergency Response Co-ordination Centre, an EU body responsible for co-ordinating civil protection activities. This centre evaluates the ability of rescEU to support the country's request and deploys the appropriate resources (EC, 2024[27]; HERA, 2024[28]; HERA, 2023[8]).

Box 9.3. EU Civil Protection Mechanism – rescEU stockpiling reserves

In 2022 and 2023, EUR 1.2 billion from the European Commission's Health Emergency Preparedness and Response Authority (HERA) budget has been invested in building up rescEU stockpiles against serious cross-border threats, including health crises such as COVID-19 and chemical, biological, radiological and nuclear (CBRN) emergencies including large-scale human induced disasters (HERA, 2023[8]; DG Sante, 2023[29]). In co-operation with HERA and DG ECHO, there are currently 22 rescEU stockpiles strategically hosted across 16 EU Member States that are either operational, being developed, or in the process of signature ((EC, 2024[27]) see Table 9.2.). The stock covers the three priority threats identified by HERA (pathogens with pandemic potential, antimicrobial resistance and CBRN) (EC, 2022[7]). Fifteen of the rescEU stockpiles are medical stockpiles, progressively available from 2020 onwards (EC, 2020[30]), that contain products such as vaccines and therapeutics, intensive care medical equipment, personal protective equipment and other laboratory supplies. Six of the rescEU stockpiles are CBRN-specific stockpiles, progressively available from 2023 onwards (EC, 2023[31]), and contain CBRN medical countermeasures such as vaccines, antidotes, antibiotics, sedatives, prophylactic treatment, medical devices and CBRN response equipment such as iodine thyroid blocking tablets, detectors and decontamination supplies and PPE (e.g. gas masks, protection suits). Collectively, the stockpiles form a flexible network of supply hubs that can be rapidly mobilised in the event of a crisis as a last resort (HERA, 2024[28]; EC, 2024[27]).

Table 9.2. RescEU capacities for stockpiles, as of June 2024

rescEU stockpiles[1]	Stockpiled items[2]	Hosting Countries
Medical stockpile	Personal protective equipment (masks/face shields, overalls, gloves, foot protection, googles); COVID-19 antigen tests; medicines/medical items; intensive care unit (ICU) equipment (ventilators, ultrasound, monitors, oxygen concentrators, infusion pumps, defibrillator, beds)	Belgium, Croatia, Denmark, France, Finland, Germany, Greece, Hungary, Lithuania, the Netherlands, Poland, Romania, Portugal, Slovenia, Sweden
CBRN stockpile	CBRN pharmaceutical products, CBRN decontamination products, CBRN personal protective equipment	Croatia, Czechia, Finland, France, Poland, Romania,

Note: 1. Stockpiles in hosting countries may already be operational, are being developed or are under signature.
2. Hosting countries may only store selected items from these lists in their stockpiles, in varying quantities.
Source: Adapted from ERCC (2024[32]), "*ECHO Daily Map of 27 March 2024*", https://erccportal.jrc.ec.europa.eu/ECHO-Products/Maps#/maps/4832 and ERCC (2024[33]), "*ECHO Daily Map of 05 June 2024*", https://erccportal.jrc.ec.europa.eu/ECHO-Products/Maps#/maps/4887.

The development, management and maintenance of the rescEU stockpiles is completely financed by the European Commission. So far, the stockpiles have been established through direct grants to Member States, and the EU Member States and Partner States own the capabilities and are responsible for procurement, management, deployment, staffing and training (Annex 2, (EC, 2025[34])). HERA offers operational support and advice on medical countermeasures, their stockpiling and deployment to the EU Civil Protection Mechanism (HERA, 2024[28]). Priorities and needs are defined by the European Commission in consultation with Member States and Partner States authorities, with decision on the deployment made by the European Commission (Annex 2, (EC, 2025[34])). According to HERA's State of Health Preparedness report published in 2023, over 3 million protective masks, ventilators and other equipment have been distributed from the strategic rescEU centres to the Member States in greatest need since 2020 (DG Sante, 2023[29]).

