A Neglected Burden: The Ongoing Economic Costs of COVID-19 in Australia, Taiwan, South Korea, Singapore, and Hong Kong

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The following is a structured, product- and brand-agnostic, fact-based review of evidence on the economic costs of COVID-19, potential interventions to reduce these costs, and the current approaches to these interventions taken by a select number of Asia Pacific markets. This report does not constitute medical, legal, financial, or policy advice. It does not recommend specific decisions or policies relating to public health or economic responses, nor the trade-offs between them.

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Preface

It has been over three years since the World Health Organization's declaration of a global pandemic, COVID-19 continues to have a profound impact on societies across Asia Pacific and the entire world. While vaccines, therapeutics, and rapid diagnostics have reduced severe illness, hospitalization, and deaths significantly, COVID-19 is still causing morbidity and mortality, particularly in vulnerable populations. Moreover, it continues to exert an ongoing and adverse impact on the economy. The cost of COVID-19 on healthcare systems, supply chains, and travel has received extensive attention over the past three years. However, as this white paper demonstrates, the indirect cost of workforce disruption is significant and underappreciated.

A deeper understanding of COVID-19's economic costs is critical to inform policies that can protect the growth and prosperity of the Asia Pacific region in the current stage of the pandemic. This report provides insights into these costs through evidence-based estimates across different COVID-19 infection scenarios in five Asia Pacific markets: Australia, Taiwan, South Korea, Singapore, and Hong Kong.

The purpose of this white paper is to inform policy discussions on assessing and mitigating COVID-19's ongoing economic impact. The report takes a high-level perspective, assessing COVID-19's potential consequences on the economies of the five markets in scope. It is inspired and informed by efforts to estimate the economic impact of COVID-19 in other economies.[1,2]

The discussion that follows is based on information available at the time of writing, and sources are provided throughout the text. Estimates are based on epidemiological scenarios that extrapolate market-specific hospitalization and transmission rates observed during various periods between February 2020 and early 2023. All content and estimates have been reviewed for validity and accuracy at the end of February 2023.

This report is not intended to be a research document, and it is recognized that the fluid evolution of the pandemic and policy makers' varied responses to it presents challenges in any attempt to estimate future costs.

Estimates provided in this report should not be directly compared across markets given their highly market-specific nature. The regional content included in this report (combined narrative, press release, and regional infographics) relies upon the percentage of GDP and percentage of total cost figures to provide an estimate of regional trends.

This report is also not intended to be a health technology assessment that re-estimates the value of lost health, nor a marketing or cost-effectiveness analysis between interventions. However, the underlying results present an informed indication that the full economic costs of COVID-19 are greatly underappreciated and are an important, but missing factor in policy discussions. It is hoped that this report provides a fresh perspective that will be useful to policy stakeholders.

1. McKinsey & Company [Internet]. One billion days lost: How COVID-19 is hurting the US workforce. 2023 Jan 9. Available from: https://www.mckinsey.com/industries/healthcare/our-insights/one-billion-days-lost-how-COVID-19-is-hurting-the-us-workforce
2. Guilford G, Weber L. WSJ [Internet]. COVID drag on the workforce proves persistent. "It sets us back." 2022, Nov 7. Available from: https://www.wsj.com/articles/covid-workforce-absenteeism-productivity-economy-labor-11667831493

Executive Summary

This white paper analyzes the ongoing impact of COVID-19 on Asia Pacific markets with a more thorough assessment of the hidden economic costs to societies than has previously been available. As the region moves from a pandemic to an endemic phase of COVID-19, we present a comprehensive view of Australia, Taiwan, South Korea, Singapore and Hong Kong.

Our report begins with a brief introduction of our methodology in Section 2, followed by a deep discussion of our five focus markets in Sections 3 to 7, and a reflection on the countermeasures available to policymakers in Section 8. The paper concludes in Section 9 by re-emphasizing the significant indirect economic costs and how they can be mitigated using available tools.

Whereas other analyses of the economic impact have varied widely depending on the type of research carried out, we have adopted a cost-of-illness approach to achieve a more stable assessment. This technique (often used in policy decision-making) allows us to estimate the ongoing cost of three possible scenarios: a lower-estimate scenario, a base case scenario where current conditions continue, and a higher-estimate scenario.

