

INSIGHTS FOR
HEALTHCARE RESILIENCE
AND ECONOMIC PERFORMANCE

The broader economic benefits of COVID-19 vaccination

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ohe.org



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AND ECONOMIC PERFORMANCE****The broader economic
benefits of COVID-19
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Executive summary

Key points

- COVID-19 generates a major economic burden, even after the pandemic. The costs from lost productivity due to COVID-19 are about twice as high as healthcare system costs in Australia and Japan, seven times larger in the UK, and ten times larger in the Netherlands.
- Investing in COVID-19 vaccines is not just a health need, it benefits the economy. Vaccines help protect societies and reduce pressure on healthcare systems, while supporting economic stability by keeping people working and productive. Continued investment in comprehensive vaccination policies and COVID-19 vaccines is essential to reduce its ongoing and future burden.
- Evaluating economic benefits demonstrates the additional value to society of broadening vaccine eligibility. Compared to the status quo, broadening vaccine eligibility would further reduce sick days, long-term disability, and workforce dropouts caused by short-term illness and long COVID, generating substantial additional benefit to national economies.

Why investigating the economic case for ongoing COVID-19 vaccination matters

While public health strategies around COVID-19 have transitioned from a pandemic to an endemic setting, the disease remains a persistent and evolving threat characterised by year-round viral activity, surges, and an ongoing health and economic burden. Nevertheless, recommendations for routine COVID-19 immunisation have become increasingly restrictive worldwide, predominantly focusing on older adults (≥ 65 years) and population groups at risk of severe outcomes, and largely exclude healthy working-age adults. Whereas the latter group are less likely to suffer severe health outcomes leading to hospitalisation, they may still experience symptomatic illness and long-term consequences, through long COVID and potential exacerbation of underlying conditions, leading to lost productivity. This lost productivity means that COVID-19 infections in the working-age population have a greater impact on the national economy.

Using a cost-of-illness analysis based on 2024 cost data, this report investigates the economic burden of COVID-19 during the post-pandemic era and the potential economic benefits of ongoing immunisation for healthcare systems and national economies. This report focuses on four high-income countries currently recommending COVID-19 vaccination to older and at-risk adults, namely the United Kingdom, Australia, Japan and the Netherlands.

COVID-19 continues to represent a significant economic burden

We estimate that without annual autumn vaccination of older adults, the economic burden of COVID-19 is substantial, averaging 0.48% of national GDP across the countries studied (min%-max%: 0.26%-0.97%).

ANNUAL ECONOMIC BURDEN OF COVID-19 IN CASE OF NO VACCINATION PROGRAMME

				
TOTAL	£6.98 bn	A\$7.35 bn	¥ 5.75 tn	€3.99 bn
TOTAL AS A % OF NATIONAL GDP*	0.26%	0.28%	0.97%	0.39%

**National GDP 2023 (million, USD): UK: 3,340,032; Australia: 1,723,827; Japan: 4,212,945; Netherlands: 1,118,124 (World Bank, 2024). Note: Based on incidence estimates for the following time frames: UK, September 2024 - August 2025; Australia, March 2024 - February 2025; Japan, September 2023 - August 2024; Netherlands, October 2023 - September 2024.*

This impact is twice the average pre-pandemic national spending on health prevention in OECD countries, and significantly surpasses the economic costs of other respiratory infections such as influenza, highlighting its continued impact in the post-pandemic era. National economies bear a disproportionate share of the COVID-19 burden - twice as large as the COVID-19 related healthcare system costs in Australia and Japan, more than seven times as large in the UK, and ten times as large in the Netherlands.

Annual vaccination of older adults and high-risk groups protects healthcare systems but leaves national economies exposed to the impact of COVID-19

Annual autumn COVID-19 vaccination of older adults (aged 60+ in the Netherlands and 65+ in the UK, Australia and Japan) and at-risk groups, aligned with 2023/2024 national recommendations¹, prevents significant healthcare costs and pressure. Based on 2023/2024 recommendations, COVID-19 vaccination programs reduce healthcare burden by preventing 22% of COVID-19-related costs on average (min%-max%: 13%-29%), primarily through averting severe cases and hospitalisations. This highlights the vital role of annual vaccination strategies in protecting healthcare systems from additional winter pressure due to seasonal infections. However, the economic benefits to national economies are more modest, with 7% of economic losses averted (min%-max%: 3%-12%) under vaccination strategies aligned with 2023/2024 recommendations.

Evaluating economic benefits demonstrates the additional value to society of broadening vaccine eligibility

Broadening vaccination eligibility to the general population aged 50 and over² could avert on average 13% (min%-max%: 5%-25%) of costs to the national economy, while broadening vaccination eligibility to the population aged 18 and over² could increase the proportion of the economic burden of COVID-19 on the national economy averted to 27% on average (min%-max%: 8%-60%). Extended vaccination policies could address the significant burden on national economies caused by absenteeism, long-term workforce attrition, and consequent productivity losses linked to both acute and long COVID cases.

Long COVID is likely a major contributor to economic losses due to prolonged absenteeism and reduced workforce participation. Though the full impact of long COVID is difficult to quantify and compare due to a lack of systematic data across countries, estimates suggest that long COVID alone could account for up to 49% of COVID-19 economic costs on the national economy in some countries, underscoring the need for continued vaccination to mitigate these impacts.

¹ 60+ in the Netherlands, 65+ in Australia, Japan and the UK. High-risk groups are only modelled in the UK and the Netherlands. The definition of high-risk varies between countries but typically includes people with underlying conditions.

² This is subject to regulatory approval, recommendation by the National Immunization Technical Advisory Group (NITAG) and approval by reimbursement decision-makers.

Policy recommendations

This report demonstrates the enduring economic burden posed by COVID-19 and highlights the potential of COVID-19 vaccination strategies. While annual autumn vaccination programmes for older adults and at-risk groups effectively reduce healthcare system pressures, extending vaccination to younger working-age populations can unlock broader economic benefits and long-term societal resilience, in particular during the winter season. Maintaining and expanding these efforts is vital to mitigate both current and future impacts of COVID-19.

Vaccination of the general population of older adults and groups at risk³ should be maintained as a cornerstone of resilient healthcare systems

Increasingly limited vaccine recommendations and excluding population groups at risk of severe outcomes hinder the ambition to build resilient healthcare systems. A more explicit and systematic recognition of vaccines' ability to mitigate pressure on healthcare system capacity in health technology assessment and vaccination policies would be consistent with this objective.

A decision-making and funding approach to annual immunisation that appreciates broader economic benefits is needed

Now more than ever, it is essential to recognise the broader value of interventions, such as vaccines, in decision-making and funding, especially as they help maintain healthy and productive societies. This is particularly urgent in the face of global trends like demographic ageing and increasing rates of chronic illness among working-age adults. Without this broader perspective, decision-makers risk overlooking the role of public health investments in supporting long-term economic productivity.

³ The eligibility criteria of the 2023/2024 COVID-19 vaccination programme in the countries under consideration typically include individuals at higher risk of severe outcomes, such as the elderly (general population aged 60 or 65 years and older) and individuals with underlying conditions (at-risk groups). At-risk groups were included in the epidemiological models for the UK and the Netherlands but were not included in the models in Australia and Japan.

1 Introduction

1.1 Background

Thanks to effective vaccination programmes that significantly altered the course of the pandemic (Watson et al., 2022), in May 2023 the WHO declared that COVID-19 is no longer considered a global health emergency (Cheng et al., 2023; WHO, 2023). However, in the post-pandemic period (i.e., since the announcement in May 2023), COVID-19 remains “an established and ongoing health issue” (WHO, 2023) requiring continued vigilance and monitoring. In fact, COVID-19 is characterised by year-round disease activity as well as winter spikes coinciding with those of other respiratory illnesses that generate pressure on healthcare systems (Wiemken et al., 2023). Moreover, since its emergence, the likelihood of severe outcomes leading to hospitalisation and mortality remains higher for COVID-19 infections compared to other seasonal respiratory infections (Xie, Choi and Al-Aly, 2024; CDC, 2024).

Vaccination has played a central role in enabling the ongoing transition from pandemic to post-pandemic burden. Conservative estimates indicate that COVID-19 vaccination prevented over 150 million cases and 620 thousand deaths globally in its first rollout (between December 2020 and September 2021) (Yang et al., 2023). Other estimates factoring in indirect benefits of vaccination, such as reduced virus transmission, report that 14.4 -19.8 million lives were saved in the first year of vaccination, equivalent to a 63% decline in the global COVID-19 related mortality (Watson et al., 2022). In 2024, the WHO estimated that COVID-19 vaccines have reduced deaths due to the pandemic by at least 57%, saving more than 1.4 million lives in the WHO European Region (WHO, 2024), with Ioannidis et al., (Ioannidis et al., 2025) estimating that globally 2.5 million deaths were averted during 2020-2024, saving 15 million life-years. Beyond the benefits associated with averting COVID-19 morbidity and mortality, vaccines have also played a crucial role in enabling countries to ease pandemic restrictions and move towards economic recovery.

Despite the ongoing health burden posed by COVID-19, recommendations for COVID-19 vaccination are becoming increasingly restrictive worldwide. Many countries now only recommend COVID-19 vaccination to older adults and at-risk individuals, such as individuals with underlying comorbidities and adults in regular contact with vulnerable individuals. For example, Table 1 displays COVID-19 vaccination recommendations for four high-income countries.

Table 1. Recommendations on Annual Autumn COVID-19 vaccination

	UK	AUSTRALIA	JAPAN	NETHERLANDS
2023	65+ general population & at-risk	Recommended*: 65+ general population & at-risk For consideration*: 18-64	Recommended*: 65+ general population & at-risk For consideration*: 6 months+	60+ general population & at-risk
2024	65+ general population & at-risk	65+ general population & at-risk	65+ general population & at-risk	60+ general population & at-risk

Key: population groups recommended for vaccination: dark green = broader eligibility; light green = targeted to older adults and priority groups, e.g. immunocompromised people with underlying medical conditions and health and social care workers in contact with vulnerable populations.

Notes: The table is based on 2023 and 2024 recommendations on the COVID-19 'autumn' vaccination. Recommendations for six-month 'spring' booster dosage are not included here. The definition of 'at risk' varies by country and has evolved over time. * Recommended = groups who should receive COVID-19 vaccination. For consideration = groups who should consider COVID-19 vaccination upon discussion with a healthcare provider.

References: Australia: (ATAGI, 2023, 2024); Japan: (Ministry of Health Labour and Welfare of Japan, 2023, 2024); Netherlands: (RIVM, 2024a; b); UK: (UKHSA, 2024a).

Recommendations by health technology assessment (HTA) bodies and National Immunization Technical Advisory Groups (NITAGs) on national immunisation programmes are typically driven by the role of COVID-19 vaccines in preventing severe outcomes and the associated healthcare resource impact. However, healthcare-related effects constitute only a fraction of the 'broader' value of vaccination including, amongst others, societal economic benefits from reduced work absence and increased labour force participation (Bell, Neri and Steuten, 2021). Broader economic effects are likely to be high among working-age adults who are less likely to suffer severe outcomes (e.g., hospitalisation) but may experience symptomatic illness leading to work absenteeism. For example, in the case of seasonal respiratory infections, including COVID-19, it has been estimated that employees in the UK are impacted by respiratory infections for over an entire workweek throughout the year (5.2 days), 1.1 of these days are due to absenteeism, and the remaining 4.2 days are impacted by reduced productivity (presenteeism) (Hayes et al., 2024). This corresponds to an annual national economic cost of £44 billion in the UK (Hayes et al., 2024). In the Netherlands, respiratory infections were associated with a total of 14.3 million lost working days annually, representing a monetary value of €4.7 billion (Beck et al., 2024).

COVID-19 infections are also uniquely associated with an additional risk of developing long COVID, a complex condition associated with one or more of over 60 possible long-term symptoms with varying severity (Subramanian et al., 2022). Coupled with uncertainty on the prevalence and duration of these symptoms, estimating the additional labour market impact of long COVID is a complex exercise. However, a tentative assessment of the impact of long COVID suggests a potential reduction of the EU labour supply by 0.3%-0.5% in 2022 (Ramos et al., 2024).

With aging populations and rising chronic disease rates among younger population that will increase the population at risk from severe illness if infected with COVID-19 and rising level of workers taking sick days and economic inactivity, it is important to understand the impact that COVID-19 has on both healthcare systems and the national economy so that we can assess the full value provided by vaccinations.

1.2

Report overview

This report describes the ongoing economic burden of COVID-19 and the economic benefits of immunisation for healthcare systems and national economies. Using a cost-of-illness analysis, we first quantify the broader economic burden of COVID-19 and then compare the benefits of 'high-risk' and 'extended' annual autumn vaccination strategies in a post-pandemic setting.

The report focuses on four high-income countries characterised by narrowing recommendations for COVID-19 vaccination, namely the United Kingdom, Australia, Japan and the Netherlands. This selection aims to balance geographic representation, differences in healthcare systems and 'attitudes' towards COVID-19, with data availability.

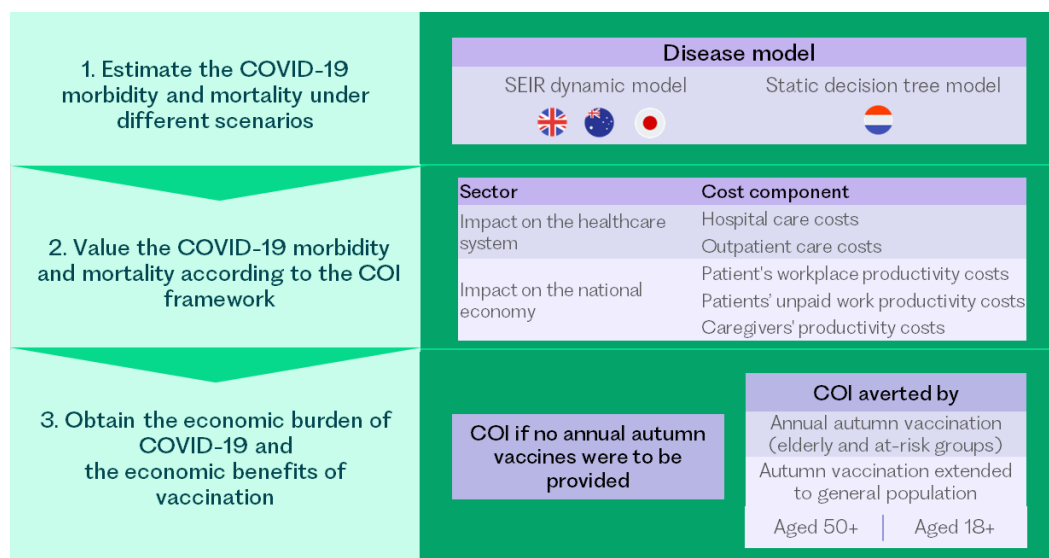
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Methodology

We conducted a cost-of-illness (COI) analysis to estimate the economic impact of COVID-19 and the potential benefits of annual autumn COVID-19 vaccination programmes. COI analyses evaluate the economic impact associated with the morbidity and mortality of a disease from a societal perspective (Johns Hopkins University - International Vaccine Access Center (IVAC), 2019; Ozawa et al., 2017).

Our COI analysis consisted of 3 steps (see Figure 1), applied to each of our four countries: the United Kingdom, Australia, Japan and the Netherlands. The analysis focuses on a post-pandemic setting, characterised by residual immunity from prior vaccination and infection, and predictable patterns of transmission based on observed country-specific data. All models consider a one-year time horizon. Sections 2.1- 2.3 provide an overview of each step of the analysis, with further details on data and assumptions explained in the Methodological Appendix in Section 9.

Figure 1. Steps of the cost-of-illness analysis



Abbreviations: COI – Cost of Illness, SEIR – Susceptible–Exposed–Infected–Recovered

2.1

Step 1: Estimate the COVID-19 morbidity and mortality under different scenarios

Disease Model

To estimate the COVID-19 morbidity and mortality in the UK, Australia and Japan, we base our analysis on existing age-stratified Susceptible–Exposed–Infected–Recovered (SEIR) dynamic transmission models for each setting. The methodology and data of these epidemiological models have previously been described in Kohli et al. (2024) (UK), Lee et al. (2024) (Australia) and Fust et al. (2024a) (Japan). The SEIR model is used to predict the total number of COVID-19 infections (symptomatic and asymptomatic). Symptomatic infections enter a decision tree describing the COVID-19 disease pathway and related outcomes (detailed in the Methodological Appendix in Section 9.2).

For the Netherlands, a dynamic transmission model was not available at the time of analysis, so we base our analysis on an adaptation of a static decision tree model by Zeevat et al. (2024). The epidemiological data are based on static model estimates which were pragmatically adapted to capture indirect protection via a reduction in exposure risk, as is typically accounted for in dynamic models.

All models account for prior COVID-19 vaccination history and have a one-year time horizon. Further details on the disease models and the vaccine programme specifications can be found in the Methodological Appendix in Section 9.2.

Population groups and coverage rates

The analyses consider working-age adults (18+) and older adults (≥ 65). Age-specific COVID-19 vaccine coverage rates depend on the country and scenario modelled and are provided in the Methodological Appendix, Table 16.

Post-pandemic modelling scenarios

In each country, the following scenarios were modelled:

- **No annual autumn COVID-19 vaccination programme** - this represents a counterfactual scenario in which COVID-19 vaccination programmes are not in place. This counterfactual scenario serves as a comparator to estimate the averted burden attributable to vaccination.
- **High-risk groups annual autumn vaccination programmes** - annual autumn vaccination of individuals at higher risk of severe outcomes based on 2023/2024 national recommendations. This scenario aims to reflect the eligibility criteria of the 2023/2024 COVID-19 vaccination programmes in the countries under consideration, which typically include individuals at higher risk of severe outcomes. The dynamic transmission models for Japan and Australia model the age-based recommendation (general population aged 65 years and older). The dynamic model for the UK and static model for the Netherlands include the full eligibility, incorporating both older adults (aged 65 and 60 years and over, respectively) but also include at-risk populations, in line with the 2023/2024 eligibility recommendations outlined in Table 1.
 - Note that some national recommendations include eligibility for a second (spring) booster, however, eligibility for the spring booster is not always the same as the autumn booster with any deviations in recommendations being more restrictive, uptake of second boosters is low in most countries and it is unclear if spring boosters will continue to be recommended in future seasons. Accordingly, to ensure continued relevance and comparability between our countries, we limit the focus of our analysis to an annual autumn vaccination.
 - The coverage rates mentioned above and resulting health outcomes are based on the epidemiological models available at the time of analysis (detailed in Section 9.2 of the Methodological Appendix).
- **Extended annual autumn vaccination programmes** - COVID-19 vaccination programmes extended to individuals aged 50+ and 18+. In these scenarios, we lower the age cut-off to the general population aged 50 and over and aged 18 and over, thereby expanding the eligibility to the working-age general population without underlying conditions. The assumed vaccination coverage rates for each scenario are detailed in the Methodological Appendix in Section 9.2.

Vaccine efficacy

The intervention considered an mRNA vaccine (mirroring the Moderna mRNA-1273 (Spikevax) bivalent original and Omicron containing BA4/5 vaccine) administered annually in the autumn. Vaccine efficacy rates and waning rates are provided in Table 2 below, where the efficacy rate is the protection provided by the vaccine against infection and hospitalisation and the waning rate is the rate at which this protection (the vaccine efficacy) declines each month after the administration of the vaccine.

Table 2. Modelled vaccine efficacy and waning rates

	SARS-COV-2 INFECTION	COVID-19 HOSPITALISATION	SOURCE
United Kingdom	Initial efficacy rate: 57.1% Monthly waning rate: 4.8%	Initial efficacy rate: 84.3% Monthly waning rate: 1.4%	Kohli et al, 2024b
Australia	Initial efficacy rate: 57.1% Monthly waning rate: 4.8%	Initial efficacy rate: 84.3% Monthly waning rate: 1.4%	Lee et al., 2024
Netherlands	Initial efficacy rate: 74.8% Monthly waning rate: 4.6%	Initial efficacy rate: 85.1% Monthly waning rate: 3.6%	Zeevat et al., 2024
Japan	Initial: 54.7% Monthly waning rate: 4.8%	Initial: 84.9% Monthly waning rate: 1.4%	Fust et al., 2024a

Note: Vaccine effectiveness against infection and hospitalisation was based on real-world evidence studies comparing populations vaccinated with mRNA-1273 bivalent to vaccine naïve populations.

In addition, we assume that a proportion of patients with symptomatic infections develop long COVID (Table 3).

Table 3. Percentage of patients with symptomatic infections that develop long COVID

PERCENTAGE OF PATIENTS WITH SYMPTOMATIC INFECTIONS THAT DEVELOP LONG COVID	
United Kingdom	3.7%
Australia	4.7%, (9.6% for hospitalised patients)*
Netherlands	10.4%
Japan	4.1%

** In the disease models for all countries except Australia, the percentage of patients with symptomatic infections that develop long COVID is constant, independent of hospitalisation status. In Australia, 4.7% of non-hospitalised patients develop long COVID, whereas 9.6% of hospitalised patients develop long COVID.*

2.2 Step 2: Value the COVID-19 morbidity and mortality according to the COI framework

We value the health (morbidity and mortality) outcomes estimated from the disease models for each scenario using a COI framework (Table 4). The framework considers a range of medical, non-medical and indirect costs to the healthcare system and the national economy.

Table 4. COI framework components

SECTOR	COST COMPONENT
Impact on the healthcare system	Hospital care costs
	Outpatient care costs
Impact on the national economy	Patient's workplace productivity costs
	Patient's unpaid work productivity costs
	Caregivers' productivity costs

The impact on the healthcare system consists of medical costs in hospital and outpatient care settings, valued according to healthcare resource use by setting and related unit costs.

The impact on the national economy consists of indirect costs, such as productivity losses of formally employed individuals and individuals undertaking unpaid work, and the productivity losses of patients' caregivers. Patient productivity costs due to non-fatal outcomes are valued based on changes in time use (e.g., lost days of work due to absenteeism and presenteeism), valued at the average wage rate. Caregiver productivity costs are also valued based on percentage lost productivity, valued at the average wage rate. Patient productivity costs due to fatal outcomes and non-fatal outcomes impacting the labour force participation (e.g., long COVID) are valued using the human capital approach, which estimates the value of productivity losses for patients for the remainder of their working life based on the average annual wage.

For each cost component of the COI framework, we obtain country-specific inputs, where available, for the relevant COVID-19 outcomes from the disease model, as well as vaccine-related adverse events occurring in each of the vaccination scenarios.

All monetary values are reported in the country currencies and adjusted to 2024 values using the Consumer Price Index (CPI), with 2024 used as the reference year for our analysis.

Main inputs for healthcare system and productivity costs are provided in Table 5 below. Further details on input parameters and full references for all countries are provided in the Methodological Appendix in Section 9.4.