The composition of the different stockpiles varies, with grant agreements of different amounts awarded to the hosting countries. As an example, Germany received EUR 108 million from EU funds to set up its rescEU medical stockpile for a period of seven years from 1 January 2021 until 31 December 2027. The stockpile intends to include "around 110 million gloves, 24 million Type II(R) medical masks, 2.5 million FFP2/FFP3 masks, 8 million protective gowns and coveralls, 1 million visors and goggles, 600 000 rapid antigen tests against COVID-19 and 1 000 patient monitors, as well as protective equipment for Ebola treatment (including rubber boots, surgical clothing, biohazard bags, body bags)" (Johanniter International, 2021[35]). Johanniter-Unfall-Hilfe, a non-profit aid organisation, leads the consortium that is in charge of operationally running the German stockpile, including the German Red Cross. The Federal Ministry of Health and the Robert Koch Institute are among those represented in an advisory group.

In its 2024 workplan, HERA sought to enhance its strategic stockpiling approach through joint actions under the EU4Health programme – via direct grants of EUR 10 million to Member States – to support MS to develop sustainable and forward looking national and EU stockpiling strategies in an efficient and co-ordinated manner (HERA, 2023[8]). The funding aims to promote the sharing of best practices in innovative stockpiling solutions, evidence-based strategies, and risk-based approaches, while enhancing networking and collaboration among Member States, allowing them to experiment with innovative stockpiling methods, such as virtual stockpiling arrangements and IT solutions. Virtual (or vendor-managed) stockpiles are where companies that make or sell the items store a certain amount of stock that the government can buy if and when needed (ibid). In HERA's 2025 workplan, HERA further intends to continue to support Member States in quantifying stockpiles and establishing a

network of regional stockpile and distribution hubs, as well as developing and deploying new technologies for stockpile management (HERA, 2025[36]). In 2025, HERA plans to work closely with Member States and other Commission services to address challenges in stockpiling management, such as product shelf-life, legal status, marketing authorisation, waste and deployment (HERA, 2025[36]).

Note: As discussed further in the main text, the European Commission has recently devised several strategic plans in the context of prepared and response, including to support EU stockpiling policies (EC, 2025[34]; EC, 2025[37]).

The rescEU stockpiles of medical and CBRN countermeasures are seen to have offered an effective contingency for preparedness (EC, 2025[38]). However, stockpiling medical products is a complex exercise, with many different factors to consider (including shelf-life, regulatory requirements, environment and security requirements, and transport), requiring strong co-ordination with EU and national authorities and experts (EC, 2025[38]). As part of a broader EU medical countermeasures strategy released in July 2025 that aims to reinforce preparedness for priority threats (viruses with pandemic or epidemic potential, AMR and CBRN) (EC, 2025[34]), the European Commission has devised a strategic plan specifically for EU medical countermeasure stockpiling (Annex 2, (EC, 2025[34])). The latter is the first sectoral deliverable of a broader EU stockpiling strategy (EC, 2025[37]), which is a cross-sectoral strategy to ensure timely and equitable access to a wide range of critical goods, including medical supplies, energy equipment, critical raw materials, and potentially food and water, by integrating national and EU-level reserves, enhancing co-ordination among Member States, and fostering public-private partnerships for efficient and scalable stockpiling (EC, 2025[37]). The specific strategic plan for EU medical countermeasure stockpiling acknowledges the complexity of stockpiling such products as described above and outlines detailed processes that intend to complement national and global initiatives, including:

- **Determining the needs for EU stockpiles** e.g. identifying essential MCMs through a specific methodology based on specific criteria such as potential impact, time-critical effectiveness, redundancy, market failure/limitations, and production capacity; and determining necessary quantities to be stockpiled;
- **Effective procurement** e.g. stronger co-ordination by the European Commission and exploring the options for procurement such as of unfinished products;
- **Efficient management of stocks** e.g. centralised, sustainable and cost-effective management framework; integrating IT tools for real-time tracking; implementing shelf-life extension programmes; and fostering stakeholder collaboration; and
- **Timely deployment** e.g. resilient logistics services and compliance with regulatory requirements; and determining replenishment needs with the plan to secure minimum EU-level buffer stocks. and for identifying essential medical countermeasures, determining necessary quantities and the potential need for replenishment, followed by effective procurement strategies. The plan also outlines elements to strengthen the efficient management of these stocks to guarantee readiness and timely access during emergencies as well as a deployment strategy.