We study the direct costs of the disease, such as healthcare costs, as well as indirect costs – i.e., productivity losses due to missed work. Our findings show that indirect costs far outweigh direct costs, accounting for up to 96% of the total ongoing economic cost of COVID-19. Across all three scenarios, the indirect costs will remain the bulk of the economic burden well into the endemic phase of COVID-19.

Should current conditions prevail in a base case scenario, the annual economic costs of COVID-19 could reach about USD 17.0 billion in Australia (1.0% of GDP), USD 5.3 billion in Hong Kong (1.4% of GDP), USD 2.6 billion in Singapore (0.6% of GDP), USD 27.5 billion in South Korea (1.6% of GDP), and USD 7.6 billion in Taiwan (0.9% of GDP).[3]

Conditions vary in each of these markets, meaning that figures cannot be compared directly, yet a clear common picture emerges. Domestic GDPs stand to lose 0.6% to 1.6% under a base case scenario, but in a higher-estimate scenario, these figures could more than triple to between 2.2% and 5.5%. In South Korea, for example, in the worst case scenario, this could equate to around USD 92.7 billion lost.

Some industries are particularly affected by indirect costs. One important example of such ensuing costs is in the health workforce, which continues to be impacted by high levels of absenteeism and a greater risk of infection compared to the wider community. This susceptibility has significant consequences for health system capacity, efficiency, and quality of care. Travel and tourism as well as logistics are also significantly impacted by workforce shortages.

3. USD currency exchange rate conversions via Google Finance as at 28 February 2023 (USD1 = AUD 1.4861 = HKD 7.8493 = KRW 1,322 = SGD 1.3484 = TWD 30.6608): https://www.google.com/finance/markets/currencies?hl=en

Not all community cohorts face the same level of risk or contribute the same economic burden when infected. The report shows an uneven distribution of costs within each market studied. Vulnerable populations, such as older adults[4] and working-age adults with one or more comorbidities (such as high blood pressure, cancer, and/or diabetes) are likely to be disproportionately impacted. In Australia and Taiwan, indigenous communities are more susceptible to severe COVID-19 due to high rates of chronic illness and greater difficulty accessing and affording health services.[5]

Meanwhile, individuals affected by long COVID experience prolonged productivity losses, which increase indirect costs and reliance on health services, and in turn escalate direct costs. This exerts a substantial burden on the health system, both in terms of capacity requirements and economic costs. In Singapore, for example, the total value of lost work and use of health systems due to long COVID is SGD 1.3 billion p.a. (USD ~972 million), which amounts to around 37% of the country's total economic cost of COVID-19 (see Section 6 for further detail).

For policymakers, the objective now should be to strengthen existing systems and protocols, whether that be community measures such as contact tracing and mask-wearing mandates, other infection control strategies, or medical responses like vaccines and therapeutics. It is their task to ensure that populations and economies can overcome any eventuality, whether that be a mild endemic future, a continuation of the status quo, or another severe pandemic.

Having a full understanding of COVID-19's cost, both current and potential, is therefore vital to designing effective countermeasures that can mitigate the disease's ongoing impact (measures we have identified in the white paper). It is hoped that this report can help policymakers to anticipate potential developments as they prepare for the future, beginning with an appreciation of the full cost already being borne and the often overlooked indirect costs.

Acting now to address these impacts will go a long way toward protecting economies, industries, livelihoods, and of course, our health.

4. Either above the age of 60 or 65, depending on the market in question.
5. Yashadhana A., Pollard-Wharton N., Zwi A., Biles B. Indigenous Australians at increased risk of COVID-19 due to existing health and socioeconomic inequities. The Lancet Regional Health – Western Pacific [Internet]. July 2020; 1:100007. Available at: https://www.thelancet.com/journals/lanwpc/article/PIIS2666-6065(20)30007-9/fulltext

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1. Looking Forward: Examining The Potential Economic Futures For COVID-19

1.1 Three Key Questions: Characterizing The Economic Future Of COVID-19

As authorities managing the health and economic impacts of COVID-19 consider how to prepare for the next phase of the pandemic, they are grappling with uncertainty about how it will evolve. This uncertainty can be distilled into three key questions:

- What will the future number of cases be and how severe (i.e., the epidemiological future)?
- How does this translate into economic cost?
- What tools are available to reduce the burden of disease and its costs?