In addition to the main inputs in Table 5, to calculate caregiver productivity losses, we apply a country-specific percentage reduction in caregiver productivity to an illness duration of 8.57 days when caring for non-hospitalised older adults who do not receive regular institutional/formal care, and an illness duration of 4.29 days when caring for paediatric cases. Further details on input parameters and references are provided in the Methodological Appendix in Section 9.4.

Finally, for the avoidance of all doubt, a COI averted approach does not consider the direct medical and indirect costs of implementing each vaccination strategy, in terms of vaccine administration and delivery costs and productivity losses associated with receiving vaccination. As such, the COI results are to be interpreted as an upper bound of potential costs averted due to vaccination.

Table 5. Healthcare system and productivity costs model inputs

		UNITED KINGDOM	AUSTRALIA	THE NETHERLANDS	JAPAN
HOSPITALISATIONS	Cost/critical care stay	£28,643	A\$49,846	€18,375	¥1,366,787
	Cost/non-critical care stay	£2,584	A\$28,693	€6,577	¥508,683
OUTPATIENT CARE	Number of primary care visits/non-hospitalised patient	0.88	2.05	1.00	2.33
	Cost/primary care visit	£47	A\$189	€40	¥28,054
PRODUCTIVITY COSTS	Daily wage	£132	A\$279	€195	¥18700
	Absenteeism (workdays):				
	• Non-hospitalised patient	3.57	3.57	3.50	3.57
	• Non-critical care stay	6.26	7.79	6.02	7.14
	• Critical care stay	8.96	15.57	11.89	13.86
	• Post-hospital recovery	13.09	19.29	19.29	32.86

Note: Costs are adjusted to 2024 values using the Consumer Price Index (CPI), with 2024 used as the reference year for our analysis.
1 GBP = 1.9374 AUD; 1.1811 EUR; 193.5322 JPY

2.3 Step 3: Obtain the economic burden of COVID-19 and the economic benefits of vaccination

The main outcomes of the analysis are:

- The economic burden of COVID-19, estimated as the COI of COVID-19 in the case of no COVID-19 vaccination programme.
- The economic benefits of vaccination, estimated as the COI averted by each vaccination scenario compared to no COVID-19 vaccination programme.

2.4 Exploring the ripple effects on the economy

An intrinsic limitation of the COI approach used to value the COVID-19 morbidity and mortality is that it ignores the ripple effects on the economy of disease-related productivity losses. Ripple effects may occur if the illness of individuals adversely affects the productivity of other workers and disrupts macroeconomic supply chains (Beutels, Edmunds and Smith, 2008). These may include, for example, effects on public sector services with limited workforces, such as public transport or healthcare, where staff illness could have a broader macroeconomic impact. For this reason, the impact of disease and vaccination on the national economy estimated using the COI approach will be underestimated. Therefore, we perform scenario analysis to estimate a plausible range of the ripple effects on the economy due to the productivity losses from COVID-19.

We identified a study estimating the productivity losses due to ill health using a human capital approach, which is commonly used in COI analyses, and other methods designed to capture the ripple effects of ill health on the national economy (general equilibrium models) (Hafner et al., 2023). The study demonstrates the consistent underestimation

achieved by COI approaches and provides a multiplier range of 3-16%. This range reflects the spillover effects of diseases with different marginal productivity costs and prevalence in the UK context on the wider economy (i.e., other individuals, other firms, the government, other markets).

In this scenario analysis, we apply this multiplier to our estimates of the COVID-19-related productivity losses to explore the potential ripple effects on the economy.

3 Economic burden of COVID-19 in post-pandemic settings

With 2024 as the reference year for costs, our counterfactual analysis shows that without COVID-19 vaccination programmes, COVID-19 would have a substantial economic impact in post-pandemic settings. It would cost on average the equivalent of 0.48% (unweighted) of the national GDP among the countries under analysis (min%-max%: 0.26%-0.97%). National economies bear a larger share of this burden than healthcare systems, around twice as large in Australia and Japan, more than seven times as large in the UK, and more than ten times as large in the Netherlands.

Table 6. Annual economic burden of COVID-19 in case of no COVID-19 vaccination

					AVERAGE
TOTAL	£6.98 bn	A\$7.35 bn	¥ 5.74 tn	€3.99 bn	-
TOTAL AS A % OF NATIONAL GDP*	0.26%	0.28%	0.97%	0.39%	0.48%
% ON HEALTHCARE SYSTEM	12%	35%	34%	9%	22%
% ON NATIONAL ECONOMY	88%	65%	66%	91%	78%

* National GDP 2023 (million, USD): UK: 3,340,032; Australia: 1,723,827; Japan: 4,212,945; Netherlands: 1,118,124 (World Bank, 2024)

Note: Based on incidence estimates for the following time frames: UK, September 2024 - August 2025; Australia, March 2024-February 2025; Japan, September 2023 - August 2024; Netherlands, October 2023 - September 2024.

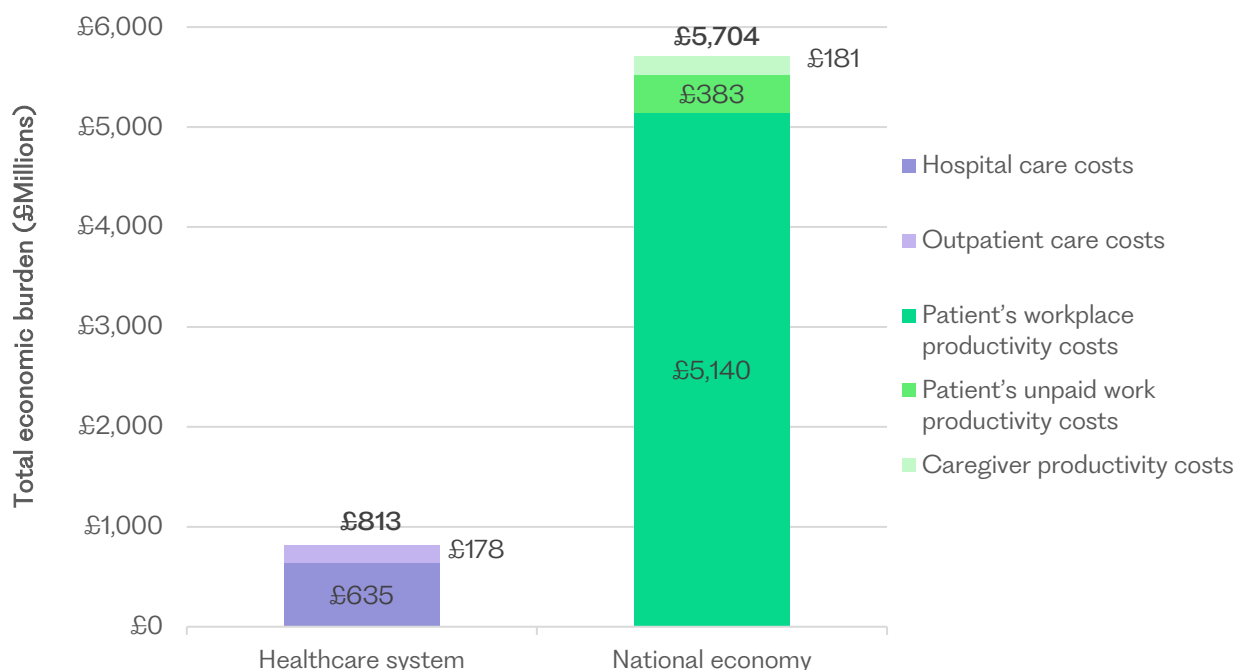
The following sections further detail the COVID-19 outcomes under a counterfactual no vaccination scenario and the associated broader economic burden for each country under analysis. Results are expressed in country-specific currencies: British Pounds (£) for the United Kingdom, Australian Dollars (A\$) for Australia, Japanese Yen (¥) for Japan, and Euros (€) for the Netherlands.

3.1 United Kingdom

Based on the COI approach, the total estimated economic burden from COVID-19 if there were no autumn COVID-19 vaccination programme in the UK would be £6.98 billion per year. This burden is generated by the COVID-19 health outcomes presented in the Results Appendix (Section 8).

Of the total COVID-19 burden of £6.98 billion per year, £6.2 billion falls on the national economy. This is nearly 7.5 times as large as the COVID-19 burden on the healthcare system which amounts to £813 million per year (Figure 2).

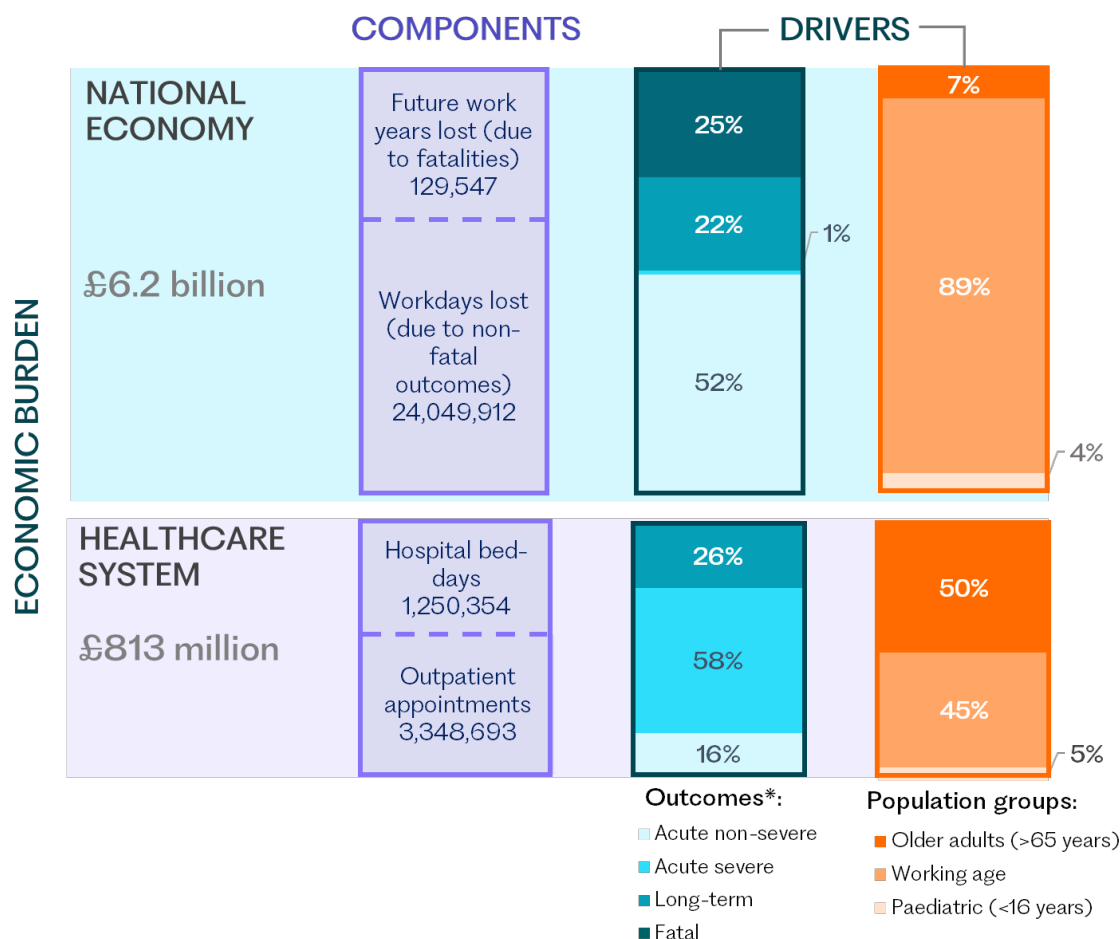
Figure 2. Annual economic burden of COVID-19 on the healthcare system and national economy in the UK



As shown in Figure 3, COVID-19 would impose a substantial economic burden on the UK national economy, leading to an estimated 24 million workdays lost due to non-fatal illness and 130,000 work-years lost due to premature deaths. Acute, non-severe COVID-19 cases – those not requiring hospitalisation – are responsible for over half of the burden on the national economy, largely through lost productivity from absenteeism. The remaining burden is split evenly between fatalities and long-term consequences of COVID-19, such as long COVID. Notably, 89% of the burden on the national economy originates from cases in working-age adults (18–64), underscoring the significance of working-age populations in generating the COVID-19 burden on the UK national economy.

The healthcare system would also face a considerable burden, with COVID-19 accounting for approximately 1.2 million hospital bed-days and over 3 million outpatient care appointments. More than half of this burden stems from acute, severe COVID-19 cases which required hospitalisation and subsequent outpatient appointments. Although older adults are at greater individual risk of severe outcomes, the overall burden on the healthcare system is almost equally driven by both working-age adults and older adults (45% and 50% respectively). This reflects the larger size of the lower-risk working-age population. The paediatric population does not generate a large healthcare burden due to their lower risk of symptomatic infection and of severe outcomes.

Figure 3. Components and drivers of the annual COVID-19 economic burden in the UK



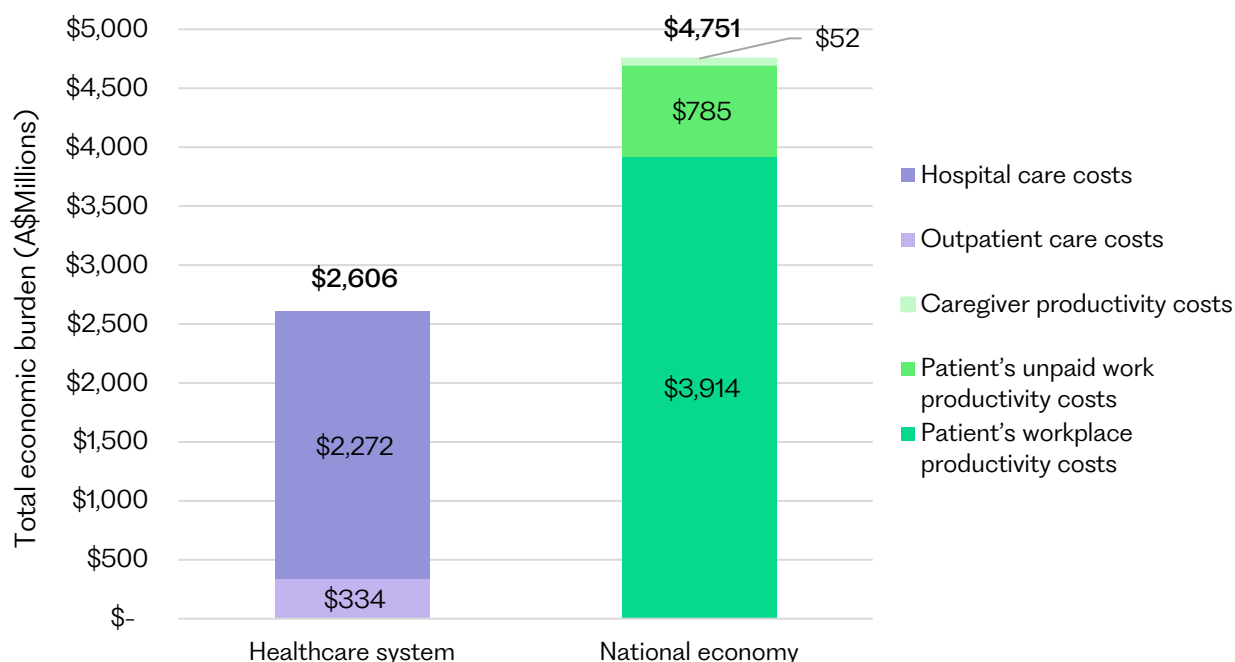
*Acute non-severe = non-hospitalised infections; Acute severe = hospitalised infections, myocarditis cases; Long-term = long Covid cases; Fatal = deaths. Fatal cases are a subset of the hospitalised infections and generate healthcare system costs as part of the acute severe outcomes.

3.2 Australia

Based on the COI approach, the total COVID-19 economic burden in case of no autumn COVID-19 vaccination programme would be A\$7.4 billion per year in Australia. This burden is generated by the COVID-19 health outcomes presented in the Results Appendix (section 8).

The burden of COVID-19 to the national economy is approximately A\$4.8 billion per year, more than 1.8 times as large as the economic burden of COVID-19 to the healthcare system (A\$2.6 billion per year) (Figure 4).

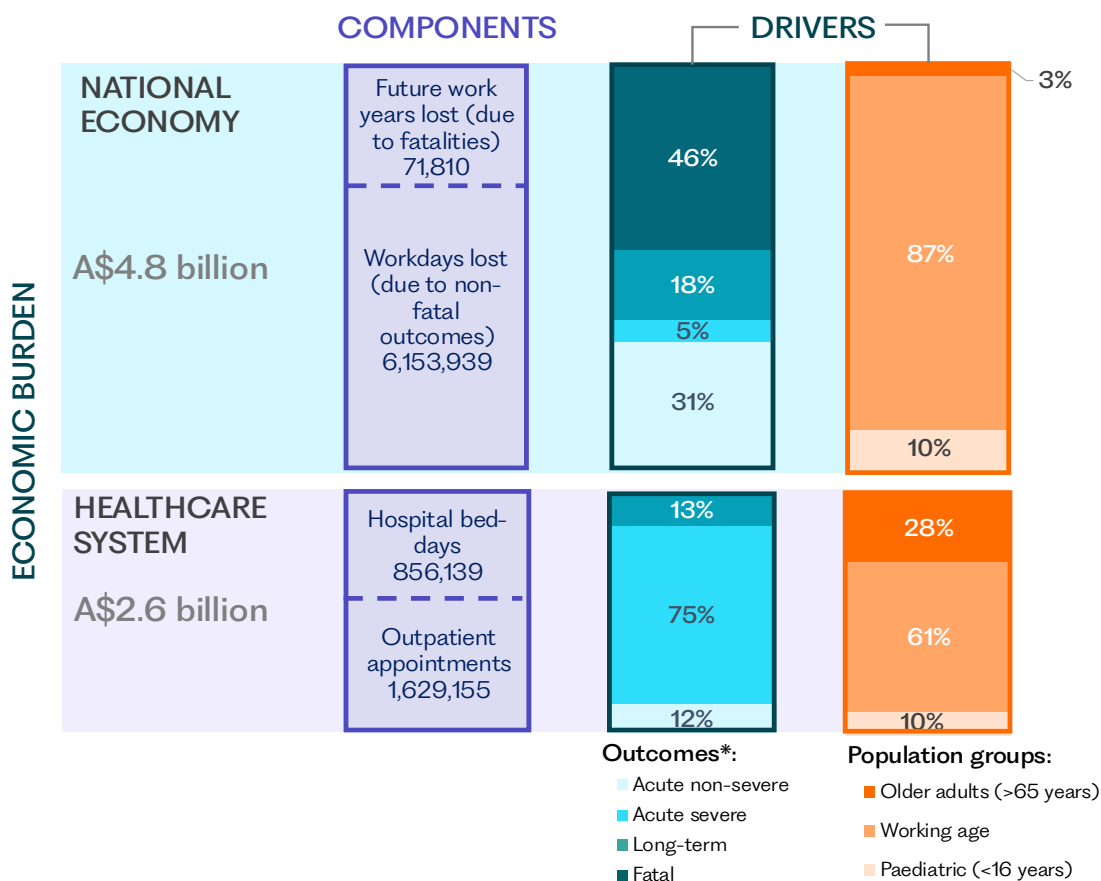
Figure 4. Annual economic burden of COVID-19 on the healthcare system and national economy in Australia



As shown in Figure 5, COVID-19 would impose a substantial economic burden on the Australian national economy, leading to an estimated 6.2 million workdays lost due to non-fatal illness and 72,000 work-years lost due to premature deaths. Fatal COVID-19 cases are responsible for over half of the burden on the national economy, while acute, non-severe COVID-19 cases – those not requiring hospitalisation – are responsible for a third of the burden, largely through lost productivity from absenteeism. Notably, 87% of the national economy burden originates from cases in working-age adults (18–64), underscoring the significance of working-age populations in generating the COVID-19 burden on the Australian national economy.

The healthcare system also faces a considerable burden, with COVID-19 accounting for approximately 856 thousand hospital bed-days and over 1.6 million outpatient care appointments. Three-quarters of this burden stems from acute, severe COVID-19 cases which require hospitalisation and subsequent outpatient appointments. Cases in the working-age population generate just under two-thirds of the COVID-19 burden on the healthcare system. This reflects the larger size of the working-age population, despite their lower individual risk. The paediatric population does not generate a large healthcare burden due to their lower risk of symptomatic infection and of severe outcomes.

Figure 5. Components and drivers of the annual COVID-19 economic burden in Australia



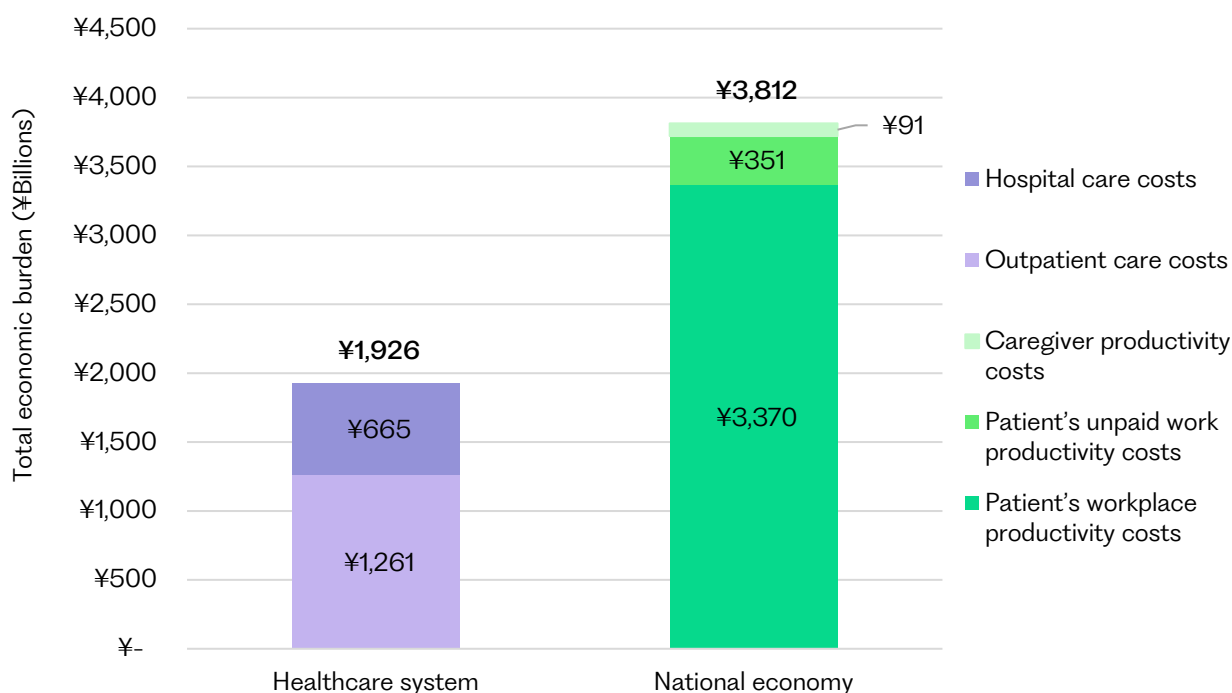
*Acute *Acute non-severe = non-hospitalised infections; Acute severe = hospitalised infections, myocarditis cases; Long-term = long Covid cases; Fatal = deaths. Fatal cases are a subset of the hospitalised infections and generate healthcare system costs as part of the acute severe outcomes.