More broadly, while regional stockpiling such as the EU example offers important efficiencies, it may not be feasible in all contexts. Countries with geographic isolation, long supply chain distances and reliance on imports may face greater supply chain vulnerability, limited access to nearby partners and differing logistical conditions. In these settings, a strong, nationally controlled stockpile supported by stable funding and modern capability is important and may require larger buffer stocks and diversified supplier arrangements. Nevertheless, key elements of regional methodologies and approaches, such as structured risk assessment and prioritisation, robust inventory management and digital visibility, can still be adopted.

9.5. Stockpiling policies face several challenges

Stockpiling policies have several practical challenges, including but not limited to financial sustainability, uncertainty and predictability, logistical and stock management challenges as well as co-ordination issues. As previously highlighted in the OECD report on medical supply chains, assessing the costs and benefits of stockpiling policies is particularly challenging as evidence on the costs and cost-effectiveness of stockpiling are sparse (OECD, 2024[2]). Countries may not use a formal methodology to assess the costs and benefits of their stockpiling strategies (HIQA, 2023[9]). Yet, evaluations of the performance of stockpiling systems can importantly highlight some of the challenges faced in their implementation and deployment, as seen with the U.S. Strategic National Stockpile and the Australian National Medical Stockpile during the COVID-19 pandemic (Australian National Audit Office, 2021[39]; Congressional Research Service, 2023[12]; US Government Accountability Office, 2024[40]).

Some examples of these challenges are described below, although these will differ depending on the stockpiling approach taken (e.g. public versus private, physical versus virtual).

- **Financial sustainability:** Creating a stockpile requires a significant amount of investment, in terms of setting up the initial stockpile (including acquisition and storage) as well as ongoing maintenance requiring sustainable multi-year funding (see Chapter 8). In the United States, the 2021 annual budget for the SNS and BioShield Project[3] was USD 1.7 billion, excluding additional budget that was allocated to respond to COVID-19 (Congressional Research Service, 2023[12]). Administration for Strategic Preparedness and Response officials have reportedly mentioned that annual allocation of funds to the SNS are insufficient to cover the costs associated with responding to the increase in threats for which the SNS may be needed (Congressional Research Service, 2023[12]). For example, while the 2022 budget for the SNS was USD 845 million, projections from 2019 indicated that USD 1.04 billion would be needed just to stockpile supplies against two threats, anthrax and smallpox (Congressional Research Service, 2023[12]). Box 9.1 gives insight into the magnitude of the annual funds needed for the procurement and maintenance of stockpiled holdings of medical countermeasures in the U.S. context. In Australia, the value of products in the national stockpile in 2019 was estimated at AUD 123.1 million, corresponding to USD 85.5 million (Australian National Audit Office, 2021[39]). The EU strategic plan for MCMs will feed into future funding discussions on EU-level stockpiles, acknowledging that it takes a “long-term commitment and requires sustainable funding” (Annex 2, (EC, 2025[34])).
- Budget constraints can reportedly limit decisions on stockpile contents, and countries may have difficulties in reaching agreements with industry stakeholders to maintain stockpiles (HIQA, 2023[9]). Costs of the maintenance of a stockpile, however, also need to be weighed against the alternative of procuring goods during a crisis event, in the context of high demand and potential supply disruptions. For example, an academic study in the United States estimated that buying PPE at non-pandemic prices to stockpile would cost only 17% of the amount needed to procure it during a pandemic, and that maintaining the stockpile would cost less than buying it during the pandemic even if it is not required for 35 years (Dow, Lee and Lucia, 2020[41]).
- **Uncertainty and predictability:** The virulence and infectiousness of future pathogens of pandemic potential are unpredictable, making it difficult to determine what and how much to stockpile. For example, Plans-Rubio (2020[42]) highlighted several difficulties in analysing the cost-effectiveness of stockpiling vaccines, antiviral treatment and ventilators as a pandemic preparedness and response strategy, one of which being that that the effectiveness of the stockpiled vaccines against the future pathogen is unknown. Another paper reported that incremental cost-effectiveness of stockpiled pneumococcal vaccines against developing secondary bacterial infections during influenza pandemics is dependent on the replacement costs of the stockpile (i.e. whether the entire stockpile needs to be fully replenished at the end of its shelf life, incurring significant replacement costs, or if it can be rotated into the routine healthcare system) (Dhankhar, Dasbach and Elbasha, 2009[43]).