Each of these questions, on epidemiology (Section 2.1.1), costs (Sections 3.3, 4.3, 5.3, 6.3, 7.3), and available tools (Section 8) will be examined in this white paper.

1.2 Existing Estimates: Building On Historical Scenarios For The Cost Of COVID-19

Existing estimates of the economic costs imposed by COVID-19 in Australia, Taiwan, South Korea, Singapore, and Hong Kong vary widely. Variation exists not only in the estimates themselves, but also in the methodologies, scopes, and assumptions used to derive them.

The disparity in cost estimates is generally driven by three factors:

- The epidemiological scenario captured in assumptions (often historical).
- A specific intervention being modeled.
- The scope of costs evaluated in the methodology.

This variation makes it difficult for decision-makers to find the relevant cost evaluations to inform whether and how much to invest in ongoing efforts to combat COVID-19. There is a need for estimates which capture plausible future epidemiological scenarios, using the expected or current set of interventions, and focusing on major costs to society. The following examples show that most existing estimates do not include indirect costs from productivity losses in their scope. As the subsequent cost estimate (Sections 3.3, 4.3, 5.3, 6.3, 7.3) will demonstrate, indirect costs are substantial (up to ~1.6% of GDP in some cases) and need to be better recognized.

The remainder of this chapter provides an overview of the existing estimates of costs in each market of interest, before turning to the methodology used for estimating economic costs.

Limitations of Estimate

- Readers of this report should observe the following limitations in relation to the estimates provided:

The fluid evolution of the pandemic and policy makers' varied responses to it presented challenges in any attempt to estimate future costs.

- Estimates provided in this report should not be directly compared across markets given their highly market specific nature.
- Regional content and findings rely upon the percentage of GDP and percentage of total cost figures to provide an estimate of regional trends.
- The findings are not intended to be a health technology assessment that re-estimates the value of lost health, nor a marketing or cost-effectiveness analysis between interventions.

1.2.1 Estimates for Australia

Range of existing estimates of the cost of COVID-19: USD ~10 billion to USD ~270 billion p.a.[6] (estimates determined by any intervention modeled, the epidemiological context, and the scope of costs evaluated).

Higher cost estimate: USD ~270 billion p.a.[6] This reflects the impact of Australia's decision not to implement lockdowns, which allowed the virus to spread with little mitigation, in the epidemiological context of the variants prevalent in 2020.[7] The estimate includes direct costs to the health system, as well as the value of lost health, using a 'value of statistical life' (VSL) methodology.[8]

Lower estimate: USD ~10 billion p.a.[6] This reflects the costs associated with 'reopening' at a national double vaccination rate of 80%, compared with other thresholds,[9] in the epidemiological context of the Delta variant prevalent in the second half of 2021. The estimate includes both direct costs to the health system as well as the value of lost health using a VSL methodology.

In another estimate, the cost impact of removing testing (and the implications this has for case quarantine) was USD ~36 billion p.a.[6], in the context of the Omicron variant circulating in early 2022.[10] As with the other studies, this estimate also includes direct costs to the health system and the value of lost health, albeit measured using quality-adjusted life years (QALYs).[11]

These disparate estimates demonstrate how shifting epidemiological scenarios tied to specific interventions and differing scopes of costs can result in widely varying estimates.

1.2.2 Estimates for Taiwan

Range of existing estimates of the cost of COVID-19: USD ~10 billion to USD ~20 billion p.a. As with Australia, there is a disparity between estimates, which is primarily due to specific interventions being modeled, the epidemiological context, and the scope of costs evaluated. Despite the need for a comprehensive cost evaluation of COVID-19's impact on Taiwan, neither of the available high or low estimates provides this.

Higher estimate: USD ~20 billion p.a. This reflects costs saved by employing wastewater surveillance rather than traditional nasopharyngeal testing alone.[12] The estimate includes both direct costs to the health system as well as indirect costs in the form of productivity losses from missed work incurred by those infected, but does not include the value of lost health.