3.3 Japan

Based on the COI approach, the total estimated COVID-19 economic burden with no autumn COVID-19 vaccination programme is ¥5.7 trillion per year in Japan. This burden is generated by the COVID-19 health outcomes presented in the Results Appendix (section 8).

The burden of COVID-19 to the national economy is approximately ¥3.8 trillion per year, almost 2 times as large as the economic burden of COVID-19 to the healthcare system (¥1.9 trillion per year) (Figure 6).

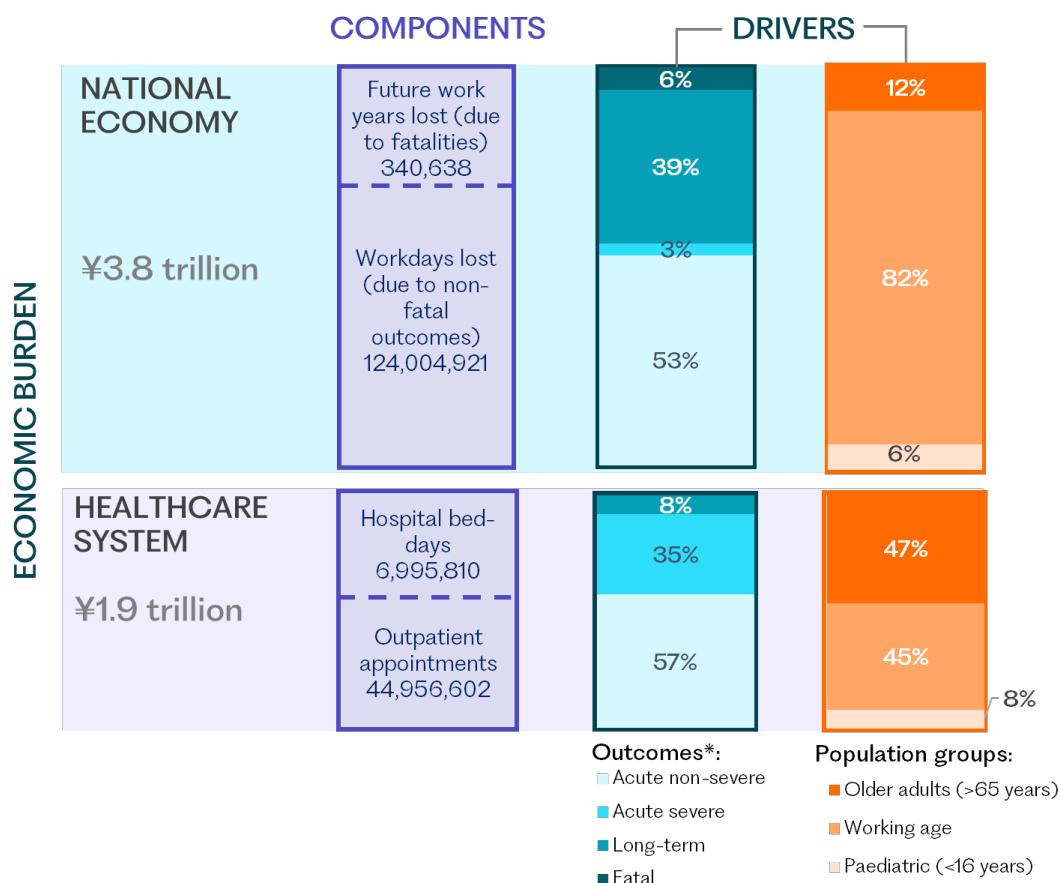
Figure 6. Annual economic burden of COVID-19 on the healthcare system and national economy in Japan



As shown in Figure 7, COVID-19 would impose a substantial economic burden on the Japanese national economy, leading to an estimated 124 million workdays lost due to non-fatal illness and almost 341 thousand work-years lost due to premature deaths. Acute, non-severe COVID-19 cases - those not requiring hospitalisation - were responsible for more than half of the burden, largely through lost productivity from absenteeism. Long-term outcomes of COVID-19 (long COVID) are responsible for over a third of the burden, both through lost productivity from absenteeism and reduced labour force participation. Notably, 82% of this national economy burden originates from cases in working-age adults (18–64), underscoring the significance of working-age populations in generating the COVID-19 burden on the Japanese national economy.

The healthcare system would also face a considerable burden, with COVID-19 accounting for almost 7 million hospital bed-days and 45 million outpatient care appointments. Acute, non-severe COVID-19 cases - those not requiring hospitalisation - are responsible for more than half (57%) of the burden, while more than a third (35%) of this burden stems from acute, severe COVID-19 cases which required hospitalisation and subsequent outpatient appointments. Although older adults are at greater individual risk of severe outcomes, the overall burden on the healthcare system is almost equally driven by both working-age adults and older adults (45% and 47% respectively). The paediatric population does not generate a large healthcare burden due to their lower risk of symptomatic infection and of severe outcomes.

Figure 7. Components and drivers of the annual COVID-19 economic burden in Japan



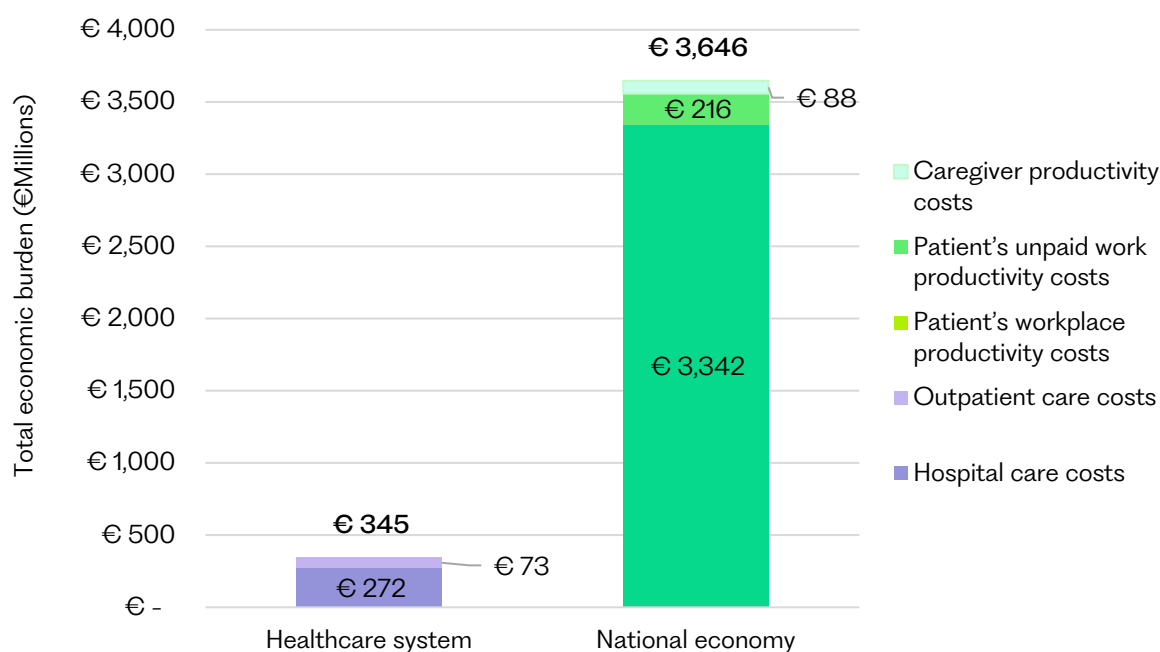
*Acute non-severe = non-hospitalised infections; Acute severe = hospitalised infections, myocarditis cases; Long-term = long Covid cases; Fatal = deaths. Fatal cases are a subset of the hospitalised infections and generate healthcare system costs as part of the acute severe outcomes.

3.4 Netherlands

Based on the COI approach, the total economic burden from COVID-19 in case of no autumn COVID-19 vaccination programme is €3.99 billion per year in Netherlands. This burden is generated by the COVID-19 health outcomes presented in the Results Appendix (section 8).

The burden of COVID-19 to the national economy is approximately €3.6 billion per year, 10.6 times as large as the economic burden of COVID-19 to the healthcare system (€345 million per year) (Figure 8).

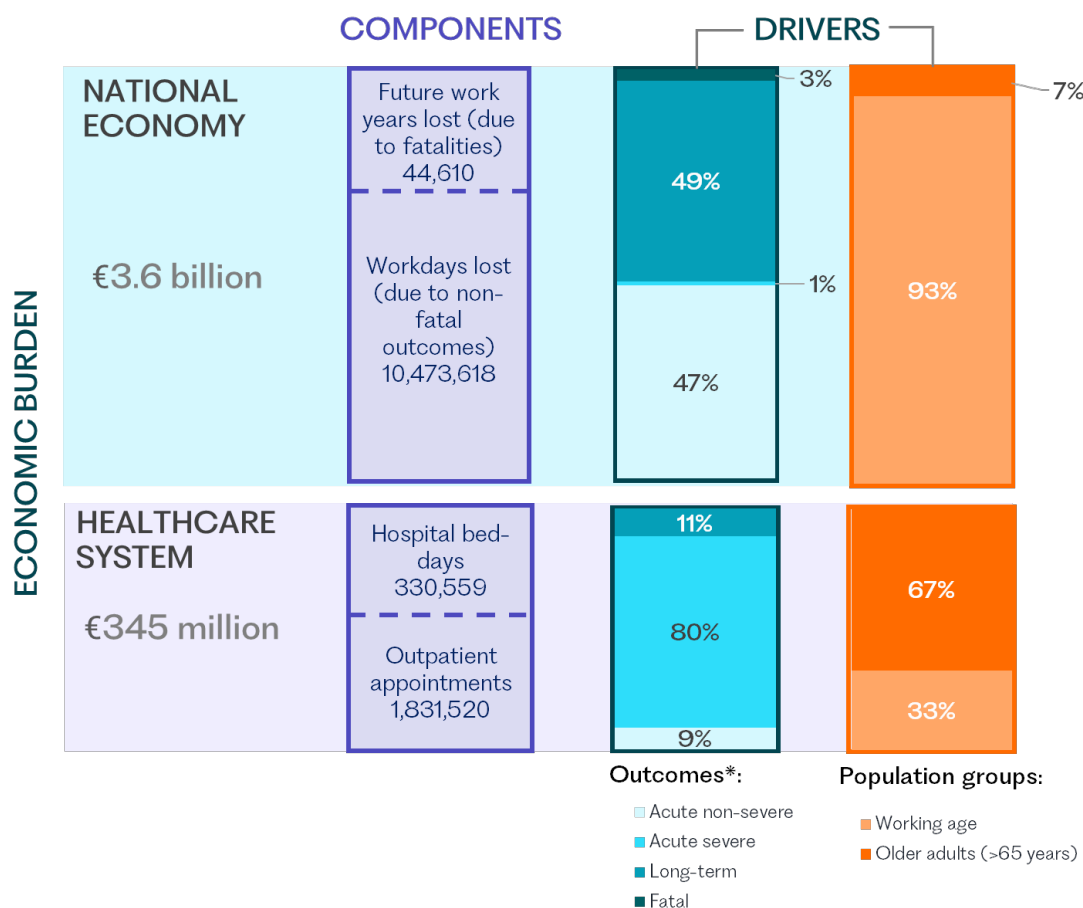
Figure 8. Annual economic burden of COVID-19 on the healthcare system and national economy in the Netherlands



As shown in Figure 9, COVID-19 would impose a substantial economic burden on the Netherlands' national economy, leading to an estimated 10 million workdays lost due to non-fatal illness and almost 45 thousand work-years lost due to premature deaths. Acute, non-severe COVID-19 cases - those not requiring hospitalisation- and long-term outcomes of COVID-19 (long COVID) are predominantly responsible for the total burden on the national economy, generating 47% and 49% of the burden, respectively. This burden is largely generated through lost productivity from absenteeism and, in the case of long COVID, reductions in labour force participation. Notably, 93% of the burden on the national economy originates from cases in working-age adults (18–64), underscoring the significance of working-age populations in generating the COVID-19 burden on the national economy.

The healthcare system also faces a considerable burden, with COVID-19 accounting for more than 330 thousand hospital bed-days and over 1.8 million outpatient care appointments. The majority (80%) of this burden stems from acute, severe COVID-19 cases which require hospitalisation and subsequent outpatient appointments. More than two-thirds of the overall burden on the healthcare system is driven by cases in older adults. The paediatric population does not generate a large healthcare burden due to their lower risk of symptomatic infection and of severe outcomes.

Figure 9. Components and drivers of the annual COVID-19 economic burden in the Netherlands



*Acute non-severe = non-hospitalised infections; Acute severe = hospitalised infections, myocarditis cases; Long-term = long Covid cases; Fatal = deaths. Fatal cases are a subset of the hospitalised infections and generate healthcare system costs as part of the acute severe outcomes.

**Paediatric cases are not included in the disease model in the Netherlands

4

Economic benefits of COVID-19 vaccination recommendations

We estimate that annual autumn COVID-19 vaccination of older adults and at-risk groups⁴ aligned with 2023/2024 COVID-19 vaccination programme recommendations could generate economic benefits equivalent to an (unweighted) average of 0.04% of the national GDP in the countries under analysis (min%-max%: 0.02%-0.07%). Autumn vaccination administered annually according to 2023/2024 recommendations would, on average, avert the economic impact of COVID-19 on the health system by ~22%, and reduce its economic impact on the national economy by ~7%.

An extended autumn vaccination policy lowering eligibility to the general population aged 50+ in the countries under analysis could generate economic benefits equivalent to an average of 0.06% of the national GDP in the countries under analysis (min%-max%: 0.02%-0.10%). Benefits to the national economy drive the additional economic benefits of vaccination in the UK, Japan, and the Netherlands. In Australia, the proportional benefits to the healthcare system and national economy contribute more equally. This is observed because there is a higher healthcare burden relative to the economic burden in Australia compared to the other countries (see Section 3.2), attributable to high healthcare costs (see main inputs in Table 5). Accordingly, the fall in healthcare costs is relatively more important in this context.

An extended autumn vaccination policy lowering eligibility to the general population aged 18+ in the countries under analysis could generate economic benefits equivalent to an average of 0.12% of the national GDP in the countries under analysis (min%-max%: 0.04%-0.19%). These improvements are driven by averted economic impact on the national economy: the average percentage of the COVID-19 economic burden on national economy averted by vaccination more than triples from 7% (min%-max%: 3%-12%) when older adults and high risk groups are vaccinated to 27% (min%-max%: 8%-60%) when vaccination is extended to the general population of adults aged 18+.

The following sections further detail the vaccine prevented COVID-19 outcomes and the associated broader economic benefits in each country under analysis. As in Section 3, results are expressed in country-specific currencies: British Pounds (£) for the United Kingdom, Australian Dollars (A\$) for Australia, Japanese Yen (¥) for Japan, and Euros (€) for the Netherlands.

⁴ At-risks groups were included in the epidemiological models for the UK and the Netherlands but were not included in the models in Australia and Japan.

Table 7. Annual economic benefits of COVID-19 Vaccination

						AVERAGE
ECONOMIC BENEFITS OF COVID-19 VACCINATION (% OF NATIONAL GDP)*	Autumn vaccination of older adults**	£836 m (0.03%)	A\$1.1 bn (0.04%)	¥397 bn (0.07%)	€210 m (0.02%)	(0.04%)
	Autumn vaccination extended to 50+	£1.1 bn (0.04%)	A\$2.0 bn (0.08%)	¥616 bn (0.10%)	€250 m (0.02%)	(0.06%)
	Autumn vaccination extended to 18+	£1.8 bn (0.07%)	A\$4.5 bn (0.17%)	¥1,104 bn (0.19%)	€367 m (0.04%)	(0.12%)
COVID-19 ECONOMIC BURDEN ON HEALTHCARE SYSTEM*** AVERTED BY VACCINATION (%)	Autumn vaccination of older adults**	29%	20%	13%	24%	(22%)
	Autumn vaccination extended to 50+	33%	33%	18%	25%	(27%)
	Autumn vaccination extended to 18+	40%	64%	25%	25%	(39%)
COVID-19 ECONOMIC BURDEN ON NATIONAL ECONOMY*** AVERTED BY VACCINATION (%)	Autumn vaccination of older adults**	10%	12%	4%	3%	(7%)
	Autumn vaccination extended to 50+	14%	25%	7%	5%	(13%)
	Autumn vaccination extended to 18+	24%	60%	16%	8%	(27%)

* Note that the denominator (total GDP) is different for each country. ** Older adults (60+ in the Netherlands, 65+ in Australia, Japan and the UK). At-risk groups additionally included for the UK and the Netherlands. See Table 1 for exact eligibility depending on 2023/2024 country recommendations. ***Under no COVID-19 vaccination programme

4.1 United Kingdom

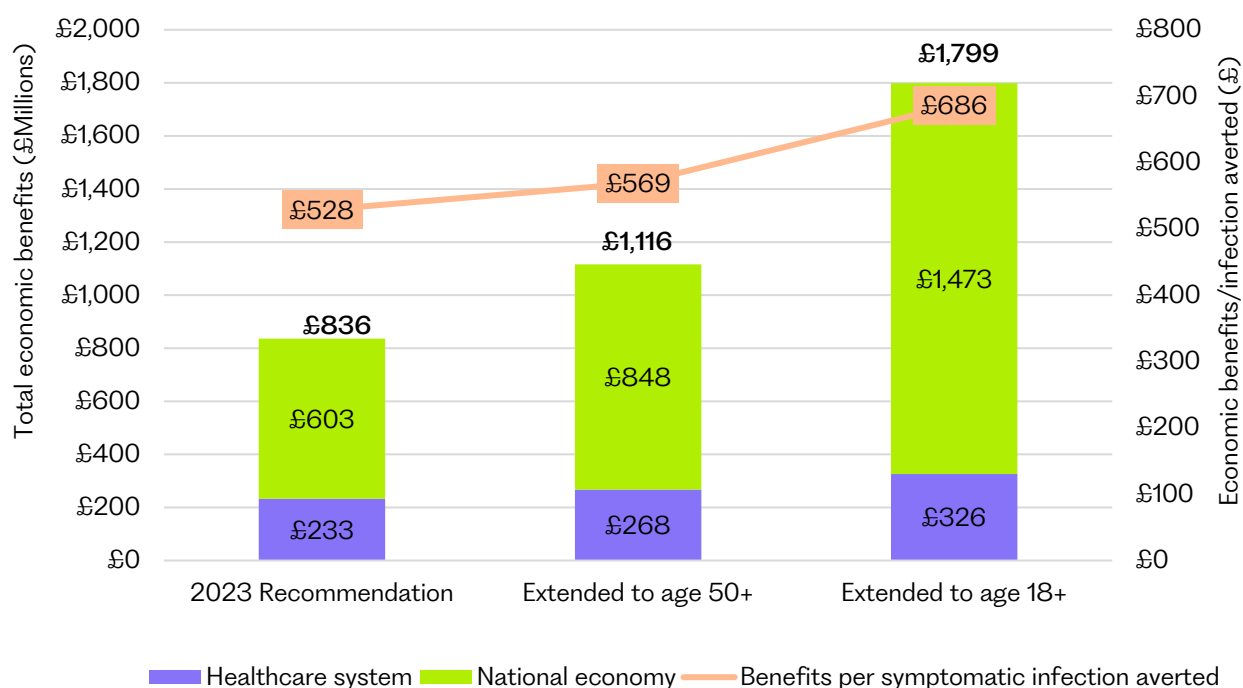
Compared to no COVID-19 autumn vaccination, vaccination aligned with the Joint Committee on Vaccination and Immunisation (JCVI)'s 2023 autumn recommendations (see Table 1) translates into overall economic benefits of £836 million per year, averting 12% of the total COVID-19 economic burden (Figure 10).

Extending COVID-19 vaccination eligibility to the general population aged 50+ and 18+ would increase the overall economic benefits to £1.1 billion and £1.8 billion per year, respectively (16% and 26% of the COVID-19 economic burden).

The economic benefit per symptomatic infection averted under JCVI 2023 autumn vaccination recommendations and vaccination extended to the 50+ general population are closely aligned, at £528 and £569, respectively. As more young individuals in the working-age population are vaccinated (the 18+ vaccination scenario), the economic benefits per symptomatic infection averted reaches £686.

These economic benefits are driven by the vaccines administered and averted symptomatic COVID-19 health outcomes presented in the Results Appendix (section 8).

Figure 10. Annual economic benefits by vaccination scenario, UK



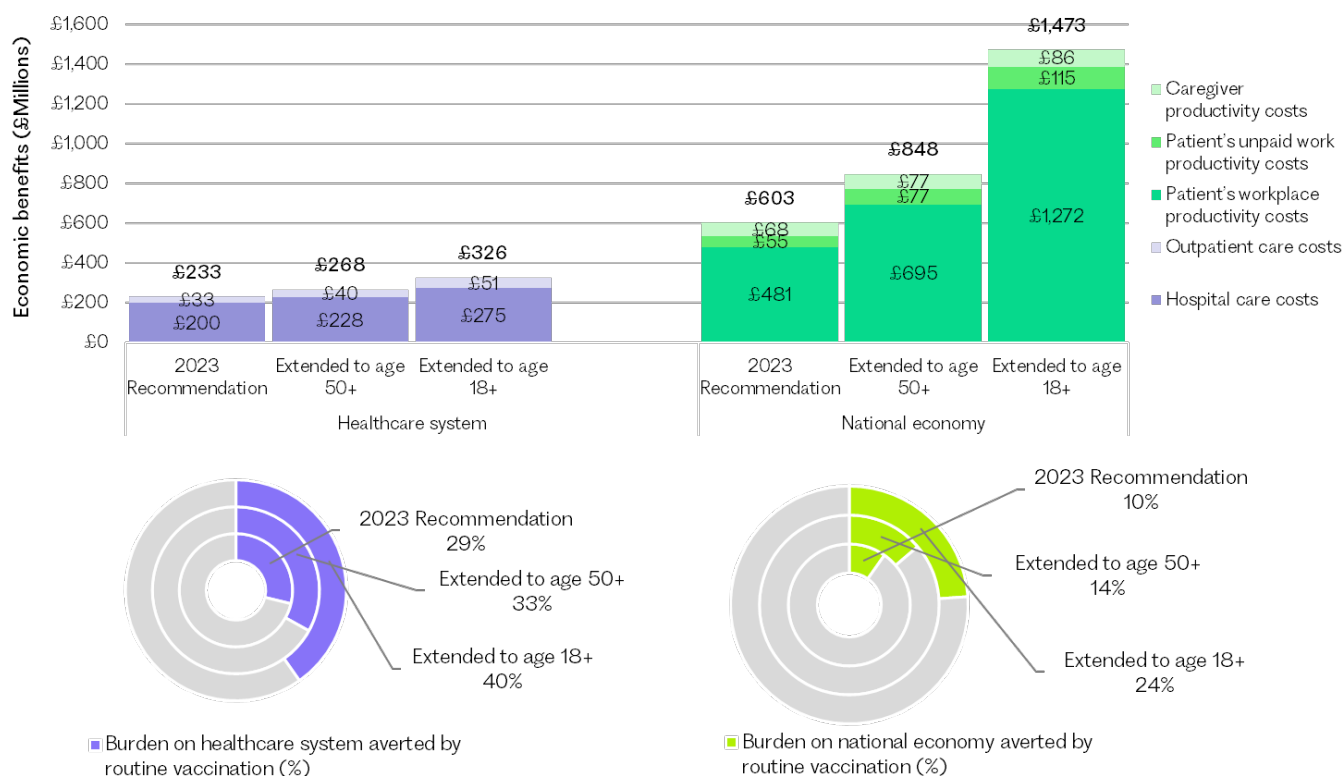
Averted productivity losses are the major driver of the economic benefits across all vaccination scenarios. Specifically, the economic benefits to the national economy are £603 million under the 2023 vaccination recommendations and £848 million and £1.47 billion under a vaccination policy extending vaccination to the general population aged 50+ and 18+, respectively (Figure 11). Compared to the 2023 recommendations for the vaccination of older and at-risk adults, extending vaccination to the working-age population could increase the economic benefits to the national economy by ~1.4 to over two times.