- **Logistical and stock management challenges:** Proper management of stockpiles requires robust logistics, including inventory management systems and regular rotation of stock. An early evaluation of the U.S. SNS system during COVID-19, for example, noted that a lack of market intelligence (i.e. knowledge of suppliers, capacity and risks) and poor visibility into supply capacity hindered its ability to procure products (Handfield et al., 2020[44]). In addition, insufficient inventory management practices such as the proper use of barcode tracking and strategic forecasting limited its ability to anticipate shortages and supply needs (Handfield et al., 2020[44]).
- Stockpiled items also have limited shelf lives and regular cycling out and replacing of expired items is necessary to ensure the stockpile remains viable and effective. Waste management has been identified as a notable issue with stockpiling policies, however countries note that while wastage cannot be completely avoided (particularly for products that may not ever be required and cannot be cycled out of the stockpile), it can be managed or minimised (HIQA, 2023[9]).
- **Co-ordination and communication issues:** Challenges with stakeholder co-ordination and communication can hamper the stockpile's effectiveness during a crisis. Effective stockpiling and deployment require co-ordination, communication and information sharing between various stakeholders, including public authorities (national, local, and in some cases internationally), health service providers (hospitals, pharmacies, primary healthcare facilities and other medical institutions etc), industry manufacturers, and distributors and logistics providers etc. Internal audits of the Australian Government-managed National Medical Stockpile found mixed feedback on the effectiveness of communications about the National Medical Stockpile procurement and deployments to state and territory health authorities and primary care sector during COVID-19. (Australian National Audit Office, 2021[39]). Handfield's evaluation of the U.S. SNS reported structural weaknesses in engaging stakeholders on both the supply and demand sides (Handfield et al., 2020[44]). A more recent report by the U.S. Government Accountability Office (2024[40]) similarly highlighted challenges faced during COVID-19 such as unclear agency roles, outdated guidance, poor communication on asset requests and deliveries, and limited transparency of inventory However, in response, HHS has begun updating guidance, clarifying responsibilities and better planning co-ordination with local authorities to enhance future emergency preparedness (US Government Accountability Office, 2024[40]). In Switzerland, international co-ordination and global market oversight were highlighted as key areas for improvement in public audits of its rolling stockpile system, whereby stockpiles are maintained and owed by private companies but the Federal Office of National Economic Supply determines what should be stockpiled and when it should be released (FOPH, 2022[45]). France, Latvia, Lithuania, the Netherlands and Norway participated in EU-wide stockpiling initiatives and reported a gap in stockpiling co-ordination between EU countries (HIQA, 2023[9]).

9.6. Conclusions

This special focus chapter provided an overview of policies for stockpiling medical goods as a short-term buffer layer for pandemic preparedness and response. Drawing on insights from several OECD countries and the European Union, it indicates that stockpiling of relevant medical goods is considered an important component of timely and effective pandemic preparedness and response capacity, albeit offering a finite supply and limited effectiveness during prolonged disruptions. Beyond pandemics, stockpiling supports responses to natural disasters, chemical, biological, radiological and nuclear threats, as well as the threat of antimicrobial resistance.