Lower estimate: USD ~10 billion p.a. By contrast, this study – conducted in the context of the variants prevalent in late 2020 – estimates that not pursuing a national vaccination program would impose lower costs on the

6. The studies in Australia used AUD figures and the amounts are as follows: AUD ~15 billion = USD ~10 billion, AUD ~400 billion = USD ~270 billion, AUD ~54 billion = USD ~36 billion.
7. Kompas, T., Grafton, R., Che, T., Chu, L., Camac, J. Health and economic costs of early and delayed suppression and the unmitigated spread of COVID-19: The case of Australia. PLOS ONE. 2021 Jun 4; 16(6): e0252400
8. Value of statistical life is an approach to estimating the value of reductions in the risk of physical harm. Based on international and Australian research, a credible estimate of the value of statistical life is $5.0m and the value of each statistical life year is $217,000 in 2020 Australian dollars.
9. Chu, L., Grafton, R., Kompas, T. What vaccination rate(s) minimize total societal costs after opening up to COVID-19? Age-structured SIRM results for the Delta variant in Australia (New South Wales, Victoria and Western Australia). PLOS Global Public Health. 2022 Jun 14; 2(6): e0000499
10. Karnon, J., Afzali, H., Bonevski, B. An economic evaluation of government-funded COVID-19 testing in Australia. Applied Health Economics and Health Policy. 2022 Sep; 20(5): 681-691
11. The quality-adjusted life-year (QALY) is a measure of the value of health outcomes. This approach values both quality and length of life, with monetary values attached per condition, in contrast to the VSL approach, which applies a universal value to each life and life-year (unless adjusted).
12. Chan Y. Cost-Effectiveness Analysis of Conventional Epidemiological Surveillance with the Counterpart of the Add-on Environmental Surveillance for COVID-19 [dissertation]. National Taiwan University; 2022. 30 p.

economy.[13] This estimate includes both direct costs of inpatient care for unvaccinated individuals who become unwell and productivity losses incurred as a result of missed work while hospitalized.

Again, these examples demonstrate how studies' focus on particular interventions in different epidemiological contexts lead to varying estimates, highlighting the need for analysis that accounts for all prevailing interventions and a range of epidemiological scenarios.

1.2.3 Estimates for South Korea

Range of existing estimates of the cost of COVID-19: USD ~400 million to USD ~64 billion p.a. Existing estimates of the costs imposed by COVID-19 in South Korea are limited, with values depending on widely varying methodologies and epidemiological contexts.

Lower estimate: USD ~400 million. This estimate reflects only the annualized costs of inpatient care that would arise from the spread of the Omicron variant in late 2021 and early 2022, when the nation was still subject to the majority of response measures employed prior to reopening.[14]

Higher estimate: USD ~64 billion. By contrast, this estimate reflects the net impact on national GDP that COVID-19 could have on the South Korean economy, in the context of the earlier variants prevalent in 2020.[15] It also takes into account the change in real value-added growth rates of each industry in the economy, acknowledging that some will contract (e.g., transport, hospitality) while others may in fact grow (e.g., biotech, semiconductors). The net impact, however, is ~3.7% of GDP, which equates to USD ~64 billion.

The disparity in existing estimates of COVID-19's cost impact is likely more pronounced in South Korea and underscores the conclusion that a more consistent and comprehensive approach to evaluating the costs of the pandemic's impact is required.

1.2.4 Estimates for Singapore

Range of existing estimates of the cost of COVID-19: USD ~32 million to USD ~72 billion p.a. This wide range is due to the various interventions explored, the epidemiological contexts assumed, and the scope of costs evaluated.

Higher estimate: USD ~72 billion. This is a historical estimate based on the Singaporean authorities' expenditure on COVID-19 in the past two financial years.[16] The scope includes direct costs to the health system and associated public health measures, as well as several indirect costs such as support measures for workers, businesses, households, and social support. This estimate is not tied to a specific epidemiological scenario, as the context in Singapore varied widely over the course of the past two years on which the estimate was based.

Lower estimate: USD ~32 million. This is based on calculations of a comparison of probable costs resulting from COVID-19 in several markets, and the effect of vaccination on these costs. Direct costs taken into account included vaccination program costs and medical treatment costs associated with COVID-19 infection, while indirect costs included productivity loss due to days spent in sickness, as well as premature death before retirement.[17] Epidemiological scenarios calculated included a comparison of costs when 0% versus 50% of the Singaporean population was fully vaccinated. A vaccination rate of 50% is predicted to save USD ~21 million, which reflects the epidemiological context of vaccination rates in Singapore in July 2021. This estimate also includes the value of lost health, albeit measured using quality-adjusted life years (QALYs).[11]

In another example, the short-term impacts of COVID-19 on consumer spending and labor market outcomes in Singapore were analyzed using historical data. It was