Autumn vaccination according to the 2023 recommendations prevents 10% of the COVID-19 economic burden on the national economy. The averted burden on the national economy increases to 14% by extending eligibility to the 50+ aged population, or to 24% by further lowering the age eligibility threshold for vaccinating the general population aged 18+ years.

The economic benefits to the UK healthcare system are £233 million under 2023 recommendations and £268 million and £326 million in the extended 50+ and 18+ vaccination scenarios, respectively (Figure 11). Averted hospitalisation costs are the main driver of the healthcare system's benefits across all scenarios.

Autumn vaccination in line with the 2023 recommendations is effective at preventing 29% of the COVID-19 economic burden on the healthcare system. The averted burden on the healthcare system could further increase to 33% and 40% under the more inclusive 50+ and 18+ vaccination scenarios respectively.

Figure 11. Annual economic benefits by vaccination scenario, healthcare system and national economy breakdown, UK



4.2

Australia

Compared to no COVID-19 vaccination programme, autumn vaccination aligned with the 2024 national age-based recommendation translates into overall economic benefits of A\$1.1 billion per year, averting 15% of the total COVID-19 economic burden (Figure 12).

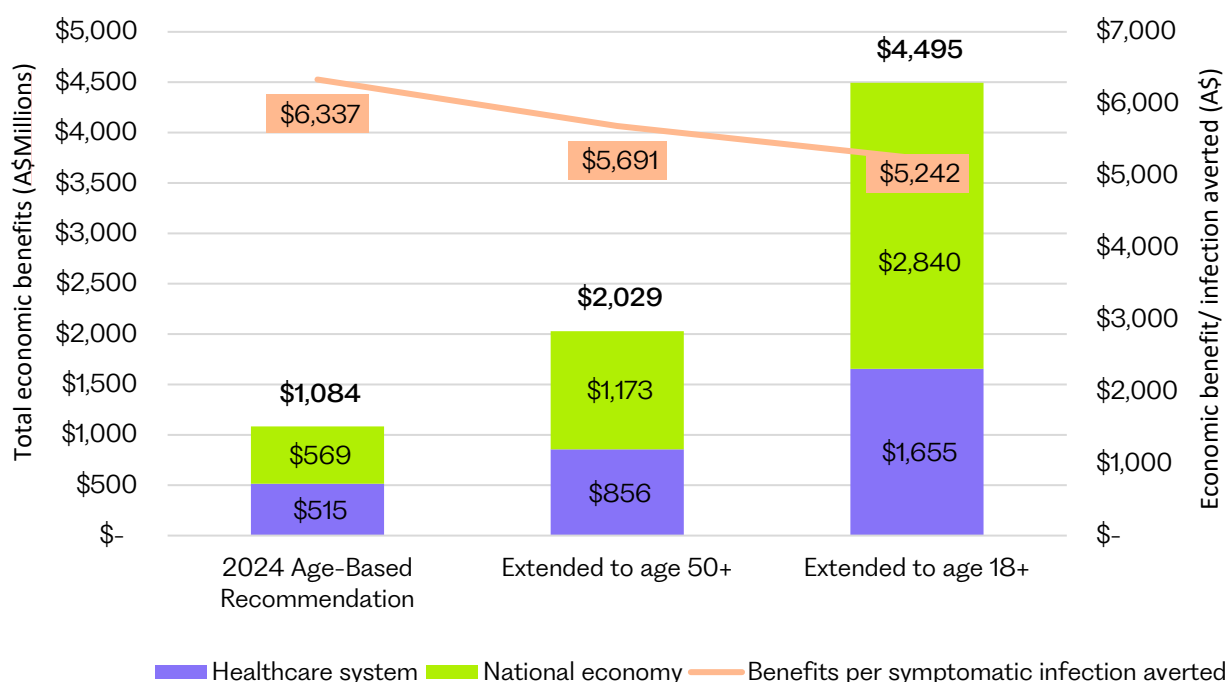
Extending COVID-19 vaccination to the general population aged 50+ and 18+ would increase the overall economic benefits to A\$2.0 billion and A\$4.5 billion per year, respectively (28% and 61% of the COVID-19 economic burden).

These economic benefits are driven by the vaccines administered and averted symptomatic COVID-19 health outcomes presented in the Results Appendix (section 8).

The economic benefit per symptomatic infection averted under autumn vaccination according to the 2024 age-based recommendation for vaccination of older adults is A\$6,337, reflecting the high hospitalisation rates and costs observed in Australia. Extending COVID-19 vaccination to the general population aged 50+ and 18+ is associated with economic benefits per symptomatic infection averted of A\$5,690 and A\$5,242, respectively. The rate at which cases prevented increases with extended COVID-19 vaccination is higher than the rate of increase in costs averted, due to the relatively

high number of non-hospitalised cases averted in Australia compared to other countries. The estimated large costs per COVID-19 hospitalisation in the Australia context may explain why this trend is observed when introducing vaccination among population groups with lower likelihood of severe outcomes. Despite this trend, the benefits per infection averted are high across all the vaccination scenarios.

Figure 12. Annual economic benefits by vaccination scenario, Australia



Averted productivity losses are the major driver of the economic benefits across all vaccination scenarios. Specifically, the economic benefits to the national economy are A\$569 million under the 2024 age-based vaccination recommendation and A\$1.2 billion and A\$2.8 billion under a vaccination policy extending vaccination to the population aged 50+ and 18+, respectively (Figure 13). Compared to the 2024 age-based vaccination recommendations for older adults, extending vaccination to the working-age population could increase the economic benefits to the national economy by two to five times.

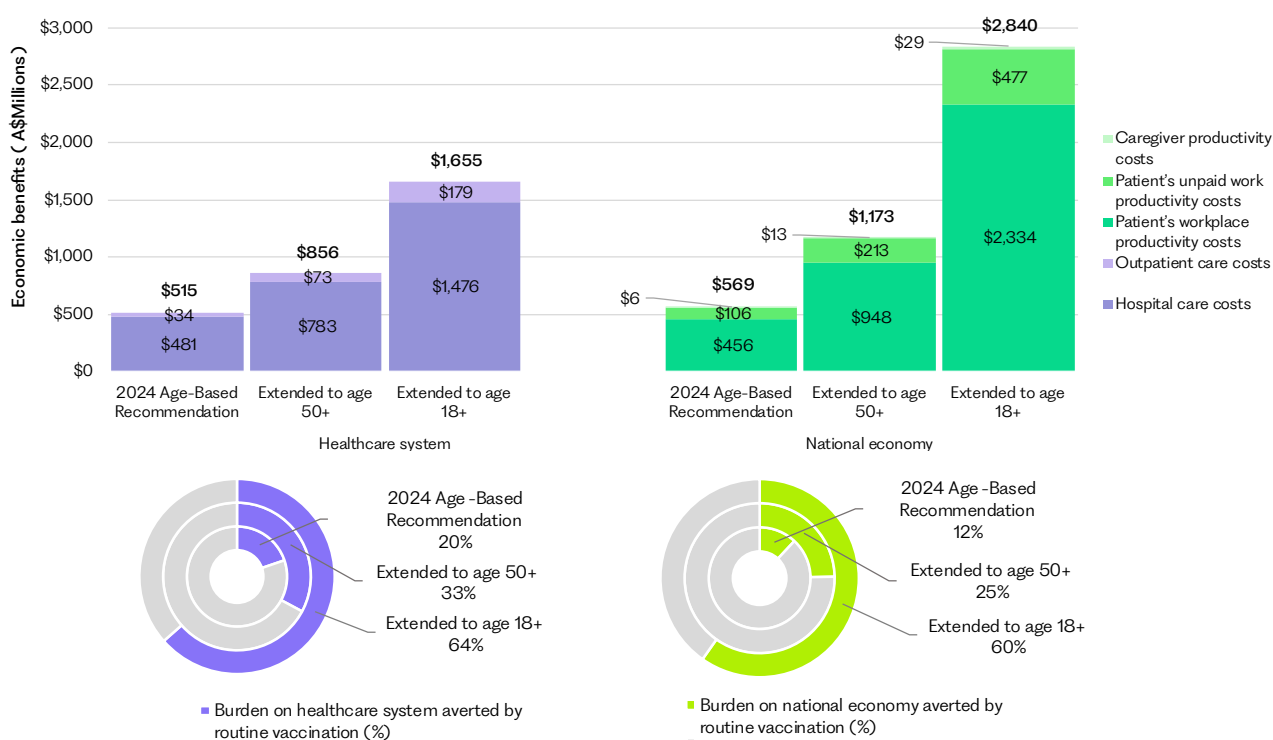
Autumn vaccination according to the 2024 age-based vaccine recommendation prevents 12% of the COVID-19 economic burden on the national economy. The averted burden on the national economy increases to 25% by extending eligibility to the 50+ aged population, or to 60% by further lowering the age eligibility threshold for vaccinating the general population aged 18+ years.

The economic benefits of autumn vaccination to the Australian healthcare system in line with the 2024 age-based recommendation are A\$515 million and A\$856 million and A\$1.7 billion in the extended 50+ and 18+ vaccination scenarios, respectively (Figure 13). Averted hospitalisation costs are the main driver of the healthcare system's benefits across all scenarios.

Autumn vaccination according to the 2024 age-based vaccine recommendations is effective at preventing 20% of the COVID-19 economic burden on the healthcare system.

The averted burden on the healthcare system could further increase to 33% and 64% under the 50+ and 18+ vaccination scenarios, respectively. The large proportion of burden averted is driven by the high percentage of hospitalised cases averted by vaccination across the scenarios considered according the epidemiological model (See the Results Appendix, section 8).

Figure 13. Annual economic benefits by vaccination scenario, healthcare system and national economy breakdown, Australia



4.3

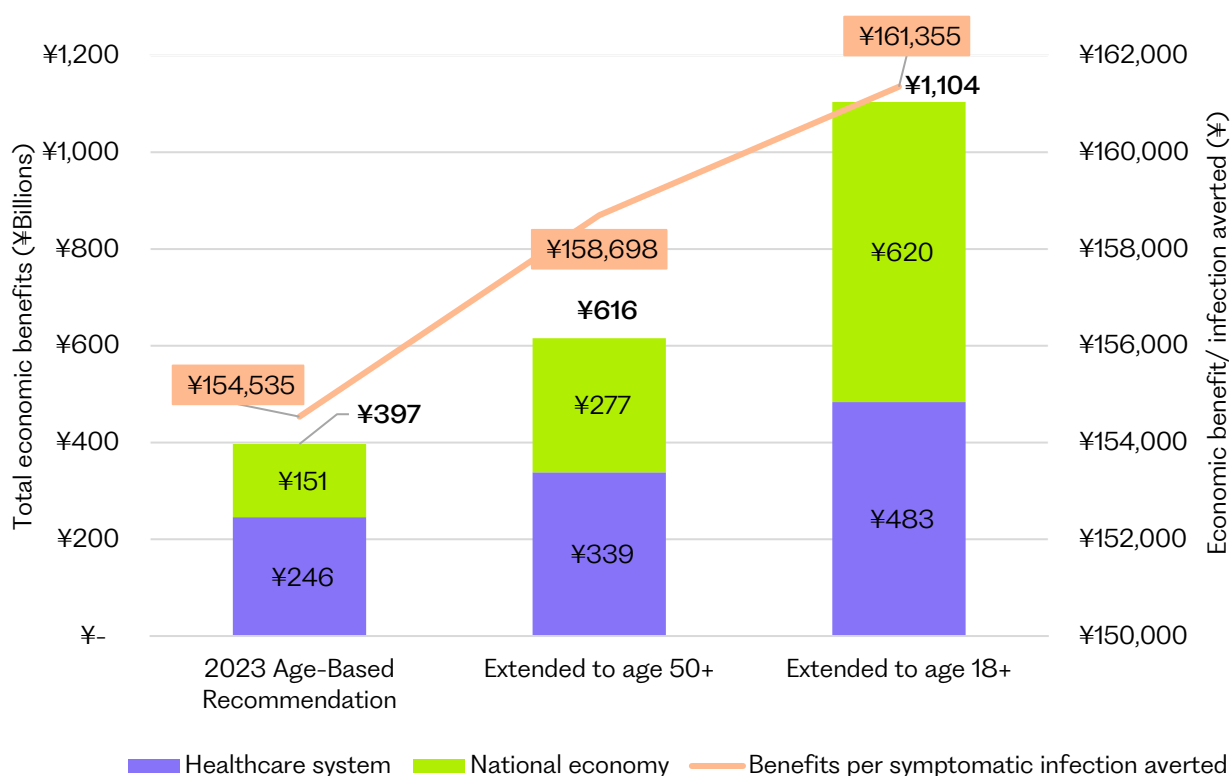
Japan

Compared to no COVID-19 vaccination programme, autumn vaccination aligned with the 2023 age-based recommendation translates into overall economic benefits of ¥397 billion per year, averting 7% of the total COVID-19 economic burden (Figure 14).

Extending COVID-19 vaccination to the general population aged 50+ and 18+ would increase the overall economic benefits to ¥616 million and ¥1.1 trillion per year, respectively (11% and 19% of the COVID-19 economic burden).

The economic benefits per infection averted increases from ¥154,535 under autumn vaccination according to the 2023 age-based recommendation to ¥158,698 and ¥161,355 when vaccination is extended to the general population aged 50+ and 18+, respectively.

These economic benefits are driven by the vaccines administered and averted symptomatic COVID-19 health outcomes presented in the Results Appendix (section 8).

Figure 14. Annual economic benefits by vaccination scenario Japan

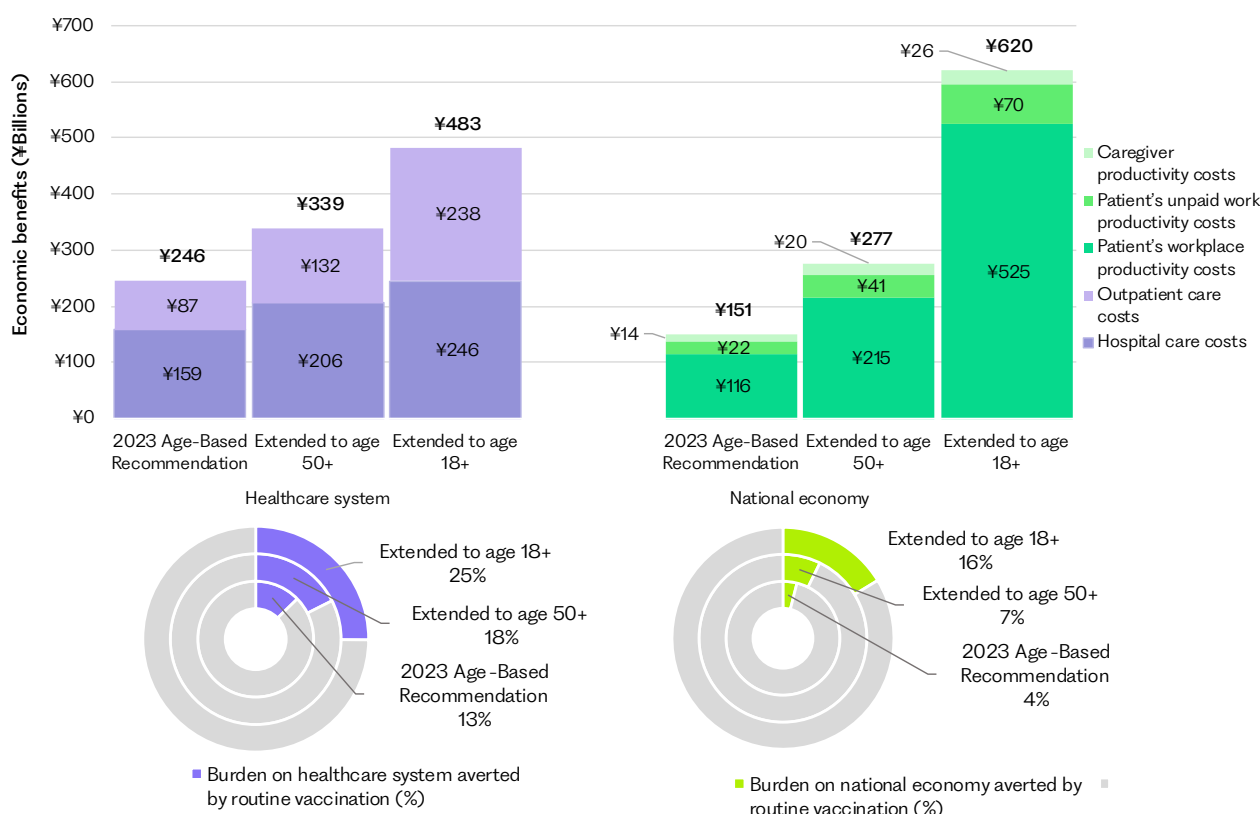
The driver of the economic benefits in Japan depends on the vaccination scenario considered. Specifically, the benefits to the national economy are ¥151 billion from autumn vaccination according to the 2023 age-based recommendation and ¥277 billion and ¥620 billion under a vaccination policy extending vaccination to the population aged 50+ and 18+, respectively (Figure 15). Compared to the 2023 age-based recommendation for older adults, extending vaccination to the working-age population could increase the economic benefits to the national economy by about two to four times.

Autumn vaccination according to the 2023 age-based recommendation prevents 4% of the COVID-19 economic burden on the national economy. The averted burden on the national economy increases to 7% by extending eligibility to the 50+ aged population, or to 16% by further lowering the age eligibility threshold for vaccinating the general population aged 18+ years.

The economic benefits to the Japanese healthcare system are ¥246 billion under autumn vaccination according to the 2023 age-based recommendation, and ¥339 billion and ¥483 billion in the extended 50+ and 18+ vaccination scenarios (Figure 15). While averted hospitalisation costs initially constitute a larger proportion (two-thirds) of the healthcare system benefits, when vaccination is extended to the working-age populations outpatient costs drive an increasing proportion of the healthcare system benefits.

Autumn vaccination of older adults is effective at preventing 13% of the COVID-19 economic burden on the healthcare system. The averted burden on the healthcare system could further increase to 18% and 25% by lowering the age eligibility threshold to 50 years and 18 years, respectively.

Figure 15. Annual economic benefits by vaccination scenario, healthcare system and national economy breakdown, Japan



4.4 Netherlands

Compared to no COVID-19 vaccination programme, autumn vaccination aligned with the Dutch Health Council's 2023 recommendations⁵ (see Table 1) translates into overall economic benefits of €210 million per year, averting 5% of the total COVID-19 economic burden (Figure 16).

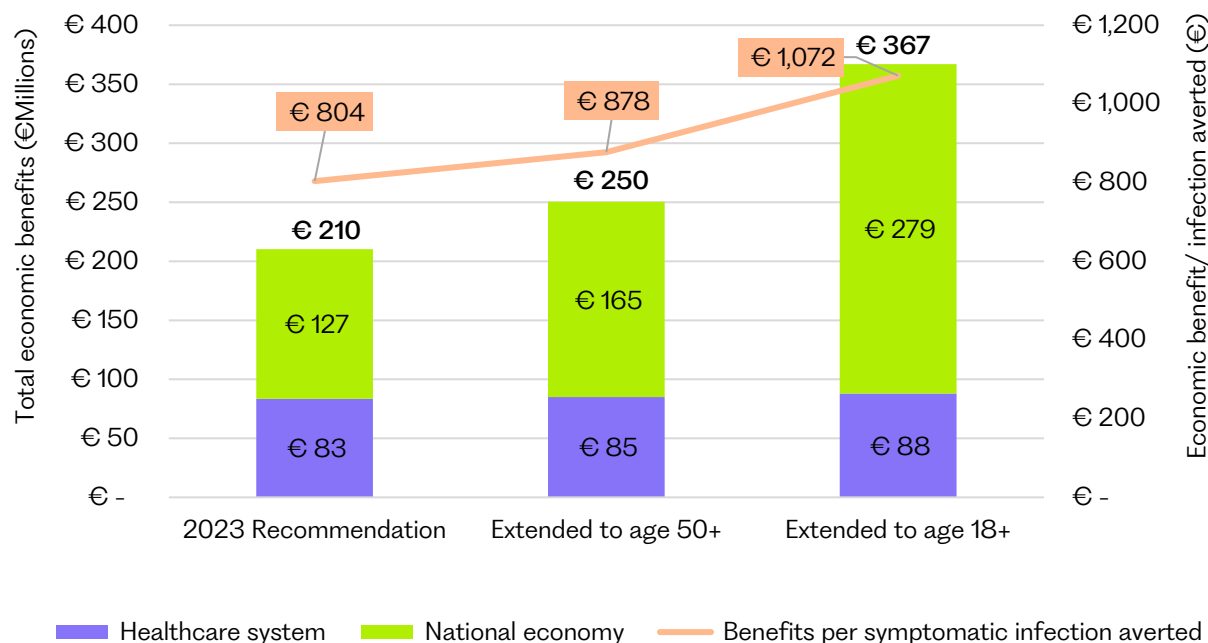
Extending COVID-19 vaccination to the general population aged 50+ and 18+ would increase the overall economic benefits to €250 million and €367 million per year, respectively (6% and 9% of the COVID-19 economic burden).

The economic benefit per infection averted increases from €804 under autumn vaccination according to the 2023 recommendations to €878 and €1,072 when vaccination is extended to the general population aged 50+ and 18+, respectively.

These economic benefits are driven by the vaccines administered and averted symptomatic COVID-19 health outcomes, as presented in the Results Appendix (section 8).

⁵ The Dutch Health Council recommendations as published by the National Institute for Public Health and the Environment (RIVM).