The analysis highlights that effective stockpiling policies require strategic planning and risk assessment, clear governance structures, sustainable funding, and effective management of risks and inventory. The findings also underline the importance of stockpiling initiatives that are strategic and co-ordinated, to ensure timely and efficient access to medical products for all worldwide.

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Annex 9.A. Examples from selected countries

Annex Table 9.A.1. Examples of stockpiling policies for pandemic preparedness and response

Scope of implementation	Stockpile (main source), [start/end dates]	Aims and objectives	Governance	Contents	Evaluations
Australia	National Medical Stockpile (Australian Department of Health and Aged Care, 2023[24]), [2012-]	Strategic reserve of supplies for national health emergencies, to supplement stock held by state and territory health authorities. Supports front-line health services (e.g. hospitals) with additional resources, where commercial supplies are unavailable and there is a demonstrable need for the products.	Managed by the Department of Health and Aged Care. Inventories are dispersed around the country in undisclosed locations. Stocks are released at the request of state and territory governments. The Australian Health Protection Principal Committee (the key decision-making committee for health emergencies) advises on managing the stockpile. The Department of Health is supported in managing the stockpile through a network of service providers and suppliers. Stockpile regulation is determined by national legislation, including the National Health Security Act 2007, National Health Security Amendment Act 2012, and the Public Governance, Performance and Accountability Act 2013.	PPE, medicines, vaccines and antidotes. Also a limited supply of highly specialised medicines that may be challenging to obtain through normal channels in an emergency. In late December 2019, the stockpile's inventory was valued at AUD 123 million (USD 87.8 million) (Australian National Audit Office, 2021[39]). Details on stockpile content are not publicly released for security reasons.	In its evaluation of COVID-19 procurements and deployments of the NMS, the Australian National Audit Office (ANAO) identified several obstacles, including narrow stockpiling objectives and eligibility criteria for healthcare providers to receive goods from the stockpile (Australian National Audit Office, 2021[39]). The ANAO made four recommendations to strengthen the NMS: improving procurement record-keeping; conducting regular and realistic deployment drills; developing a risk-based strategic deployment plan in consultation with stakeholders; and establishing a performance framework to better assess the effectiveness of NMS deployments (ibid).

Scope of implementation	Stockpile (main source), [start/end dates]	Aims and objectives	Governance	Contents	Evaluations
Canada	National Emergency Strategic Stockpile (NESS) (Public Health Agency of Canada, 2022[46]), [1952-]	Guarantee supply of essential medical equipment and pharmaceuticals to provinces and territories during public health emergencies or when resources are depleted or not immediately available. Emergencies include natural disasters, naturally occurring diseases (e.g. COVID-19), and other CBRN threats.	Federally owned and managed by the Public Health Agency of Canada. In Canada, emergencies are first managed at local level; managing healthcare systems is a shared responsibility of provinces and territories. If assistance is needed, provinces and territories can ask the federal government for support through the NESS.	Essential medical equipment and supplies (e.g. ventilators, cardiac monitors, PPE), pharmaceuticals (e.g. vaccines, therapeutics), and social service supplies (e.g. beds, blankets). NESS also works as the sole provider of some niche medical countermeasures, such as vaccines and antidotes and antivirals to respond to emergencies.	N/A
Colombia	Centro de Reservas del Sector de Salud (CRSS) (Ministerio de Salud y Protección Social, n.d.[47]), [2010-]	Supports hospitals during health emergencies or disaster situations. Provides specialised teams to support disaster response efforts.	Maintained by the Ministry of Health and Social Protection and managed by the Centre of Communication and Co-ordination for Health Sector Emergency Response, which is responsible for supplying regional stockpiling centres. Stockpiles function at both national and regional levels.	Medicines, medical/surgical supplies, PPE, antidotes, equipment and other medical products.	N/A
Korea	Korea National Stockpile (OECD, 2020[48]), [Start date unclear]	Stockpile a variety of products for emergency capabilities, including medical countermeasures for disease outbreaks and emergency relief supplies for disaster management.	The Ministry of Food and Drug Safety develops a list of the essential medical products that must be stockpiled. Stocks are maintained by both national and local authorities. National legislation provides that the stockpiling for disaster management must be reviewed every year by the agency responsible for keeping such stocks.	Variety of medicines and other essential medical products. The list of essential medicines stockpiled currently contains 351 different products (Ministry of Food and Drug Safety, 2019[25]). PPE and other medical countermeasures for the 11 priority diseases identified by Korea's Centers for Disease Control and Prevention are also stored in the stockpile.	Recent measurements of volumes of stockpiled antivirals indicated quantities sufficient for 26% of the population, above the WHO-recommended level of 20% (OECD, 2020[48]).