13. Wang, W., Fann, J., Chang, R., Jeng, Y., Hsu, C., Chen, H., Liu, J., Yen, A. Economic evaluation for mass vaccination against COVID-19. Journal of the Formosan Medical Association. 2021 Jun; 120(1): 95-105
14. Jo Y., Kim S., Radnaabaatar M., Huh K., Yoo J., Peck K., Park H., Jung J. Model-based cost-effectiveness analysis of oral antivirals against SARS-CoV-2 in South Korea. Epidemiology and Health. 2022 Mar 12; 44: e2022034
15. Kang et al. Bank of Korea, National Statistics Office [Internet].The Impact of the Covid-19 Pandemic on the Korean Economy and Industry: An Interim Assessment One Year after the Outbreak. 2023 Jan 10. Available from: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4192204.
16. Kit TS. Channel News Asia [Internet]. Singapore spent S$72.3 billion to fight COVID-19 over past 2 years, lower than initially committed. 2022 Sep 13. Available from: https://www.channelnewsasia.com/singapore/singapore-spent-s723-billion-fight-covid-19-past-two-years-2934946
17. Jiang Y., Cai D., Shi S. Economic evaluations of inactivated COVID-19 vaccines in six Western Pacific and South East Asian countries and regions: A modeling study. Infectious Disease Modelling. 2022 Mar; 7(1): 109-121

found that COVID-19 reduced both components relatively quickly after its outbreak, followed by a rebound that was restriction-dependent. In the epidemiological context of the variants and infection rate at the peak of COVID-19 in April 2022, total household consumer spending decreased by 22.8% and labor income decreased by 5.9%.[18]

1.2.5 Estimates for Hong Kong

Range of existing estimates of the cost of COVID-19: USD ~56 million to USD ~1 billion. As in the other markets, the range of estimates is due to the various interventions explored, the epidemiological contexts assumed, and the different scope of costs evaluated.

Lower estimate: USD ~56 million. This is based on calculations of a comparison of probable costs resulting from COVID-19 in several markets, and the effect of vaccination on these costs. Direct costs taken into account include vaccination program costs and medical treatment costs, while indirect costs include productivity loss due to sick days and premature death before retirement. Epidemiological scenarios calculated include a comparison of costs when 0% versus 50% of the Hong Kong population is fully vaccinated. A vaccination rate of 50% is predicted to save USD ~40 million, reflecting the epidemiological context of vaccination rates in Hong Kong in September 2021.[19] This estimate also includes the value of lost health, albeit measured using quality-adjusted life years (QALYs).[11]

Higher estimate: USD 1 billion p.a. This is a historical estimate based on the reported funding allocated by the Hong Kong Special Administrative Region to the Hong Kong Hospital Authority (public health system) in 2022 for pandemic-related expenditure.[20] The estimate includes direct healthcare costs as well as costs associated with public health measures, such as vaccinations and operating costs for isolation and treatment facilities. This estimate reflects the impact of rapidly escalating infections from a novel variant in the setting of a vaccination rate of ~60%, reflecting the epidemiological context when the Omicron variant emerged in late 2021.

One estimate of the economic losses associated with COVID-19, based on the recorded fall in economic activity experienced during 2020, was a 6.1% reduction in Hong Kong's GDP.[21] This estimate reflects the context of public health measures such as social distancing, lockdowns, and border closures, with none of the population vaccinated – which was the epidemiological scenario experienced by Hong Kong in 2020 at the start of the pandemic.

As an interesting aside, an estimate for the whole of China put forward by the University of Hong Kong estimates the indirect economic cost of COVID-19 at USD ~46 billion per month, or 3.1% of GDP.[22] This estimate reflects the impact of implementing targeted lockdowns and the associated fall in economic activity.

1.2.6 The need for better targeted, future-looking cost estimates

The variation in existing estimates of the economic impacts of COVID-19 leads to a lack of clarity. An approach better aligned to today's environment could take three steps to establish a more consolidated framework:

- **Establish a set of plausible epidemiological scenarios** that decision-makers find relevant for planning purposes.
- **De-anchor estimates from specific interventions used in the pandemic phase (e.g., lockdowns, vaccinations, welfare payments)** and ensure that estimates instead reflect conditions in today's reopened societies.
- **Target the scope of costs included to reflect the way the pandemic impacts society today:** health service utilization and productivity loss from missed work.