Figure 16. Annual economic benefits by vaccination scenario, Netherlands

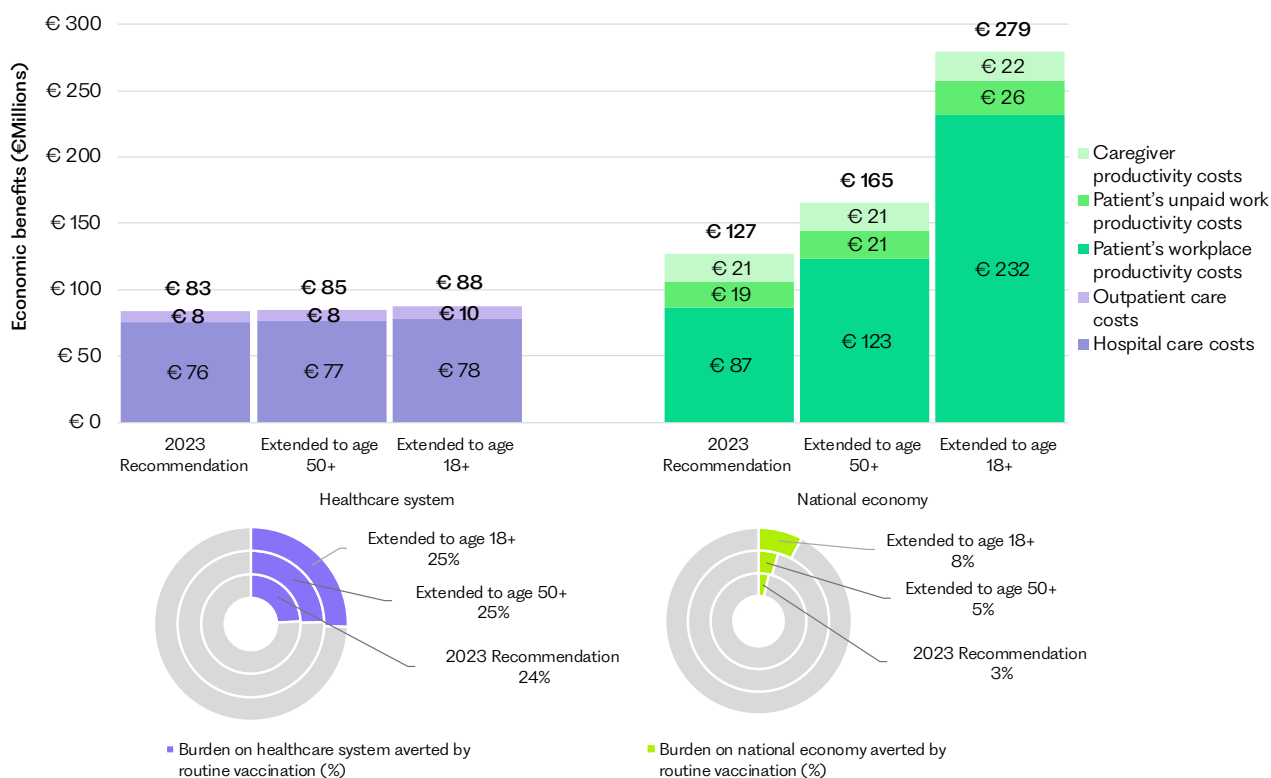


Averted productivity losses are the major driver of the economic benefits across all vaccination scenarios. Specifically, the economic benefits to the national economy are €127 million under autumn vaccination according to the Dutch Health Council's 2023 recommendations and €165 million and €279 million under a vaccination policy extending vaccination to the population aged 50+ and 18+, respectively (Figure 17). Compared to the 2023 recommendations for older adults and at-risk groups, extending vaccination to the working-age population could increase the economic benefits to the national economy by 1.3 to 2.2 times.

Autumn vaccination according to the Dutch Health Council's 2023 recommendations prevents 3% of the COVID-19 economic burden on the national economy. The averted burden on the national economy increases to 5% by extending eligibility to the population aged 50+, or to 8% by further lowering the age eligibility threshold for vaccinating the general population aged 18+ years.

The economic benefits to the Netherlands healthcare system are €83 million under autumn vaccination according to the Dutch Health Council's 2023 recommendations, or 24% of the COVID-19 economic burden (Figure 17). When COVID-19 vaccination eligibility is extended to the population aged 50+, these benefits increase to €85 million (25% of the burden), and when eligibility is extended to the population aged 18+, they further increase to €88 million (25% of the burden). Averted hospitalisation costs are the main driver of the healthcare system's benefits across all scenarios.

Figure 17. Annual economic benefits by vaccination scenario, healthcare system and national economy breakdown, Netherlands

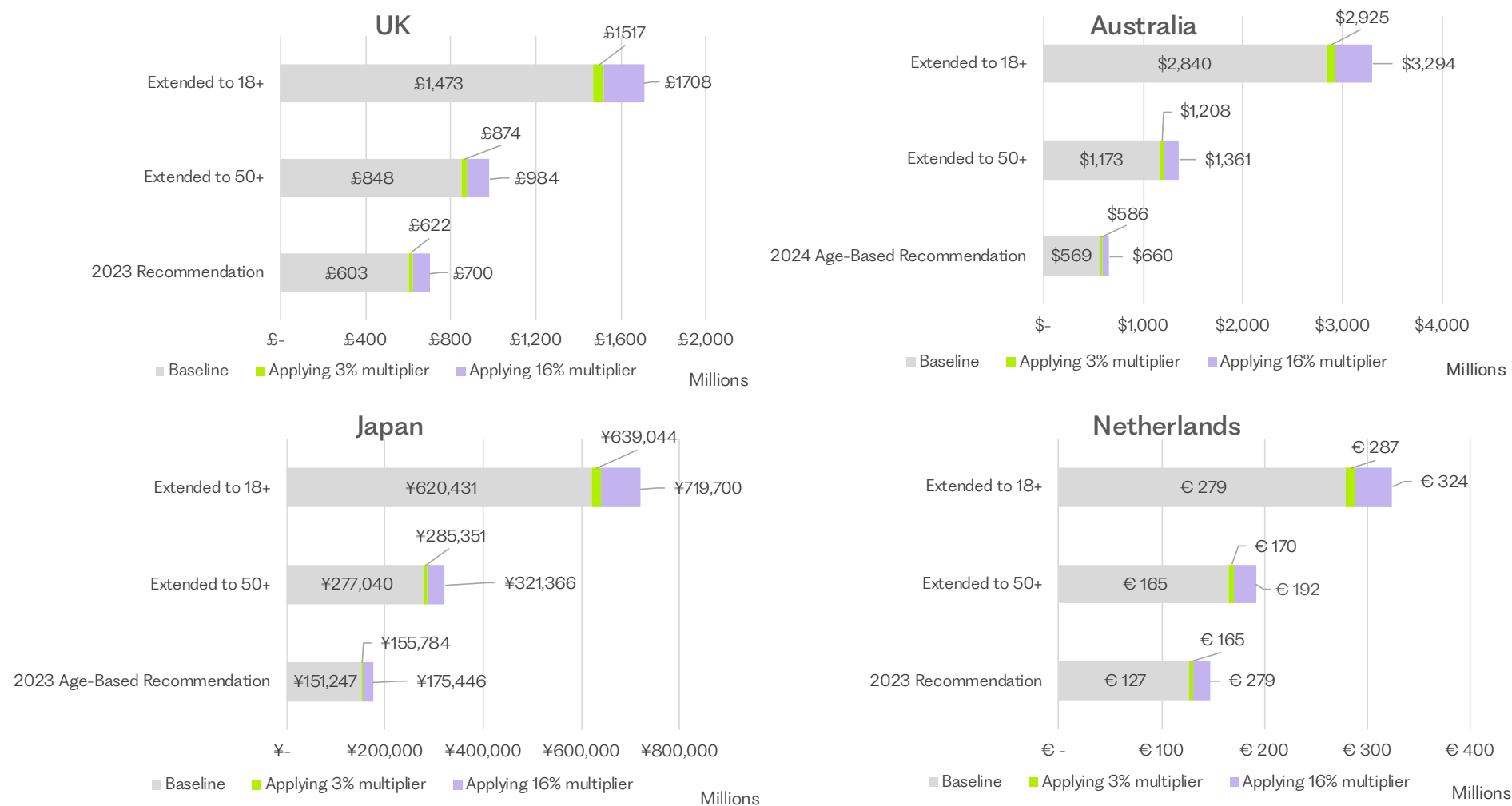


5

Exploring the ripple effects on the economy

Estimates of the ripple effects are obtained by applying a multiplier of 3%-16% (Hafner et al., 2023) to the productivity effects estimated with the COI approach. Figure 18 shows the total economic benefits of vaccination to the national economy (i.e., patients' and caregivers' productivity losses averted) when the ripple effects are included for each of the vaccination scenarios in the four countries. The baseline values when no ripple effects are included are also displayed for comparison. For example, in the UK, autumn vaccination of older adults (65+) and at-risk groups according to 2023 recommendations is estimated to yield a benefit of £603 million to the national economy. Applying a 3% multiplier to account for ripple effects in the economy increases the estimated benefit to £622 million, while a 16% multiplier increases the estimated benefit to £700 million.

Figure 18. Annual economic benefits of vaccination to national economy when ripple effects are included



6 Vaccination for healthcare resilience and economic performance

6.1 Discussion

The findings of this report suggest continued impact of COVID-19 as a disease disrupting healthcare systems and national economies and highlight the significance of vaccination as a tool to unlock healthcare system resilience and economic performance.

COVID-19 continues to represent a significant threat to our societies

Left unaddressed without further annual autumn vaccination programs, we estimated based on 2023/2024 data that COVID-19 has a substantial economic burden, costing on average the equivalent of 0.48% of the national GDP across the countries under analysis (min%-max%: 0.26%-0.97%). This impact is approximately twice the average spending on health prevention by OECD countries before the COVID-19 pandemic (0.26% of national GDP)⁶. Importantly, national economies bear a larger share of this burden than healthcare systems, around twice as large in Australia and Japan, more than seven times as large in the UK, and ten times as large in the Netherlands.

Drawing direct comparisons between our estimates and the economic impact of other seasonal respiratory infections is challenging because of the heterogeneity in methodologies used in the literature and a lack of studies in the UK, Australia, Japan and the Netherlands. However, a US modelling study found that a seasonal influenza outbreak in a non-vaccinated population could cost the economy around 0.07% of the national GDP per year (Prager, Wei and Rose, 2017). A model in the UK focusing on the national economy impact of influenza in unvaccinated working-age adults estimated an associated annual loss of £1.85 billion⁷ (Romanelli et al., 2023). Based on 2023/2024 season incidence estimates for Japan and the Netherlands and 2024/2025 season incidence estimates in the UK and Australia, our COI estimates suggest that the annual economic burden of unaddressed COVID-19 infections may be higher than that of seasonal influenza. Further, similar to COVID-19, evidence on influenza from the US finds that working-age adults (aged 18-64) have the highest numbers of symptomatic illness and outpatient visits, highlighting the importance of protecting this age group, given that they often constitute a large percentage of a country's population and represent the main workforce, and that the rate of chronic medical conditions among this population is increasing (Torcel-Pagnon et al., 2025).

Annual COVID-19 vaccination of older adults protects healthcare systems but leaves national economies exposed to the impact of COVID-19.

On average, annual autumn vaccination according to 2023/2024 recommendations generates economic benefits equivalent to 0.04% of national GDP in the countries under analysis (min%-max%: 0.02%-0.07%). These benefits are generally similarly distributed between healthcare systems and national economies. However, while on average 22% of the COVID-19 economic impact on healthcare systems is averted through autumn vaccination programs (min%-max%: 13%-29%), they prevent only 7% of the impact on the national economy on average (min%-max%: 3%-12%).

⁶ Based on 8.8% GDP average spend on health (OECD, 2021), of which 3% was allocated to prevention on average (OECD, 2023a).

⁷ Our model estimates a £6.2 billion annual impact on the UK national economy, of which is 89% attributable to working-age adults.

The economic benefits of the annual autumn COVID-19 immunisation to healthcare systems are propelled by prevented hospital care costs. This result emphasises the effectiveness of autumn COVID-19 vaccination programmes in preventing severe COVID-19 cases among older adults and groups at higher risk of hospitalisation. In this way, COVID-19 vaccination also plays a vital role in protecting healthcare systems from additional winter pressure due to seasonal infections. In fact, vaccine-preventable hospitalisations translate to missed opportunities to treat other patients in circumstances of high bed-occupancy. Research on the 'opportunity cost' of missed treatment opportunities demonstrates that the true value of vaccine-preventable hospitalisations in situations of severe excess demand could be up to two 2 times larger than the simple hospital cost savings (Neri et al., 2023; Brassel et al., 2022).

This analysis demonstrates the importance of vaccination of older adults and at-risk groups for healthcare system resilience, yet vaccine recommendations are increasingly limited and vaccination rates continue to decline. Our analysis of autumn vaccinations is based on 2023/2024 recommendations for COVID-19 vaccinations, which continue to exclude more population groups. For example, in the UK, the 2025 guidance from the JCVI proposes to narrow eligibility to adults aged 75 and over and at-risk groups, compared to adults aged 65 and over (and at-risk groups) before (JCVI, 2024). Therefore, the vaccination rates used in the epidemiological models in this analysis, which are based on historical data, are likely optimistic and so the economic benefits of the recent, more restricted vaccine programmes may be lower than those demonstrated in this analysis.

Moreover, while the ongoing shift from the pandemic phase to a post-pandemic phase may have resulted in a reduction in perceived risk and lower uptake rates, policy transitions such as those ending free of charge COVID-19 vaccination programmes and moving to out-of-pocket payments in Japan may further discourage vaccination, and lead to ever lower vaccination rates (Nagano et al., 2024b). These policy changes that limit the proportion of the population protected by vaccination can hinder ambitions to build resilient healthcare systems.

This analysis, however, demonstrates the substantial burden on the national economy that persists, even with annual autumn COVID-19 vaccinations according to 2023/2024 recommendations, and shows that the burden is mostly generated by working-age adults who are not eligible for vaccination.

Evaluating economic benefits demonstrates the additional value to society of broadening vaccine eligibility

An extended vaccination policy lowering eligibility to the general population aged 50+ in the countries under analysis could generate economic benefits equivalent to 0.06% of the national GDP on average (min%-max%: 0.02%-0.10%), compared to 0.04% under the 2023/2024 vaccination recommendations. This improvement is driven by the averted economic impact on the national economy, which is almost double compared to the 2023/2024 vaccination recommendations. Further expanding recommendations to the general population aged 18+ in the countries analysed could generate economic benefits equivalent to 0.12% of the national GDP on average (min%-max%: 0.04%-0.19%), with more than triple the economic impact on the national economy averted compared to the 2023/2024 autumn vaccination recommendations. The economic benefits per infection prevented also mostly follow an increasing trend across scenarios as vaccination eligibility is extended, suggesting that more value could be accrued to overall society when working-age individuals are vaccinated.

These results emphasise the critical contribution of COVID-19 vaccination to long-term economic prosperity and workforce resilience. Importantly, COVID-19 vaccines have enduring benefits to national economies extending well beyond the acute infection phase. While a consistent share of COVID-19-related productivity losses is attributable to short-term absenteeism due to non-severe infections (31%-53% across the countries analysed),

premature mortality and long COVID with long-term implications on workforce participation also play a major role (3%-46% and 18%-49% across the countries analysed, respectively). In the case of long COVID, our estimates capture the disease impact on both prolonged absenteeism and workforce participation dropout. Due to patchy and heterogeneous evidence, our analysis uses plausible yet conservative assumptions informed by country-specific evidence or extrapolated from comparable contexts (see the Technical Appendix for a detailed description). Consequently, our estimates likely sit on the lower end of the potential impact of long COVID. For example, we estimate that long COVID has a burden of approximately £1.4 billion on the UK national economy⁸. Other research in the UK based on long COVID cases presenting at clinics suggests £2 billion as a lower bound of the likely impact of long COVID on the national economy (UCL, 2024).

6.2 Methodological notes

This work uses a COI analysis to estimate the economic burden of COVID-19 and the economic benefits of vaccination to both healthcare systems and national economies. As such, it does not directly assess the cost-benefit or cost-effectiveness profile of COVID-19 vaccination, which consider the interventions' benefits and costs and are central criteria guiding HTA and reimbursement decisions.

However, cost-effectiveness evidence of COVID-19 vaccination strategies targeting older adults (and at-risk groups) is available for the countries under analysis for Japan in Fust et al. (2024a), the UK in Kohli et al. (2024), Australia in Lee et al. (2024) and the Netherlands in Zeevat et al. (2024). Where analyses of vaccination programmes with recommendations extended to the working-age population are performed, they also show favourable cost-effectiveness profiles (Fust et al., 2024a; Kohli et al., 2024). The epidemiological models of these studies were used to model the COVID-19 morbidity and mortality in our work.

Data availability at the time of analysis guided our methodological decisions. While multiple COVID-19 vaccines are licensed for use in the countries analysed, for pragmatic reasons, we model a vaccine with the same characteristics as the Spikevax vaccine, which was analysed in these cost-effectiveness studies. Further, our analysis uses 2024 as the reference year for costs, and we base our analysis on the epidemiological models from the cost-effectiveness studies available, which project estimates for 2023/2024. While this may, to an extent, limit the relevance of the findings given changing incidence trends and vaccination recommendations since then, the insights from our study likely still hold that the economic burden of COVID-19 and the benefits of vaccination programmes and extending vaccination eligibility are largely driven by the impact on the national economy.

Given that our analysis includes various countries with different population demographics and healthcare system contexts, we observe differences in the drivers and size of the burden of COVID-19 and in the distribution of benefits. Furthermore, the disease models we based our COI analysis on follow similar, but not identical, approaches for each country and may yield different trends in health outcomes (shown in the Results Appendix in Section 8). For example, for the UK, Australia, and Japan we consider a dynamic model which captures indirect effects due to vaccination. The magnitude of the indirect effect is driven by the vaccination rates considered. For the Netherlands, indirect effects were included through pragmatic adaptation of the static model estimates to quantify the magnitude of indirect protection due to reduced exposure risk. Additionally, according to the disease models, we observe almost the same number of hospitalisations in Australia as we do in the UK, despite a significantly lower number of overall cases. Details on the

⁸ 22% of the annual COVID-19 burden on the national economy £6.165 billion.

disease models can be found in Section 9.2 in the Methodological Appendix and in the original analyses.

Further differences in our results can be explained by the use of country-specific data and assumptions around costs to value morbidity and mortality, obtained from the secondary literature or official sources where available. For example, the large number of hospital bed days observed in Australia relative to the UK, which has a larger population, may be explained by the longer hospital length of stay found in Australia (see Section 9.4.2.1 in the Methodological Appendix). All input parameters can be found in the Methodological Appendix in Section 9.4. Our results are thus a function of unique combinations of country-specific epidemiological data, vaccine efficacy, underlying cost structures, and population demographics. Consequently, absolute results should be interpreted with these methodological considerations in mind and cross-country comparisons made with caution.

Using the COI approach, we also do not exhaustively capture all the impact of COVID-19 and consequent benefits of vaccination. Most importantly, the analysis does not capture the impact of COVID-19 and the availability of vaccination programmes on health-related quality of life or wellbeing. The analysis also does not consider the cost of vaccination: benefit-cost analysis has found that when benefits beyond the healthcare system are monetised, adult vaccines can return up to 19 times their initial investment to society (El Banhawi et al., 2024). Further, the COI approach does not capture the 'ripple effects' of disease-related productivity losses on the productivity of other workers or the macroeconomy supply chains. Therefore, we perform a scenario analysis to showcase the magnitude of the 'ripple effects' on the national economy based on a 3%-16% multiplier of the disease-related productivity losses (Hafner et al., 2023). Due to a lack of availability of specific data capturing the ripple effects of COVID-19, the multiplier range used in this scenario analysis reflects diseases with different marginal productivity costs and prevalence in the UK context.

Underestimation of the overall COVID-19 economic burden may also arise due to the exclusion of certain states from the disease model used to estimate the COVID-19 morbidity and mortality in certain countries. We refer the reader to the Technical Appendix for details on the country-specific exceptions. Our COI framework also excludes the impact on individuals, driven by out-of-pocket costs, due to a lack of consistent data availability on, for example, the cost of travel to and from appointments for carers and patients, and additional out-of-pocket expenses such as for medicine, aids and equipment.

Finally, productivity costs due to fatal outcomes and non-fatal outcomes impacting labour force participation (e.g., long COVID) were valued using the human capital approach, which is most commonly used globally. We note that some countries, like the Netherlands, use a friction cost approach which limits productivity losses to the time it takes to replace an absent employee, or the 'friction period' (Kigozi et al., 2016) and thus generates lower productivity cost estimates.

6.3

Conclusion & policy recommendations

While the pandemic phase has ended, COVID-19 continues to pose challenges to healthcare systems and national economies around the world. Disease activity levels of COVID-19 and other respiratory illnesses, such as influenza and RSV, vary throughout the year, yet winter spikes often coincide, generating substantial morbidity and mortality and adding significant pressure on healthcare systems (Wiemken et al., 2023). These challenges are further exacerbated by a global context in which countries are trying to rebuild healthcare system resilience and are experiencing slow economic growth.

Vaccination of older adults and groups at risk should be maintained as a cornerstone of resilient healthcare systems

Annual autumn COVID-19 vaccination of older adults generates substantial benefits to healthcare systems, particularly to hospitals. Increasingly limited vaccine recommendations, excluding population groups at risk of severe outcomes, may threaten the ambition to build resilient healthcare systems and health equity. A more explicit and systematic recognition of vaccines' ability to mitigate pressure on healthcare system capacity in HTA would be consistent with this objective.

A decision-making and funding approach to annual immunisation that appreciates broader economic benefits is needed

Vaccination of working-age individuals is an effective approach to both short- and long-term economic productivity. Adopting a societal perspective in HTA would facilitate the recognition and realisation of these benefits. However, this perspective is not aligned with healthcare budget allocation principles of some countries (e.g., the UK). Beyond the HTA context, investing in public health and maintaining a healthy population should be recognised as a driver of economic productivity, on par with more commonly endorsed measures such as labour market reforms and investments in education, skills, and emerging sectors like technology and the green economy (McKee, de Ruijter and Hervey, 2025). Employers often bear the high costs of absenteeism and presenteeism from respiratory infections, including COVID-19, and so are likely to benefit financially from a reduction in COVID-19 infections in the working-age population (Hayes et al., 2024). This indicates that there are incentives for funders beyond governments to invest in a healthy workforce and boost economic productivity.

Finally, broader value recognition in decision-making and funding of interventions, such as vaccines, that maintain a resilient healthcare system and healthy and productive societies is needed now more than ever given global trends of demographic ageing and rising rates of illness among working-age adults (Eurostat, 2021).

7

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8 Results appendix

8.1 United Kingdom

The COVID-19 outcomes occurring under a no further vaccination scenario are presented in Table 8.