Scope of implementation	Stockpile (main source), [start/end dates]	Aims and objectives	Governance	Contents	Evaluations
Switzerland	Switzerland compulsory stockpiling system (FOPH, 2022[45]) [1951-]	Guarantee the uninterrupted supply of essential medicines, to be deployed in the event of a severe nationwide supply shortage (including as part of pandemic preparedness).	Stockpiles are maintained and owned by private firms, but the Federal Office of National Economic Supply (FONES) determines the products and volumes that should be kept in a compulsory rolling stock system. FONES orders the release of privately held supplies when faced with a shortage.	Anti-infectives for human use, both commercially available products and active substances (~3 months' supply), neurominidase inhibitors, both active substances and capsules (enough to treat 25% of the population; prevention for health staff for 40 days), pain medicines and opioids (3 months' supply), vaccines (4 months' supply), immunoglobulins (2-3 months' supply), and several other selected products. A catalogue of 30 APIs essential to respond to the COVID-19 pandemic that would require stockpiling was developed after the first wave in 2020. The list is periodically updated.	During the first months of the COVID-19 pandemic, the Swiss Federal Office of Public Health (FOPH), in partnership with FONES, developed a prioritisation strategy for allocating essential medicines to hospitals facing shortages. The rolling stock scheme allows for better monitoring of overall supplies and demand for essential medicines by public health authorities. Strict weekly monitoring of stocks, deliveries and demand for the 30 API products was implemented. Rolling stockpiles were considered an efficient and effective strategy to respond to shortages during COVID-19. However, international co-ordination and global market oversight have been identified as key areas for improvement in public audits (FOPH, 2022[45]). Recommendations on which medical goods should be held in a reserve for a future pandemic and in what quantities will form part of a revision to Switzerland's existing Influenza Pandemic Plan (FONES, 2023[49]). This will include examining alternative ways of building up reserves.

Scope of implementation	Stockpile (main source), [start/end dates]	Aims and objectives	Governance	Contents	Evaluations
United States	Strategic National Stockpile (SNS) (ASPR, n.d.[11]), [1999-]	Provide emergency medical supplies to states and local health jurisdictions in the event of a bioterrorist attack or other public health emergency.	Managed by the Administration for Strategic Preparedness and Response. The list of products to be stockpiled is defined by the HHS Secretary following advice by an inter-agency working group. Most supplies are stored in SNS-managed physical storages facilities across the country, but vendor and user-based inventories are also used. Vendor-managed inventories account for 10% of current SNS contracts and are directly funded by the SNS. When Federal and local authorities decide when the SNS is needed, each state has plans for rapid distribution to local communities.	Generally includes medicines, vaccines, medical products, and ancillary supplies.	During the recent mPox outbreak, the SNS provided 1 million vials of JYNNEOS vaccines (CDC, 2022[50]). There have been several evaluations of the SNS' response during COVID-19, citing challenges around inadequate preparedness, inefficient management, and unclear co-ordination with states and local jurisdictions ((HHS OIG, 2023[51]; US Government Accountability Office, 2024[40]; Congressional Research Service, 2023[12])). Reviews found that the stockpile was not positioned to meet nationwide demand and that roles and guidance within HHS and ASPR remained outdated ((HHS OIG, 2023[51]; US Government Accountability Office, 2022[18])). In response, HHS and ASPR have begun updating inventory review procedures, clarifying responsibilities, and modernising the SNS's strategic plan to improve readiness for future public-health emergencies.).

Scope of implementation	Stockpile (main source), [start/end dates]	Aims and objectives	Governance	Contents	Evaluations
EU Member States and some Partner Countries	rescEU stockpile reserve (EC, 2022[52]), [2019-]	Provide countries with essential material and human resources to respond to cross-border threats, including health crises and CBRN emergencies. Support is intended as a last resort when countries' own resources are not able to fully respond to the emergency.	22 stockpiles are held strategically in 16 EU Member States, which are also responsible for their maintenance, logistics and procurement. The European Commission provides funding for the programme, through the Health Emergency Preparedness and Response Authority (HERA) and maintains full control of their operation, in close co-operation with DG ECHO and hosting states. Countries request assistance to the Emergency Response Co-ordination Centre (ERCC), an EU body responsible for co-ordinating civil protection activities. ERCC evaluates the ability of rescEU resources to support the country's request and deploys the resources.	Stockpiles cover the three priority threats identified by HERA (pathogens of pandemic potential, antimicrobial resistance threats, and CBRN threats). Contents of each stockpile vary. Products may include vaccines and therapeutics, intensive care medical equipment, PPE and other laboratory supplies, CBRN-specific medical countermeasures including antidotes, detectors and decontamination supplies etc.	The stockpile has been a key element in the EU's response to the pandemic, supplying various EU and non-EU countries with PPE, ventilators, and protective masks. A review of HERA's activities found that the rescEU stockpiles of medical and CBRN countermeasures are seen to have offered an effective contingency for preparedness (EC, 2025[38]).

Note: N/A not available. CBRN chemical, biological, radiological or nuclear threats.
Source: Adapted from (OECD, 2024[2]).

Notes

[1] Medical countermeasures (MCMs) diagnose, prevent, protect from, or treat conditions during a public health emergency. Examples include vaccines, antibiotics, antivirals, medical equipment, chemical antidotes, therapeutics, diagnostic tests or personal protective equipment such as gloves or masks (FEMA, 2023[53]).

[2] Physical stockpiles hold physical items in warehouses that can be immediately deployed in the event of an emergency. Virtual (or vendor-managed) stockpiles are another option, where companies that make or sell the items store a certain amount of stock that the government can buy if and when needed.

[3] The SNS comprises U.S. Food and Drug Administration – approved medicines, vaccines, and other medical countermeasures. The BioShield project enhances the SNS by adding 25 products, which include vaccines for anthrax and smallpox, as well as treatments for anthrax, botulism, nerve agents, radiation exposure, and thermal burns (Congressional Research Service, 2023[12]).

OECD Health Policy Studies

The Economic Case for Pandemic Preparedness and Response

Beyond Lockdowns

Pandemics are rare but severe shocks for the health of populations and economies. The frequency and intensity of smaller outbreaks have been increasing over the past decades and the risk of local outbreaks escalating into global pandemics remains high. This report examines the potential consequences of future pandemics on population health, health system resilience and the economy across 51 OECD, EU/EEA and G20 countries, using advanced epidemiological and economic modelling techniques and scenario-based analyses. It assesses the extent to which eight non-pharmaceutical interventions (NPIs) for community infection prevention and control can mitigate health and economic consequences in the early phases of five types of outbreak scenarios before pharmaceutical interventions or vaccines are available at scale.

The central message is clear: in the OECD, investing, on average, almost 6 USD PPP per capita per year in pandemic preparedness and response is a smart investment for both public health and economic resilience. Early implementation of NPIs such as hand hygiene, mask use and physical distancing can save more lives and limit economic disruption than delayed action, which may necessitate the introduction of lockdowns to regain control of transmission. Robust disease surveillance and stockpiling systems are essential for enabling timely and effective response.

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