Table 8 COVID-19 outcomes for symptomatic cases under no further vaccination, United Kingdom

OUTCOME TYPE		OUTCOMES	TOTAL
ACUTE	Non-severe	Non-hospitalised infections	8,188,286
	Severe	Hospitalised infections	69,254
		COVID-19-related myocarditis	11,025
LONG-TERM		Long COVID cases	306,314
FATAL		Deaths	13,454

The number of vaccines administered increases from 12.8 million in the 2023 vaccination recommendation scenario to 17.1 million and 23.8 million in the 50+ and 18+ vaccination scenarios, respectively. Table 9 displays COVID-19 acute and longer-term outcomes prevented by different vaccination strategies.

Table 9 Prevented COVID-19 outcomes for symptomatic cases under different autumn vaccination scenarios, United Kingdom

Outcome Type		Outcomes	Vaccination Scenario		
			2023 Recommendation (65+ and high-risk)	Extended to 50+ population	Extended to 18+ population
ACUTE	Non-severe	Non-hospitalised infections	1,556,254	1,932,152	2,586,966
	Severe	Hospitalised infections	26,551	29,503	34,483
		COVID-19-related myocarditis	2,844	3,394	4,148
LONG-TERM		Long COVID cases	58,596	72,652	97,136
FATAL		Deaths	5,762	6,313	7,145

8.2

Australia

The distribution of the COVID-19 outcomes occurring under a no further vaccination scenario is presented in Table 10.

Table 10 COVID-19 outcomes for symptomatic cases under no further vaccination, Australia

OUTCOME TYPE		OUTCOMES	TOTAL
ACUTE	Non-severe	Non-hospitalised infections	1,415,089
	Severe	Hospitalised infections	57,933
		COVID-19-related myocarditis	1,548
LONG-TERM		Long COVID cases	71,640
FATAL		Deaths	4,483

The number of vaccines administered increases from 2.1 million in the 2024 vaccination recommendation scenario to 3.7 million and 7.1 million in the 50+ and 18+ vaccination scenarios, respectively. Table 11 displays COVID-19 acute and longer-term outcomes prevented by different vaccination strategies.

Table 11 Prevented COVID-19 outcomes for symptomatic cases under different autumn vaccination scenarios, Australia

OUTCOME TYPE		OUTCOMES	VACCINATION SCENARIO		
			2024 Recommendation (65+ and high-risk)	Extended to 50+ population	Extended to 18+ population
ACUTE	Non-severe	Non-hospitalised infections	157,849	335,672	819,163
	Severe	Hospitalised infections	13,177	20,887	38,232
		COVID-19-related myocarditis	195	401	905
LONG-TERM		Long COVID cases	8,566	17,608	41,880
FATAL		Deaths	1,223	1,808	3,032

8.3

Japan

The distribution of the COVID-19 outcomes occurring under a no further vaccination scenario is presented in Table 12.

Table 12 COVID-19 outcomes for symptomatic cases under no further vaccination, Japan

OUTCOME TYPE		OUTCOMES	TOTAL
ACUTE	NON-SEVERE	Non-hospitalised infections	34,550,950
	SEVERE	Hospitalised infections	689,973
		COVID-19-related myocarditis	44,838
LONG-TERM		Long COVID cases	1,435,311
FATAL		Deaths	61,738

The number of vaccines administered increases from 32.1 million in the 2023 vaccination recommendation scenario to 49.9 million and 72.5 million in the 50+ and 18+ vaccination scenarios, respectively. Table 13 displays COVID-19 acute and longer-term outcomes prevented by different vaccination strategies.

Table 13 Prevented COVID-19 outcomes for symptomatic cases under different autumn vaccination scenarios, Japan

OUTCOME TYPE		OUTCOMES	VACCINATION SCENARIO		
			2023 Recommendation (65+ and high-risk)	Extended to 50+ population	Extended to 18+ population
ACUTE	Non-severe	Non-hospitalised infections	2,406,546	3,667,658	6,588,505
	Severe	Hospitalised infections	161,630	211,107	252,923
		COVID-19-related myocarditis	4,774	6,793	10,090
LONG-TERM		Long COVID cases	104,068	157,412	278,164
FATAL		Deaths	17,495	20,616	23,673

8.4 Netherlands

The distribution of the COVID-19 outcomes occurring under a no further vaccination scenario is presented in Table 14.

Table 14 COVID-19 outcomes for symptomatic cases under no further vaccination, Netherlands

OUTCOME TYPE		OUTCOMES	TOTAL
ACUTE	Non-severe	Non-hospitalised infections	2,595,146
	Severe	Hospitalised infections	32,266
		COVID-19-related myocarditis	3,509
LONG-TERM		Long COVID cases	272,276
FATAL		Deaths	4,621

The number of vaccines administered increases from 2.5 million in the 2023 vaccination recommendation scenario to 2.8 million and 3.5 million in the 50+ and 18+ vaccination scenarios, respectively. Table 15 displays COVID-19 acute and longer-term outcomes prevented by different vaccination strategies.

Table 15 Prevented COVID-19 outcomes for symptomatic cases under different autumn vaccination scenarios, Netherlands

OUTCOME TYPE		OUTCOMES	VACCINATION SCENARIO		
			2023 Recommendation (60+ and high-risk)	Extended to 50+ population	Extended to 18+ population
ACUTE	Non-severe	Non-hospitalised infections	252,076	275,729	332,665
	Severe	Hospitalised infections	9,568	9,654	9,782
		COVID-19-related myocarditis	370	404	476
LONG-TERM		Long COVID cases	26,878	29,346	35,280
FATAL		Deaths	1,589	1,592	1,593

9 Methodological appendix

9.1 Summary of the key elements of the model

Table 16 Key elements of the model for each country

		UK	JAPAN	NETHERLANDS	Australia
DISEASE MODEL	Model type	Dynamic SEIR* transmission model	Dynamic SEIR* transmission model	Static decision- analytic model with multiplier	Dynamic SEIR* transmission model
DISEASE STATES	Symptomatic infections not hospitalised	✓	✓	✓	✓
	Symptomatic infections, hospitalised - no critical care	✓	✓	✓	✓
	Symptomatic infections, hospitalised - critical care	✓	✓	✓	✓
	Hospital readmissions	✓	✗	✓	✓
	Long covid	✓	✓	✓	✓
	Severe long covid	✓	✗	✗	✓
POPULATIONS INCLUDED	Paediatric (0 -17)	✓	✓	✗	✓
	Working age (18-64)	✓	✓	✓	✓
	Older adults (65+)	✓	✓	✓	✓
COST-OF-ILLNESS FRAMEWORK COMPONENTS	Hospital care costs	✓	✓	✓	✓
	Outpatient care costs	✓	✓	✓	✓
	Patient's workplace productivity costs	✓	✓	✓	✓
	Patients' unpaid work productivity costs	✓	✓	✓	✓
	Caregivers' productivity costs	✓	✓	✓	✓

*SEIR = susceptible-exposed-infected-recovered

9.2 Step 1: Estimate the COVID-19 morbidity and mortality under different scenarios

Disease model

For the UK, Australia and Japan, we base our analysis on existing age-stratified dynamic susceptible-exposed-infected-recovered (SEIR) transmission models, which were originally developed for the United States (Kohli et al., 2023) and adapted for each country. We used the latest available models that include the data needed to perform the analysis. The methodology and data of these epidemiological models have previously been

described in Fust et al. (2024a) (Japan), Kohli et al. (2024) (UK), Lee et al. (2024) (Australia). The SEIR model was used to predict the total number of infections (asymptomatic and symptomatic) during a one-year analytic time horizon. The time frames considered are: UK: Sept 2024 - Aug 2025; Australia: March 2024- Feb 2025; Japan: Sept 2023 - Aug 2024.

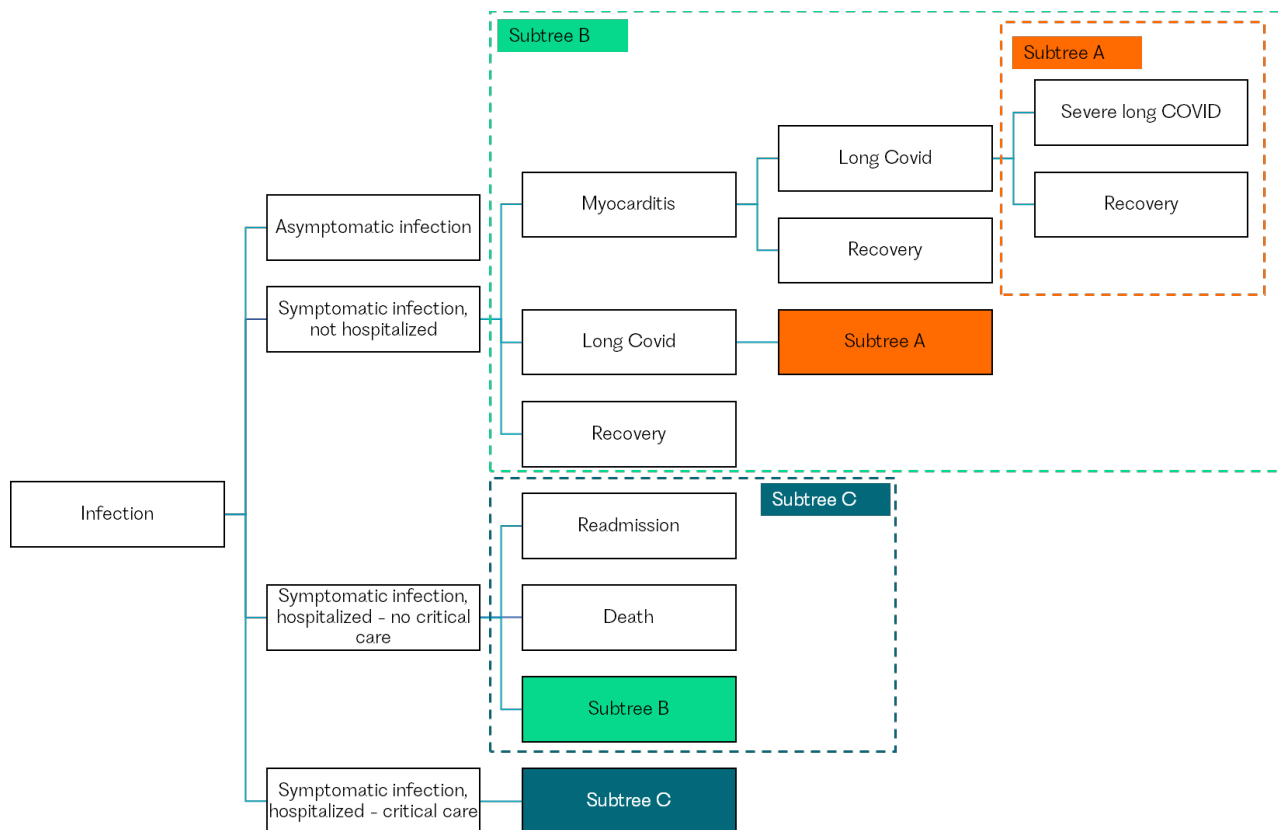
In the model, individuals start the simulation in the Susceptible (S) state and move into the Exposed (E) state according to the force of infection. After a time in E with asymptomatic and non-transmissible infection, individuals move to the Infectious (I) state which represents asymptomatic and symptomatic transmissible infections. After clearing the infection, individuals move to the Recovered (R) state and remain there until they transition back to S and lose their natural immunity. The total number of infections (asymptomatic and symptomatic) is calculated for each month of the 1-year analytic time horizon and outputted from the SEIR model by age groups. Only symptomatic infections enter a decision tree describing the COVID-19 disease pathway and related outcomes.

For the Netherlands, we base our analysis on epidemiological data from an adaptation of a static decision tree model over a 1-year analytic time horizon (October 2023 – September 2024) by Zeevat et al. (2024). Here, static model estimates were pragmatically adapted to quantify the magnitude of indirect protection due to reduced exposure risk, as is typically accounted for in dynamic models and systematically account for their impacts. This adaptation was achieved by using a dynamic transmission model which accounts for the population-level impact of vaccination. For each coverage scenario (18+ coverage, 50+ coverage, and 65+ coverage) in the dynamic model, a multiplier was generated and applied to the corresponding static model for the Netherlands. The multiplier was generated by taking the average ratio of the overall incidence in the vaccinated arm and the unvaccinated arm across all months and age groups, generating a single multiplier across each coverage scenario.

We use a common disease pathway across the countries in scope (Figure 19). Certain disease states are excluded in some countries due to a lack of data (i.e., hospital readmissions in Japan and severe long COVID in Japan and the Netherlands). The age groups modelled for all countries are: paediatric, working age, and elderly, except in the Netherlands where a population-level multiplier was applied to cases in adults ages 18 and over, but paediatric cases were excluded (in line with Zeevat et al. (2024)).

Separately, the adverse consequences of vaccination were also estimated (Grade 3 local and systemic solicited events, anaphylaxis, and vaccine-induced myocarditis/pericarditis).

Figure 19 COVID-19 decision tree model



Post-pandemic modelling scenarios

We estimate the COVID-19 morbidity and mortality under no COVID-19 vaccination programme, annual autumn vaccination of older adults based on 2023/2024 vaccine recommendations, and annual autumn vaccination extended to the general population aged 50+ and 18+, respectively. The intervention considered in the vaccination scenarios is an mRNA vaccine (Moderna Spikevax bivalent vaccine) administered annually in autumn, with efficacy and coverage values as reported in Table 17.

Note that some national recommendations include eligibility for a second (spring) booster, however, uptake of second booster is low in most countries and it is unclear for how long second boosters will continue to be recommended. Accordingly, to ensure continued relevance of our analysis, and comparability between our countries, we limit the focus of our analysis to an annual autumn vaccination.

Table 17 Vaccination programmes specifications

		VACCINE EFFICACY		COVERAGE		
		SARS-CoV-2 infection	COVID-19 hospitalisation	2023/24 recommendation	Extended to 50+ population	Extended to 18+ population
UNITED KINGDOM	10–19 years	Initial: 0.571 Waning: 0.048	Initial: 0.843 Waning: 0.014	0.27%	0.27%	3.91%
	20–29 years			2.67%	2.67%	24.52%
	30–39 years			4.49%	4.49%	28.21%
	40–49 years			7.88%	7.88%	36.63%
	50–59 years			16.96%	46.36%	46.36%
	60–69 years			44.09%	66.44%	66.44%
	70–79 years			72.69%	72.69%	72.69%
	80+ years			75.71%	75.71%	75.71%
	References	(Kohli et al., 2024)	(Kohli et al., 2024)	Assumed the same as coverage in UKHSA surveillance data up to week 7 of 2024 (UKHSA, 2024b)	Assumed Autumn 2022 uptake rates for ages 50–64 (UKHSA, 2024b)	Calculated the ratio of "Dose 3" uptake rate for Age 10–19 (and separately for 20–29, 30–39, 40–49) to Age 50–59 "Dose 3" and apply to Age 50–59 rate for Autumn 2022. "Dose 3" means "Number Vaccinated (at least 3 Doses)" from (UKHSA, 2024b).
AUSTRALIA	18–29 years	Initial: 0.571	Initial: 0.843	0.0%	0.0%	23.3%
	30–49 years	Waning: 0.048	Waning: 0.014	0.0%	0.0%	34.5%
	50–64 years			0.0%	34.5%	34.5%
	65+ years			45.9%	45.9%	45.9%
	References	(Lee et al., 2024)	(Lee et al., 2024)	Coverage rates for Winter 2024 Campaign based on "Number of people who received at least 3 doses by age band" (May 2022–March 2023) (Australian Government DoHaC, 2024) scaled down based on 2023 observations for vaccine uptake rates by age. Uptake pattern based on "Number of people who received at least 3 doses by age band" (May 2022–March 2023) compressed to March 1 2024 to Aug 31 2024). (Australian Government DoHaC, 2024)		
NETHERLANDS	0–17 years	Initial: 0.748	Initial: 0.851	0.00%	0.00%	0.00%
	18–29 years	Waning: 0.046	Waning: 0.036	1.34%	1.34%	11.55%
	30–39 years			1.32%	1.32%	11.55%
	40–49 years			1.35%	1.35%	11.55%
	50–59 years			1.37%	11.55%	11.55%

	60-64 years			32.00%	32.00%	32.00%
	65-69 years			46.00%	46.00%	46.00%
	70-79 years			57.67%	57.67%	57.67%
	80+ years			63.31%	63.31%	63.31%
	References	(Zeevat et al., 2024)	(Zeevat et al., 2024)	Based on Autumn 2023 (RIVM, 2024b). Coverage scaled by the proportion of the population considered to be high-risk.		
JAPAN	10-19 years	Initial: 0.547	Initial: 0.849	0.0%	0.0%	20.0%
	20-29 years	Waning: 0.048	Waning: 0.014	0.0%	0.0%	33.2%
	30-39 years			0.0%	0.0%	42.8%
	40-49 years			0.0%	0.0%	58.5%
	50-59 years			0.0%	71.8%	71.8%
	60-69 years			40.7%*	77.5%	77.5%
	70-79 years			79.7%	79.7%	79.7%
	80+ years			73.9%	73.9%	73.9%
	References	Based on (Fust et al., 2024a)	Based on (Fust et al., 2024a)	Based on maximum uptake rate of the first COVID-19 booster (Fust et al., 2024a) with coverage for ages 60+ reduced by 10% (i.e., 90% of base case value) *Assumes zero coverage for ages 60-64.		

9.3

Step 2: Valuing the COVID-19 morbidity and mortality according to the cost of illness (COI) framework

We value the COVID-19 morbidity and mortality estimated in each scenario using a COI approach, which includes several direct medical and non-medical costs and indirect costs to the healthcare system and the national economy.

Table 18 shows the cost components considered in the COI approach. Healthcare costs in hospital and outpatient care settings consist of the direct medical costs to the healthcare system. Productivity costs due to illness are indirect costs to the national economy due to lost workdays of formally employed patients or patients undertaking unpaid work, and of formally employed caregivers. Productivity costs due to premature mortality are also indirect costs due to lost working years of patients dying prematurely.

The COI components also apply to the vaccine-related adverse events occurring under different vaccination strategies. In this way, we attempt to capture the COI of all the morbidity and mortality occurring in the modelled scenarios.

By following the COI averted approach, we do not consider the direct medical and indirect costs of implementing each vaccination strategy, in terms of vaccine administration and delivery costs and productivity losses associated with receiving vaccination.

Table 18 **Cost-of-illness (COI) framework**

SECTOR	COST COMPONENTS	
IMPACT ON THE HEALTHCARE SYSTEM	Healthcare costs	Hospital care costs
		Outpatient care costs
IMPACT ON THE NATIONAL ECONOMY	Patient's productivity costs	Patient's workplace productivity costs
		Patients' unpaid work productivity costs
	Caregivers' productivity costs	Caregiver's workplace productivity losses due to patient illness

For each cost component of the COI framework, we identify the applicable morbidity and mortality outcomes of the disease model, and the population groups affected by the specific outcome (all age groups, paediatric, working age, elderly). We obtain country-specific inputs, where available, to estimate each COI component depending on the relevant COVID-19 outcomes estimated by the disease model. A comprehensive list of data inputs and sources for each country can be found in Section 9.4 of this Appendix.

All costs are presented in 2023 values. Costs found in other years are adjusted to 2023 levels using the relevant CPI for their country of origin. Costs incurred in the years after vaccination (e.g. due to mortality) are discounted at appropriate country-specific rates to reflect social preferences for the timing of consumption.

Healthcare costs

We consider healthcare costs of hospital care and outpatient care for COVID-19 infections and vaccine-related adverse events.

Hospital care costs

For all patients hospitalised for acute COVID-19 infections, we included the cost of a hospitalisation episode. This cost depended on the type of care (critical/non-critical) and, in some countries, the length of stay and the age of the patient. A small percentage of hospitalised patients required readmission. We assumed readmission occurred only once, required the same type of care (critical/non-critical) and incurred the same costs as the original hospitalisation.

We assume a percentage of long COVID patients develop severe long COVID (the percentage may vary by hospitalisation status during acute infection) and require hospitalisation once in non-critical care. Severe long COVID cases incur hospitalisation costs depending on the length of stay. This disease state is not considered in the disease model for Japan and the Netherlands due to a lack of data availability.

A percentage of COVID-19 patients also develop infection-related myocarditis and require hospitalisation. These cases would be managed as cases of myocarditis, and we assume the myocarditis-related hospitalisation costs, which were age-dependent in some countries.

Based on data availability for each country, we assume that certain vaccine-related adverse events (vaccine-related myocarditis and anaphylaxis cases) may require hospitalisation.

Outpatient care costs

For all non-hospitalised symptomatic cases of COVID-19, we assume that a country-specific proportion will seek outpatient care (see country input parameter tables). Depending on data availability for each country, we calculated the outpatient care cost based on the healthcare utilisation rate for each type of outpatient care (primary care or emergency department) and the unit costs.

We assume that patients hospitalised for acute COVID-19 infections incur outpatient care costs in the recovery period, for example due to primary or other specialist care appointments. We apply these costs only to hospitalised patients who do not die in the hospital. These follow-up costs are incurred per hospitalised case, so readmitted cases incur outpatient costs only once. Resource use and unit costs varied by country depending on data availability.

We assume that long COVID cases incur outpatient care costs, for example due to primary or other specialist care appointments. Healthcare utilisation and unit costs varied by country depending on data availability.

Depending on data availability for each country, we also determine outpatient care costs for Grade 3 local/ systemic vaccine-related based on relevant healthcare utilisation and the unit costs.

Patient's productivity costs

We calculated productivity losses associated with work that cannot be undertaken by patients due to morbidity and mortality. This includes workplace's productivity losses associated with working time lost by individuals who are formally employed, and unpaid work productivity losses associated with lost time providing (non-market) care.

To value workplace productivity losses, we used OECD data and official sources when OECD data were not available. We calculated an adjusted population employment rate by multiplying the labour force participation rate (%) by the reciprocal of the unemployment

rate (%). Labour force participation rates were categorised for the following OECD age categorisation groups: 18-24, 25-64 and 65-75. OECD unemployment rates were reported for the age groups 18-24 and 25-75 and are applied accordingly. Given a lack of standardised reporting across our selected countries and the higher rates of economic inactivity in adults aged 65+, we assume no labour force participation for those older than 75. To calculate the expected value per lost workday, we multiply average daily wages (obtained from official sources) by the adjusted population employment rate. All currency values were converted to 2023 values. Given a lack of age-specific data, average daily wages are assumed to be equal across the selected age groups. Assumptions around time-use and workdays lost for acute, long-term, and fatal outcomes are described in the following sections.

To value unpaid work productivity losses, we found the percentage of the working-age (younger than 65 years) population and of the elderly (65-74) who are informal carers. Akin to the formal market, we assume no informal care provision by individuals older than 75, although this likely leads to an underestimation of the averted productivity costs given that elderly adults often provide a significant amount of informal care. Days of unpaid work lost are valued at the same rate as workplace productivity losses, as we assume that the value of unpaid labour is equivalent to that of paid labour (Park, Jit and Wu, 2018; Deloitte, 2020). We assume the same changes in time-use and workdays lost for acute, long-term, and fatal outcomes among informal carers as we do for formally employed workers, described in the section below.

Patient's productivity costs were calculated in association with the acute, fatal and long-term outcomes of disease as described below.

Patient's productivity costs due to acute outcomes

For each acute disease state, we assumed that patients are too ill to work (fully absent) for a specific number of workdays. For symptomatic infections which are not hospitalised, we assume a duration of presenteeism after the initial absenteeism period, in which patient productivity is reduced by a certain percentage for the remaining illness duration. Productivity loss of hospitalised cases is calculated as a sum of the period when the patient is fully absent prior to hospitalisation, during the length of their hospital stay, and for a full recovery period. For readmitted cases, the productivity loss associated with the length of hospital stay is incurred twice.

For infection-related and vaccine-related myocarditis episodes, we assume a productivity loss is incurred for the period in which the patient is fully absent during their hospital length of stay. The same assumption is applied to vaccine-related anaphylaxis cases. For other vaccine-related adverse events, we assume specific absenteeism periods based on the literature and country-specific data.

All numbers of workdays lost are adjusted for the work week when necessary, assuming a 5-day work week.

Patient's productivity costs due to fatal outcomes

For fatal outcomes, we estimate these using the human capital approach, which assumes that when a patient dies, their productivity loss lasts for the remainder of their working life. Accordingly, the productivity loss is a cost incurred annually from the age of infection until they would stop working at the cut-off age of 75. We approximated the value of each year of work lost based on the average annual pay, applying country-specific discount rates to productivity losses from the second year following infection. We apply these productivity losses differentially to patients of all age groups. For deaths among working-age patients, the productivity losses accrue until the formal retirement age, after which the value of the productivity loss is revised downward to reflect that some people stop working. The revised productivity loss is incurred until a cut-off age of 75 when everyone is assumed to stop working. For deaths among paediatric patients, the productivity losses accrue over a

future period, beginning when they would reach the legal working age. The productivity value is adjusted to reflect the proportion of paediatric patients who would be working at different stages in life. For deaths among elderly patients (65+), the productivity loss value only applies until age 75.

Patient's productivity costs due to long-term outcomes

For long-term outcomes such as long COVID we consider time taken off work. However, there is no empirically agreed-upon duration of long COVID (Baimukhamedov, 2022). Based on the available data per country, the productivity loss of long COVID episodes is based on time taken off work (or reduced productivity) in severe long COVID cases or, where not modelled, severe cases.

We also apply additional long-term productivity losses to long COVID-19 cases (working age or elderly) who prematurely leave the workforce or are unable to continue with unpaid work. This assumption is based on evidence that people affected by post-COVID-19 conditions experience changes in their employment status, with some dropping out of the workforce. Given the lack of country-specific data, we calculate an average value from two studies which suggests that these patients represent 1.23% of all long COVID-19 cases (Kerksieck et al., 2023; Ziauddeen et al., 2022). We do not differentiate between non-hospitalised and hospitalised (severe) long COVID-19 patients, which may result in an underestimation given that the study used has a relatively low proportion of hospitalised long COVID patients.

Productivity losses of the long COVID-19 cases are calculated using the same approach and parameters as productivity losses due to premature mortality, using the human capital approach.

Caregiver's productivity costs

We assume some level of caregiver productivity loss is accrued for non-hospitalised (outpatient) symptomatic infections among paediatric and elderly cases. We also assume that a percentage of long COVID patients (all ages) will require informal care from family members. We value all caregiving productivity losses of employed family members according to the opportunity cost method (van den Berg et al., 2006), using daily wages as a measure of their opportunity cost. We assume that caregiving family members are employed according to the formal employment rate, and that employed family members will incur some degree of productivity loss while caring for COVID-19 patients.

We assume that each child under age 16 and a proportion of elderly patients aged 65+ (those who are not hospitalised and do not receive regular institutional/formal care) with a symptomatic outpatient infection will receive informal care from a working-age family member. When available, we use local data on COVID-19 (or similar) to approximate the proportion of employed family members who experience productivity losses due to caring for a sick child or elderly patient, and the average level of productivity loss due to providing care for a child/elderly patient with acute outpatient illness.

We assume that a percentage of long COVID patients (all ages) will require informal care from family members. Given the long-term nature of this health state, we assume only a proportion of these long COVID cases will be significantly limited in daily activities and require care, and that only a proportion of their informal caregivers will have reduced paid work hours due to caregiving. If no specific data on the duration of caregiving for long COVID patients is available, we assume that caregivers' productivity losses are accumulated for the same duration that long COVID patients themselves, on average, experience work-related absenteeism or presenteeism.

9.4 Input parameters by country

This section includes the parameters used for all countries included in the model. We specify:

1. Healthcare resource use and unit costs for each disease state,
2. Values used to calculate the patient and caregiver productivity losses associated with different disease states,
3. Healthcare resource use and unit costs and productivity losses associated with vaccine-related adverse events.

The first (left) column in the tables indicates the COVID-19 outcome to which the parameter value is applied in the model, based on the outcome abbreviations listed in the box. In the last (right) column, we include all sources and, where needed, explanations for the parameter values used.

COVID-19 outcome abbreviations

Symptomatic infections, not hospitalised - NH

Symptomatic infections, hospitalised critical care - H_CC

Symptomatic infections, hospitalised non-critical care - H_Non-CC

Long covid - LC

Severe long covid - SLC

Disease-related myocarditis - MYO

Adverse events - AE

United Kingdom

United Kingdom - Healthcare costs

	Relevant COVID-19 outcome	PARAMETER	VALUE	REFERENCES/ EXPLANATION
HOSPITALISATION COSTS	H_CC	Hospitalisation cost	£28,642.58	(NHS England, 2023)
	H_Non-CC	Hospitalisation cost	£2,583.55	(NHS England, 2023)
	SLC	Hospitalisation cost (ages 0-17)	£2,527.59	(NHS England, 2023)
	SLC	Hospitalisation cost (ages 18+)	£3,299.28	(NHS England, 2023)
	MYO	Hospitalisation cost (ages 0-17)	£9,279.23	Weighted average for non-elective long stay for people aged less than 18 (NHS England, 2023)
	MYO	Hospitalisation cost (ages 18+)	£4,577.57	Weighted average for non-elective long stay for people aged over 18. (NHS England, 2023)
OUTPATIENT CARE RESOURCE USE PER EPISODE*	NH	Proportion not hospitalized who seek outpatient care	34.91%	(Tufts et al., 2023)
	NH	Primary care visit rate	0.88	(Whittaker et al., 2021)
	NH	Emergency visit rate	0.01	(Whittaker et al., 2021)
	H_CC, H_Non-CC	Number of Chest X-rays, post-hospitalisation	2	(Metry et al., 2022)
	H_CC, H_Non-CC	Number of GP visits, post-hospitalisation	6	(Metry et al., 2022)
	LC	Outpatient care visit rate	1	Assumption, based on (Tufts et al., 2023)
OUTPATIENT CARE UNIT COSTS*	NH, H_CC, H_Non-CC	Primary care visit cost	£47.40	(Jones et al., 2023)
	NH	Emergency department visit cost	£347.45	(NHS England, 2023)
	H_CC, H_Non-CC	Chest X-ray cost	£47.72	(NHS England, 2023)
	LC	Outpatient care cost	£75.92	Weighted average unit cost per long COVID patient calculated from estimates of the annual primary care resource use and costs associated with Long COVID in (Tufts et al., 2023)

Note: All costs are adjusted from the baseline year of the original estimate to 2023 GBP (£) using the relevant CPI; *Outpatient care cost per episode derived by multiplying resource use by relevant unit costs. Abbreviations: NH - symptomatic infections, not hospitalised, H_CC - symptomatic infections, hospitalised, critical care, H_Non-CC - symptomatic infections, hospitalised non-critical care, LC - long covid, SLC - Severe long covid, MYO - Disease-related myocarditis

United Kingdom - Patients' and caregivers' productivity costs

	RELEVANT COVID-19 OUTCOME	PARAMETER	VALUE	REFERENCES/ EXPLANATION
LABOUR FORCE	N/A	Daily wage (overall)	£131.9	(ONS, 2023a)
	N/A	Formal employment rate (16-24)	53.6%	Calculated by adjusting the labour force participation rate (%) for each age group by

PARAMETER S				the unemployment rate (%) from (OECD, 2023b; c)
	N/A	Formal employment rate (25-64)	79.6%	Calculated by adjusting the labour force participation rate (%) for each age group by the unemployment rate (%) from (OECD, 2023b; c)
	N/A	Formal employment rate (65-74)	10.79%	Calculated by adjusting the labour force participation rate (%) for each age group by the unemployment rate (%) from (OECD, 2023b; c)
	N/A	Proportion of working age who are informal carers (16-64)	3.53%	(Department for Work and Pensions, 2023)
	N/A	Proportion of elderly who are informal carers (65-74)	8.42%	(Department for Work and Pensions, 2023)
DURATION OF PATIENT PRODUCTIV ITY LOSSES*	NH	Absenteeism (days)	3.57	Recommendation for isolation for adults (5 days) (NHS, 2023)
	NH	Presenteeism (days)	1.75	Calculated, workday-adjusted remainder of average illness duration (12 days) from (Medline, 2023), assuming 35% work impairment based on (Johnsen et al., 2021)
	H_Non-CC	Absenteeism, Hospitalisation period (days)	6.26	Equivalent to length of stay for non-critical cases (Leclerc et al., 2021)
	H_CC	Absenteeism, Hospitalisation period (days)	8.96	Equivalent to length of stay for critical cases (Leclerc et al., 2021)
	H_CC, H_Non-CC	Absenteeism, Hospitalisation, Recovery (days)	13.09	Baseline calculated based on weighted average of employment status post-discharge data from (Halpin et al., 2021)
	LC	Absenteeism (days)	0	Assumption, apply employment impact only to severe long COVID cases, based on (Reuschke, Houston and Sissons, 2024)
	SLC	Absenteeism, Additional due to severe long COVID (days)	28.43	Calculated, assuming that workers with severe long COVID and symptoms for less than 28 weeks work zero hours (Reuschke, Houston and Sissons, 2024). Weighted average derived based on data on symptom duration (ONS, 2024) and proportion of severe cases (Kohli et al., 2024).
	MYO	Absenteeism	4.77	(Hospital Episode Statistics (HES), 2024).
DURATION OF CAREGIVER S' PRODUCTIV ITY LOSSES*	NH (ages ≥65)	Work-week adjusted duration of acute illness in adults (days)	8.57	Duration of adult illness (Medline, 2023)
	NH (ages ≥65)	Proportion of elderly requiring care from a working-age adult (%)	89.87%	Calculated, remainder of proportion of people age 65+ receiving either formal or informal care or a mixture of both. (Department for Work and Pensions, 2023)
	NH (ages ≥65)	Proportion of family members experiencing productivity losses due to care for sick elderly (%)	23.3%	Percentage of family or other unpaid caregivers who were employed and experienced caregiving related work productivity loss (Keita Fakeye et al., 2023)

NH (ages ≥65)	Average productivity loss due to providing care for elderly (%)	34.0%	Productivity reduction among employed family caregivers reporting absenteeism or presenteeism due to caregiving of elderly (Keita Fakeye et al., 2023)
NH (ages ≤16)	Work-week adjusted duration of acute illness in children (days)	4.29	(Molteni et al., 2021a)
NH (ages ≤16)	Proportion of family members experiencing productivity losses due to care for sick child (%)	23.3%	Due to a lack of evidence specific to paediatric patients, we use the assumption in (Keita Fakeye et al., 2023) on caregiving for older adults
NH (ages ≤16)	Average productivity loss due to providing care for sick child (%)	34.0%	Due to a lack of evidence specific to paediatric patients, we use the assumption in (Keita Fakeye et al., 2023) on caregiving for older adults
LC	Work-week adjusted duration of long COVID	19.6 weeks	Assumption, midpoint of follow-up duration (Waters and Wernham, 2022)
LC	Average productivity loss due to providing care for a long COVID patient (%)	34.0%	Due to a lack of evidence specific to paediatric patients, we use the assumption in (Keita Fakeye et al., 2023) on caregiving for older adults
LC	Proportion of Long COVID patients requiring any informal care (%)	31.7%	(Kwon et al., 2023)
LC	Proportion of Long COVID caregivers having reduced paid work hours for caregiving (%)	22.8%	(Kwon et al., 2023)
LC	Proportion of long COVID cases severely limited in their ability to undertake daily activities (%)	19.27%	(ONS, 2023b)

Note: *Days adjusted by length of working week (x 5/7). Abbreviations: NH - symptomatic infections, not hospitalised, H_CC - symptomatic infections, hospitalised, critical care, H_Non-CC - symptomatic infections, hospitalised non-critical care, LC - long covid, SLC - Severe long covid, MYO - Disease-related myocarditis

United Kingdom - Vaccine adverse event costs

	Relevant COVID-19 outcome	PARAMETER	VALUE	REFERENCES/ EXPLANATION
HEALTHCARE RESOURCE USE PER EPISODE	G3 local AE	GP visits	0	Assumption
	G3 systemic AE	GP visits	9.8%	(Tsang et al., 2023)
	Anaphylaxis	Hospitalisation rate	100%	Assumption
	Vaccine related myocarditis	Hospitalisation rate	100%	Assumption
UNIT COSTS PER ADVERSE EVENT EPISODE	Grade 3 systemic AE	G3 systemic adverse event Unit Cost	£4.65	Assume patients only seek medical attention for headaches and lymphadenopathy. Unit cost is calculated by adjusting cost by percentage of the population who present to a general practice in England with an adverse event within 1 week of a COVID-19 vaccine from Tsang et al (2023), 9.82%. Medicinal costs for painkillers are excluded.

DURATION OF PATIENT PRODUCTIVITY LOSSES***	Anaphylaxis	Anaphylaxis Unit Cost	£506.13	Utilising currency code WH05Z, opting for the non-elective short stay unit cost. A weighted average cost of the codes was taken, weighted by activity level (NHS England » National Cost Collection for the NHS, 2024).
	Vaccine-related myocarditis	Myocarditis Unit Cost	£4577.57	NHS England. 2021/22. (NHS England » National Cost Collection for the NHS, 2024). Accessed December 2023. Utilising currency code WH05Z, opting for the non-elective short stay unit cost. Value is a weighted average cost of the listed codes, weighted by activity level.
	Grade 3 local AE	Absenteeism (days)	0.54	Due to lack of data assume same loss of time as Grade 3 systemic adverse event, Table 2 in (González-Celestino et al., 2023)
	Grade 3 systemic AE	Absenteeism (days)	0.54	Table 2 in (González-Celestino et al., 2023)
	Anaphylaxis	Absenteeism (days)	0.80	Weighted average of the mean length of stay for relevant diagnostic codes, weighted by activity level associated with anaphylactic shock. (Hospital Episode Statistics (HES), 2024)
	Vaccine-related myocarditis	Absenteeism (days)	2.61	Weighted average of mean length of stay of for relevant diagnostic codes containing myocarditis and pericarditis (Hospital Episode Statistics (HES), 2024).

Note: *Days are adjusted for the work week (x 5/7); **Total adverse event productivity costs are calculated using formal workplace productivity parameters. Abbreviations: AE — adverse events

Australia

Australia - Healthcare costs

	RELEVANT COVID-19 OUTCOME	PARAMETER	VALUE	REFERENCES/ EXPLANATION
HOSPITALISATION COSTS	H_CC	Hospitalisation cost	A\$49,845.51	Calculated as a weighted average of the cost of ICU only and ICU + ventilator hospitalisations (Markey et al., 2023), with weights corresponding to the average probability of care setting (Australian Institute of Health and Welfare, 2023a).
	H_Non-CC	Hospitalisation cost	A\$28,692.72	(Markey et al., 2023)
	SLC	Hospitalisation cost (ages 0-17)	N/A	State not modelled for the population aged 0-17
	SLC	Hospitalisation cost (ages 18+)	A\$29,630.48	Calculated using the distribution of long COVID episodes by hospital care settings (Woldegiorgis et al., 2023) and costs (Markey et al., 2023)
	MYO	Hospitalisation cost (ages 0-17)	A\$25,105.29	DRGs for endocarditis were used to estimate myocarditis costs. Costs for infection related myocarditis is estimated based on weighted major and minor DRGs (Independent Health and Aged Care Pricing Authority, 2021b, a; c)

	MYO	Hospitalisation cost (ages 18+)	A\$25,105.29	DRGs for endocarditis were used to estimate myocarditis costs. Costs for infection related myocarditis is estimated based on weighted major and minor DRGs (Independent Health and Aged Care Pricing Authority, 2021b, a; c)
OUTPATIENT CARE RESOURCE USE PER EPISODE*	NH	Proportion not hospitalized who seek outpatient care	51.5%	(Australian Institute of Health and Welfare, 2023b)
	NH	Primary care visit rate	2.05	(Australian Institute of Health and Welfare, 2023b)
	NH	Emergency visit rate	0.104	(NSW Health, 2023)
	H_CC, H_Non-CC	Number of Chest X-rays, post-hospitalisation	N/A	Excluded because no post-hospitalisation chest x-rays were assumed in Australia
	H_CC, H_Non-CC	Number of GP visits, post-hospitalisation	1.26	Assumption, calculated based on probability of seeking 2 general practice consultations (63.3%) during hospitalisation recovery period (Menges et al., 2021)
	LC	Primary care visit rate	0.382	(Woldegiorgis et al., 2023)
	LC	Emergency department visit rate	0.039	(Woldegiorgis et al., 2023)
OUTPATIENT CARE UNIT COSTS*	NH, H_CC, H_Non-CC, LC	Primary care visit cost	A\$188.79	(Australian Government Department of Health and Aged Care, 2024)
	NH, LC	Emergency department visit cost	A\$887.92	(Independent Health and Aged Care Pricing Authority, 2021c)
	H_CC, H_Non-CC	Chest X-ray cost	N/A	Excluded because no additional post-infections costs were assumed in Australia

Note: All costs are adjusted from the baseline year of the original estimate to 2023 AUD (A\$) using the relevant CPI; *Outpatient care cost per episode derived by multiplying resource use by relevant unit costs. Abbreviations: NH - symptomatic infections, not hospitalised, H_CC - symptomatic infections, hospitalised, critical care, H_Non-CC - symptomatic infections, hospitalised non-critical care, LC - long covid, SLC - Severe long covid, MYO - Disease-related myocarditis

Australia - Patients' and caregivers' productivity costs

	RELEVANT COVID-19 OUTCOME	PARAMETER	VALUE	REFERENCES/ EXPLANATION
LABOUR FORCE PARAMETERS	N/A	Daily wage (overall)	278.82	(Australian Bureau of Statistics, 2023b)
	N/A	Formal employment rate (16-24)	64.73%	Calculated by adjusting the labour force participation rate (%) for each age group by the unemployment rate (%) from (OECD, 2023b; c)
	N/A	Formal employment rate (25-64)	80.08%	Calculated by adjusting the labour force participation rate (%) for each age group by the unemployment rate (%) from (OECD, 2023b; c)
	N/A	Formal employment rate (65-74)	14.60%	Calculated by adjusting the labour force participation rate (%) for each age group by the unemployment rate (%) from (OECD, 2023b; c)
	N/A	Proportion of working age who are informal carers (16-64)	12.3%	Proportion of Australians who provide informal care by age by (Australian Bureau of Statistics, 2020) weighted by population from (Australian Bureau of Statistics, 2023a)

	N/A	Proportion of elderly who are informal carers (65-74)	18.7%	Proportion of Australians who provide informal care by age by (Australian Bureau of Statistics, 2020)
DURATION OF PATIENT PRODUCTIVITY LOSSES*	NH	Absenteeism (days)	3.57	(Prosser et al., 2019)
	NH	Presenteeism (days)	1.75	Calculated, remainder of average illness duration (12 days) from (Medline, 2023), assuming 35% work impairment based on (Johnsen et al., 2021)
	H_Non-CC	Absenteeism, Hospitalisation period (days)	7.79	Based on LoS (Department of Health and Aged Care, 2023)
	H_CC	Absenteeism, Hospitalisation period (days)	15.57	Calculated as a weighted average of the LoS of ICU only and ICU+ ventilator hospitalisations (Markey et al., 2023), with weights corresponding to the average probability of care setting (Australian Institute of Health and Welfare, 2023a).
	H_CC, H_Non-CC	Absenteeism, Hospitalisation, Recovery (days)	19.29	(Chopra et al., 2020)
	LC	Absenteeism (days)	0	Assumption, apply employment impact only to severe long COVID cases, based on (Reuschke, Houston and Sissons, 2024)
	SLC	Absenteeism, Additional due to severe long COVID (days)	24.66	(Ham, 2022)
	MYO	Absenteeism	2.14	Assumption, based on data from (Kohli et al., 2023)
DURATION OF CAREGIVERS' PRODUCTIVITY LOSSES*	NH (ages ≥65)	Work-week adjusted duration of acute illness in adults (days)	8.57	Calculated from (Medline, 2023) (x 5/7)
	NH (ages ≥65)	Proportion of elderly requiring care from a working-age adult (%)	85.9%	Remaining proportion of elderly population (65+) who are not receiving formal or informal care (OECD, 2021)
	NH (ages ≥65)	Proportion of family members experiencing productivity losses due to care for sick elderly (%)	23.30%	Same as assumption used for UK. US study reporting proportion of employed family caregivers reporting either absenteeism or presenteeism over a 1-month period owing to caregiving from (Keita Fakeye et al., 2023)
	NH (ages ≥65)	Average productivity loss due to providing care for elderly (%)	34%	Same as assumption used for UK. US study reporting level of work productivity loss among caregivers affected by any productivity loss from (Keita Fakeye et al., 2023)
	NH (ages ≤16)	Work-week adjusted duration of acute illness in children (days)	4.29	(Molteni et al., 2021)
	NH (ages ≤16)	Proportion of family members experiencing productivity losses due to care for sick child (%)	53.4%	(Willis et al., 2019) percentage of parents who take time off to care for a child with influenza
	NH (ages ≤16)	Average productivity loss due to providing care for sick child (%)	25%	(MSD, 2023)
	LC	Work-week adjusted duration of long COVID	64	(MSD, 2023)

LC	Average productivity loss due to providing care for a long COVID patient (%)	21%	Due to no data on long COVID, based on the number of caregiving hours per week provided by primary caregivers of elderly and disabled people in Australia (Deloitte, 2020)
LC	Proportion of Long COVID patients requiring any informal care (%)	31.70%	Due to limited availability of country-specific data on long COVID, use UK values from (Kwon et al., 2023), assuming same given same disease across countries.
LC	Proportion of Long COVID caregivers having reduced paid work hours for caregiving (%)	22.80%	Due to limited availability of country-specific data on long COVID, use UK values from (Kwon et al., 2023), assuming same given same disease across countries.
LC	Proportion of long COVID cases severely limited in their ability to undertake daily activities (%)	30%	European workers with long COVID whose activities are limited 'a lot' (Ramos et al., 2024)

Notes: *Days adjusted by length of working week (x 5/7). Abbreviations: NH - symptomatic infections, not hospitalised, H_CC - symptomatic infections, hospitalised, critical care, H_Non-CC - symptomatic infections, hospitalised non-critical care, LC - long covid, SLC - Severe long covid, MYO - Disease-related myocarditis

Australia - Vaccine adverse event costs

	RELEVANT COVID-19 OUTCOME	PARAMETER	VALUE	REFERENCES/ EXPLANATION
HEALTHCARE RESOURCE USE PER EPISODE	G3 local AE	GP visits	1.98%	(AusVaxSafety, 2023)
	G3 local AE	Steroid cream use	100%	Assumption, based on (Lee et al., 2024)
	G3 systemic AE	GP visits	1.98%	(AusVaxSafety, 2023)
	G3 systemic AE	Paracetamol use	100%	Assumption, based on (Lee et al., 2024)
	Anaphylaxis	Hospitalisation rate	100%	Assumption
	Vaccine related myocarditis	Hospitalisation rate	100%	Assumption
UNIT COSTS PER ADVERSE EVENT EPISODE	G3 local AE, GP systemic AE	GP visit	A\$42.11	(Australian Government Department of Health and Aged Care, 2024)
	G3 local AE	Steroid cream cost	A\$30.00	Pharmaceutical benefits scheme code 10800K in (Australian Government Department of Health, 2023)
	G3 systemic AE	Paracetamol 500 mg tablet cost	A\$7.30	Pharmaceutical benefits scheme code 10582Y in (Australian Government Department of Health, 2023)
	Anaphylaxis	Anaphylaxis Unit Cost	A\$975.87	Calculated, using DRG separations and inlier weights from the national hospital cost data collection (NHCDC) tables and national efficient price (NEP) determination (2020–21) price weight tables from (Independent Health and Aged Care Pricing Authority, 2021b, a; c)
	Vaccine-related myocarditis	Myocarditis Unit Cost	A\$12,373.83	Calculated, using DRG separations and inlier weights from the national hospital cost data collection (NHCDC) tables and national efficient price (NEP) determination (2020–21) price weight tables from (Independent Health and Aged Care Pricing Authority, 2021b, a; c)

**DURATION
OF PATIENT
PRODUCTIVITY
LOSSES*,

Grade 3 local AE	Absenteeism (days)	0.50	Due to a lack of data for Australia, assume the same values as for Japan based on (Fust et al., 2024a).
Grade 3 systemic AE	Absenteeism (days)	0.50	Due to a lack of data for Australia, assume the same values as for Japan based on (Fust et al., 2024a).
Anaphylaxis	Absenteeism (days)	1.43	Due to a lack of data for Australia, assume the same values as for Japan based on (Fust et al., 2024a). Assumption based on US data (inpatient length of stay of 2 days and 8 hours missed per day) (AHRQ, 2018)
Vaccine-related myocarditis	Absenteeism (days)	1.64	Assumption, based on inpatient LoS of 2.3 days from (Varma et al., 2022)

Note: *Days are adjusted for the work week ($\times 5/7$); **Total adverse event productivity costs are calculated using formal workplace productivity parameters. Abbreviations: AE — adverse events

Japan**Japan - Healthcare costs**

	RELEVANT COVID-19 OUTCOME	PARAMETER	VALUE	REFERENCES/ EXPLANATION
HOSPITALISATION COSTS	H_CC	Hospitalisation cost	¥1,366,787	(Igarashi and Maeda, 2023)
	H_Non-CC	Hospitalisation cost	¥508,683	(Igarashi and Maeda, 2023)
	SLC	Hospitalisation cost (ages 0-17)	N/A	Excluded - disease state not included for Japan
	SLC	Hospitalisation cost (ages 18+)	N/A	Excluded - disease state not included for Japan
	MYO	Hospitalisation cost (ages 0-17)	¥20,262	(Igarashi and Maeda, 2023)
	MYO	Hospitalisation cost (ages 18+)	¥20,262	(Igarashi and Maeda, 2023)
OUTPATIENT CARE RESOURCE USE PER EPISODE*	NH	Proportion not hospitalized who seek outpatient care	0.49	(Fust et al., 2024a)
	NH	Primary care visit rate	2.33	Calculated, taking the total outpatient care cost by (Fust et al., 2024a) (¥65,361) and dividing it by the cost per outpatient care episode in (Nagano et al., 2024a) (¥28,054)
	NH	Emergency visit rate	0	Assumed, primary care rate captures whole outpatient care resource use
	H_CC, H_Non-CC	Number of Chest X-rays, post-hospitalisation	N/A	Assumption
	H_CC, H_Non-CC	Number of GP visits, post-hospitalisation	0	Assumed, the hospitalisation costs used by (Igarashi and Maeda, 2023) include follow-up treatment cost up to 6 months post-discharge
	LC	Primary care visit rate	3.84	Assumed, taking the total long COVID cost by Nagano et al (¥107,725) et al and dividing it by the cost per outpatient care episode (¥28,054)

OUTPATIENT
CARE UNIT
COSTS*

NH, H_CC, H_Non-CC, LC	Primary care visit cost	¥28,054	(Nagano et al., 2024a)
NH	Emergency department visit cost	N/A	None assumed in Japan
H_CC, H_Non-CC	Chest X-ray cost	N/A	None assumed in Japan

Note: All costs are adjusted from the baseline year of the original estimate to 2023 JPY (¥) using the relevant CPI; *Outpatient care cost per episode derived by multiplying resource use by relevant unit costs. Abbreviations: NH - symptomatic infections, not hospitalised, H_CC - symptomatic infections, hospitalised, critical care, H_Non-CC - symptomatic infections, hospitalised non-critical care, LC - long covid, SLC - Severe long covid, MYO - Disease-related myocarditis

Japan - Patients' and caregivers' productivity costs

	RELEVANT COVID-19 OUTCOME	PARAMETER	VALUE	REFERENCES/ EXPLANATION
LABOUR FORCE PARAMETER S	N/A	Daily wage (overall)	¥18700.00	(e-STAT, 2023)
	N/A	Formal employment rate (16-24)	46.75%	Calculated by adjusting the labour force participation rate (%) for each age group by the unemployment rate (%) from (OECD, 2023b; c)
	N/A	Formal employment rate (25-64)	84.52%	Calculated by adjusting the labour force participation rate (%) for each age group by the unemployment rate (%) from (OECD, 2023b; c)
	N/A	Formal employment rate (65-74)	24.99%	Calculated by adjusting the labour force participation rate (%) for each age group by the unemployment rate (%) from (OECD, 2023b; c)
	N/A	Proportion of working age who are informal carers (16-64)	5.71%	Age-weighted from (Statistics Bureau of Japan, 2021)
	N/A	Proportion of elderly who are informal carers (65-74)	8.80%	Age-weighted from (Statistics Bureau of Japan, 2021)
DURATION OF PATIENT PRODUCTIVITY LOSSES*	NH	Absenteeism (days)	3.57	(Fust et al., 2024b)
	NH	Presenteeism (days)	1.75	Calculated, workday-adjusted remainder of average illness duration (12 days) from (Medline, 2023), assuming 35% work impairment based on (Johnsen et al., 2021)
	H_Non-CC, H_CC	Absenteeism, Hospitalisation period (days)	7.14	Adjusted 10 days LoS from (MHLW, 2023).
	H_Non-CC	Absenteeism, Hospitalisation, Recovery (days)	13.86	Subtracting LoS from 21 days used in (Nagano et al., 2024a) as the total number of working days lost for general ward patients (LoS + recovery).
	H_CC	Absenteeism, Hospitalisation period (days)	32.86	Subtracting LoS from 40 days used in (Nagano et al., 2024a) as the total number of working days lost for ICU patients (LoS + recovery)
	LC	Absenteeism (days)	23.23	Calculated, assuming a proportion of long COVID cases switches to zero hours of work (Waters and Wernham, 2022) for one year.

	SLC	Absenteeism, Additional due to severe long COVID (days)	N/A	Excluded - disease state not included for Japan
	MYO	Absenteeism	2.14	Assumption based on US data used in (Fust et al., 2024a)
DURATION OF CAREGIVERS, PRODUCTIVITY LOSSES*	NH (ages ≥65)	Work-week adjusted duration of acute illness in adults (days)	8.57	Calculated from 12 days (Medline, 2023)
	NH (ages ≥65)	Proportion of elderly requiring care from a working-age adult (%)	89%	Remaining proportion of elderly population (65+) not receiving formal or informal care from (Fu, Iizuka and Noguchi, 2023)
	NH (ages ≥65)	Proportion of family members experiencing productivity losses due to care for sick elderly (%)	23.3%	Percentage of employed adults who become the primary caregivers when parent/parent in-law became in need of care (48%), adjusted by percentage who are in regular employment (45%) from (Niimi, 2021)
	NH (ages ≥65)	Average productivity loss due to providing care for elderly (%)	28.9%	Assumption, using mean overall work impairment from (Igarashi et al., 2020) for caregivers of elderly dementia patient in Japan.
	NH (ages ≤16)	Work-week adjusted duration of acute illness in children (days)	4.29	Assumption, illness duration in symptomatic UK school-aged children (6 days) from (Molteni et al., 2021b). Assumed to be applicable across countries in the case of a lack of country-specific data, same virus.
	NH (ages ≤16)	Proportion of family members experiencing productivity losses due to care for sick child (%)	20%	Assumption from (Fukushima et al., 2018) - almost a fifth of parents took leave at work to care for their children with influenza.
	NH (ages ≤16)	Average productivity loss due to providing care for sick child (%)	25%	Assumption, based on Asia Pacific report (MSD, 2023)
	LC	Work-week adjusted duration of long COVID	60	Clinical case definition of long COVID (12 weeks), same as (Nagano et al., 2024a).
	LC	Average productivity loss due to providing care for a long COVID patient (%)	28.9%	Due to a lack of evidence specific to Long COVID patients, we use the mean overall work impairment from (Igarashi et al., 2020) for caregivers of elderly dementia patients in Japan
	LC	Proportion of long COVID patients requiring any informal care (%)	31.7%	Due to limited availability of country-specific data on long COVID, we assume UK values from (Kwon et al., 2023)
	LC	Proportion of long COVID caregivers having reduced paid work hours for caregiving (%)	22.8%	Due to limited availability of country-specific data on long COVID, we assume UK values from (Kwon et al., 2023).
	LC	Proportion of long COVID cases severely limited in their ability to undertake daily activities (%)	19.2%	Due to limited availability of country-specific data on long COVID, we assume UK values from (Kwon et al., 2023).

Note: *Days adjusted by length of working week (x 5/7). Abbreviations: NH - symptomatic infections, not hospitalised, H_CC - symptomatic infections, hospitalised, critical care, H_Non-CC - symptomatic infections, hospitalised non-critical care, LC - long covid, SLC - Severe long covid, MYO - Disease-related myocarditis

Japan - Vaccine adverse event costs

RELEVANT COVID-19 OUTCOME	PARAMETER	VALUE	REFERENCES/ EXPLANATION
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HEALTHCARE RESOURCE USE PER EPISODE	G3 local AE	GP visits	0	(Teng et al., 2022) cited in (Fust et al., 2024b)
	G3 systemic AE	GP visits	20%	(Teng et al., 2022) cited in (Fust et al., 2024b)
	Anaphylaxis	Hospitalisation or ED visit rate	100%	60% assumed hospitalised, 40% assumed ED visit (Teng et al., 2022) cited in (Fust et al., 2024b)
	Vaccine related myocarditis	Hospitalisation rate	100%	Assumption, in line with (Fust et al., 2024b)
UNIT COSTS PER ADVERSE EVENT EPISODE	G3 local AE	GP visits	0	(Teng et al., 2022) cited in (Fust et al., 2024a)
	Grade 3 systemic AE	G3 systemic adverse event Unit Cost	788.00	(Teng et al., 2022) cited in (Fust et al., 2024a).
	Anaphylaxis	Anaphylaxis Unit Cost	128,733	(Teng et al., 2022) cited in (Fust et al., 2024a).
	Vaccine-related myocarditis	Myocarditis Unit Cost	20,262	(DeSC Healthcare. Insurance Database., 2023) cited in (Fust et al., 2024a).
DURATION OF PATIENT PRODUCTIVITY LOSSES***	Grade 3 local AE	Absenteeism (days)	0.50	Assumption, in line with (Fust et al., 2024a).
	Grade 3 systemic AE	Absenteeism (days)	0.50	Assumption, in line with (Fust et al., 2024a)
	Anaphylaxis	Absenteeism (days)	1.43	Assumption, in line with (Fust et al., 2024a). Based on US data (inpatient length of stay of 2 days and 8 hours missed per day) (AHRQ, 2018).
	Vaccine related myocarditis	Absenteeism (days)	1.61	Assumption, in line with (Fust et al., 2024a). Based on US data (inpatient length of stay of 2.25 days and 8 hours missed per day) (AHRQ, 2018).

Note: *Days are adjusted for the work week ($\times 5/7$); **Total adverse event productivity costs are calculated using formal workplace productivity parameters. Abbreviations: AE — adverse events

Netherlands

Netherlands - Healthcare costs

	RELEVANT COVID-19 OUTCOME	PARAMETER	VALUE	REFERENCES/ EXPLANATION
HOSPITALISATION COSTS	H_CC	Hospitalisation cost	€18375.00	(Rozenbaum et al., 2015) cited in (Zeevat et al., 2024) based on costs for individuals hospitalised with community-acquired pneumonia
	H_Non-CC	Hospitalisation cost	€6577.00	(Rozenbaum et al., 2015) cited in (Zeevat et al., 2024), based on costs for individuals hospitalised with community-acquired pneumonia
	SLC	Hospitalisation cost (ages 0-17)	N/A	Disease state not included in the Netherlands model
	SLC	Hospitalisation cost (ages 18+)	N/A	Disease state not included in the Netherlands model
	MYO	Hospitalisation cost (ages 0-17)	N/A	Age group not included in the Netherlands model

	MYO	Hospitalisation cost (ages 18+)	€4681.40	(Prosser et al., 2019) cited in (Zeevat et al., 2024)
OUTPATIENT CARE RESOURCE USE PER EPISODE*	NH	Proportion not hospitalized who seek outpatient care	29.6%	(Zeevat et al., 2021)
	NH	Primary care visit rate	1	Assumption
	NH	Emergency visit rate	0	Assumption
	H_CC, H_Non-CC	Number of Chest X-rays, post-hospitalisation	N/A	Assumption
	H_CC, H_Non-CC	Number of Primary care visits, post-hospitalisation	2.8	Assumed, based on ratio of outpatient care cost for hospitalised cases (€117 from (Zeevat et al., 2024)) and non-hospitalised cases (€40.31)
	LC	Primary care visit rate	3.58	Assumed, based on ratio of outpatient care cost of long COVID (€144.25 from (Fens et al., 2022)) and non-hospitalised cases (€40.31)
OUTPATIENT CARE UNIT COSTS*	NH, H_CC, H_Non-CC, LC	Primary care visit cost	40.31	Dutch Costing Manual (Ministerie van Volksgezondheid, 2016) cited in (Zeevat et al., 2024)

Note: All costs are adjusted from the baseline year of the original estimate to 2023 EUR (€) using the relevant CPI; *Outpatient care cost per episode derived by multiplying resource use by relevant unit costs. Abbreviations: NH - symptomatic infections, not hospitalised, H_CC - symptomatic infections, hospitalised, critical care, H_Non-CC - symptomatic infections, hospitalised non-critical care, LC - long covid, SLC - Severe long covid, MYO - Disease-related myocarditis

Netherlands - Patients' and caregivers' productivity costs

	RELEVANT COVID-19 OUTCOME	PARAMETER	VALUE	REFERENCES/ EXPLANATION
LABOUR FORCE PARAMETERS	N/A	Daily wage (overall)	194.67	Dutch Statistics (StatLine - Werkzame beroepsbevolking; arbeidsduur, 2003-2022, 2023) and Dutch Costing Manual (Ministerie van Volksgezondheid, 2016)
	N/A	Formal employment rate (16-24)	74.93%	Calculated by adjusting the labour force participation rate (%) for each age group by the unemployment rate (%) from (OECD, 2023b; c)
	N/A	Formal employment rate (25-64)	83.27%	Calculated by adjusting the labour force participation rate (%) for each age group by the unemployment rate (%) from (OECD, 2023b; c)
	N/A	Formal employment rate (65-74)	10.73%	Calculated by adjusting the labour force participation rate (%) for each age group by the unemployment rate (%) from (OECD, 2023b; c)
	N/A	Proportion of working age who are informal carers (16-64)	3.00%	Table 4 (European Commission and Zigante, 2018)
	N/A	Proportion of elderly who are informal carers (65-74)	6.74%	Share of daily informal carers among the population aged 50 and over, from Health at a Glance 2023 Report (OECD, 2023a).
DURATION OF PATIENT PRODUCTIVITY LOSSES*	NH	Absenteeism (days)	3.50	(Postma et al., 2005) cited in (Zeevat et al., 2024)

	NH	Presenteeism (days)	1.75	(Postma et al., 2005) cited in (Zeevat et al., 2024)
	H_Non-CC	Absenteeism, Hospitalisation period (days)	6.02	(Bekker, uit het Broek and Koole, 2023) cited in (Zeevat et al., 2024)
	H_CC	Absenteeism, Hospitalisation period (days)	11.89	(Bekker, uit het Broek and Koole, 2023) cited in (Zeevat et al., 2024)
	H_CC, H_Non-CC	Absenteeism, Hospitalisation, Recovery (days)	19.29	(Chopra et al., 2020) cited in (Zeevat et al., 2024).
	LC	Absenteeism (days)	11	(Zeevat et al., 2024)
	SLC	Absenteeism, Additional due to severe long COVID (days)	N/A	Disease state not included in Netherlands model
	MYO	Absenteeism	5.03	Age-weighted average, based on (StatLine - Ziekenhuisopnamen en -patiënten; diagnose-indeling ICD-10 (3-teken niveau), 2023) data cited in (Zeevat et al., 2024)
DURATION OF CAREGIVERS' PRODUCTIVITY LOSSES*	NH (ages ≥65)	Work-week adjusted duration of acute illness in adults (days)	8.57	Calculated from 12 days (Medline, 2023)
	NH (ages ≥65)	Proportion of elderly requiring care from a working-age adult (%)	88.10%	Remaining proportion of elderly population (65+) who are not receiving formal or informal care (OECD, 2021)
	NH (ages ≥65)	Proportion of family members experiencing productivity losses due to care for sick elderly (%)	23.30%	Assumption, same as UK. Proportion of employed family caregivers reporting either absenteeism or presenteeism over a 1-month period owing to caregiving from (Keita Fakeye et al., 2023)
	NH (ages ≥65)	Average productivity loss due to providing care for elderly (%)	34.00%	Assumption, same as UK. Level of work productivity loss among caregivers affected by any productivity loss from (Keita Fakeye et al., 2023)
	NH (ages ≤ 16)	Work-week adjusted duration of acute illness in children (days)	N/A	Age group not included in Netherlands model
	NH (ages ≤ 16)	Proportion of family members experiencing productivity losses due to care for sick child (%)	N/A	Age group not included in Netherlands model
	NH (ages ≤ 16)	Average productivity loss due to providing care for sick child (%)	N/A	Age group not included in Netherlands model
	LC	Work-week adjusted duration of long COVID	43	Dutch National Institute for Public Health and the Environment (RIVM) guidance on Long COVID, number of patients declines from 4 weeks after COVID and continues to decline after 12 weeks (60 days)
	LC	Average productivity loss due to providing care for a long COVID patient (%)	28.93%	Due to a lack of evidence specific to Long COVID patients, we use the assumption by (Elayan et al., 2024) on productivity losses due to long-term care

LC	Proportion of Long COVID patients requiring any informal care (%)	31.70%	Due to limited availability of country-specific data on long COVID, use UK values from (Kwon et al., 2023), assuming same given same disease across countries.
LC	Proportion of Long COVID caregivers having reduced paid work hours for caregiving (%)	22.80%	Due to limited availability of country-specific data on long COVID, use UK values from (Kwon et al., 2023), assuming same given same disease across countries.
LC	Proportion of long COVID cases severely limited in their ability to undertake daily activities (%)	30%	European workers with long COVID whose activities are limited 'a lot' (Ramos et al., 2024)

Note: *Days adjusted by length of working week ($\times 5/7$). Abbreviations: NH - symptomatic infections, not hospitalised, H_CC - symptomatic infections, hospitalised, critical care, H_Non-CC - symptomatic infections, hospitalised non-critical care, LC - long covid, SLC - Severe long covid, MYO - Disease-related myocarditis

Netherlands - Vaccine adverse event costs

	RELEVANT COVID-19 OUTCOME	PARAMETER	VALUE	REFERENCES/ EXPLANATION
HEALTHCARE RESOURCE USE PER EPISODE	G3 local AE, G3 systemic AE	GP visits	N/A	Assumption, no GP visits assumed in (Zeevat et al., 2024) for G3 local and systemic adverse events, just expenses for painkillers
	G3 local AE, G3 systemic AE	Painkiller	100%	Assumption, expenses for painkillers assumed in (Zeevat et al., 2024) for G3 local and systemic adverse events
	Anaphylaxis	Hospitalisation rate	N/A	Assumption: only ED visits assumed for anaphylaxis cases in (Zeevat et al., 2024)
	Anaphylaxis	ED visit rate	100%	Assumption: ED visits assumed for all anaphylaxis cases in (Zeevat et al., 2024)
	Vaccine related myocarditis	Hospitalisation rate	100%	Assume 1 hospitalisation (5.3 days) as in (Zeevat et al., 2024)
UNIT COSTS PER ADVERSE EVENT EPISODE	G3 local AE, G3 systemic AE	Painkiller Unit cost	€0.24	Cost of painkillers, Medicijnkosten.nl (Nederland, 2023) in Moderna paper
	Anaphylaxis	ED visit Cost	€316.40	Dutch Costing Manual (Ministerie van Volksgezondheid, 2016) in (Zeevat et al., 2024)
	Vaccine related myocarditis	Hospitalisation Cost	€3,082	Dutch Costing Manual (Ministerie van Volksgezondheid, 2016) in (Zeevat et al., 2024), based on hospital LoS
DURATION OF PATIENT PRODUCTIVITY LOSSES***	Grade 3 local AE	Absenteeism (days)	N/A	Assumption, (Zeevat et al., 2024)
	Grade 3 systemic AE	Absenteeism (days)	N/A	Assumption, (Zeevat et al., 2024)
	Anaphylaxis	Absenteeism (days)	0.71	Dutch statistics (StatLine - Ziekenhuisopnamen en -patiënten; diagnose-indeling ICD-10 (3-teken niveau), 2023) cited in (Zeevat et al., 2024).

Vaccine related myocarditis	Absenteeism (days)	Dutch statistics (StatLine - Ziekenhuisopnamen en -patiënten; diagnose- indeling ICD-10 (3-teken niveau), 2023) cited in (Zeevat et al., 2024).
	2.14	

Notes: *Days are adjusted for the work week (x 5/7); **Total adverse event productivity costs are calculated using formal workplace productivity parameters. Abbreviations: AE — adverse events

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