18. Kim S., Koh, K., Zhang X. Short-term impact of COVID-19 on consumption and labor market outcomes: evidence from Singapore. Canadian Journal of Economics. 2022 Jun; 55(1): 115–134
19. Zhang W. Statista [Internet].COVID-19 vaccination doses in Hong Kong 2021-2022. 2022 Jun 8. Available from: https://www.statista.com/statistics/1297793/hong-kong-covid-19-vaccination-doses/
20. Epidemic-related expenditure of Hospital Authority. The Government of the Hong Kong Special Administrative Region Press Releases [Internet]. 2022 May 4. Available from: https://www.info.gov.hk/gia/general/202205/04/P2022050400430.htm
21. Hong Kong Monetary Authority. Annual Report 2020 [Internet]. Available from: https://www.hkma.gov.hk/eng/data-publications-and-research/publications/annual-report/2020/
22. Hancock T. Lockdowns cost at least $60b a month: study. Financial Review [Internet]. 2022 Mar 29. Available from: https://www.afr.com/world/asia/china-lockdowns-cost-at-least-60b-a-month-study-20220329-p5a93g#:~:text=Hong%20Kong%20%7C%20China%27s%20COVID%2D19,if%20more%20cities%20tighten%20restrictions.

2. Our Approach: Uncovering The Future Economic Costs Of COVID-19

2.1 The Cost-Of-Illness Concept In Estimating Economic Costs

This white paper uses the cost-of-illness concept to derive cost estimates and present a coherent snapshot of the COVID-19 price tag faced by various Asia Pacific economies. Commonly used to support decision-making, the cost-of-illness approach is a pragmatic health economics methodology that assesses two types of cost: direct costs of the illness (i.e., those incurred by the health system) and indirect costs (i.e., those resulting from productivity losses due to work missed by affected individuals). By assessing these two major categories of burden, the approach helps policymakers understand the value at stake when investing in interventions to address the disease.

This report has collated publicly available data and existing cost estimates of both direct and indirect costs into an overall estimate for the five markets and a detailed look into the factors affecting each. Figures from the five economies assessed are not fully equivalent as each market relies on vastly different data collection methods and varying estimates. Market estimates provided in this report should therefore be viewed within this context and not directly compared given their highly specific nature. However, their similarity allows us to reveal a broad picture of the general situation in the Asia Pacific region.

The cost-of-illness approach – particularly the focus on indirect costs – has been recently used in the 'One Billion Days Lost' analysis published by McKinsey & Company,[1] detailing the significant and ongoing economic costs wrought by COVID-19 on the US labor force. The approach to estimating economic costs arising from productivity loss in that piece of research is substantively similar to the approach used in this white paper. This report identifies factors driving productivity loss by focusing on cohorts of key affected individuals, such as working-age individuals (looking at those who can and cannot work from home), and caregivers of children unwell with COVID-19 (looking at the children's age and the caregiver's ability to work concurrently).

Cohorts contributing to direct costs include inpatients and outpatients. Within each cohort, the major determinants of cost are volume (i.e., number of people affected by COVID-19 in that cohort), price or value (i.e., of the service provided), and time (e.g., duration of service provision). For example, the costs arising from the cohort requiring inpatient care for COVID-19 would be the product of the number of patients admitted to hospitals, the average number of days they stay there, and the average cost per day of admission.

This approach does not typically account for the value of lost health, such as that quantified in a value of statistical life (VSL) methodology.[8] As a result, the cost-of-illness approach can lead to an underestimation of costs, as a population's willingness to pay to avoid harm is generally higher than the cost to the economy.

The total economic costs of COVID-19 range from USD ~2.6 billion p.a. (0.6% of GDP) in Singapore to USD ~17.0 billion p.a. in Australia (1.0% of GDP) and USD ~27.5 billion p.a. (1.6% of GDP) in South Korea. In the worst-case scenario, this could grow to as much as USD ~92.7 billion annually in South Korea. The four primary drivers of variation are the number of infections (closely tied to population), GDP and average monthly wages, quarantine periods causing missed work, and the relative cost of healthcare delivery.

Exhibit 1 illustrates how total cost estimates compare across the five markets in a base case scenario; costs are expressed in billion USD and as a percentage of each nation's GDP. The aim here is to give an overall sense of the scale of the cost burden posed by COVID-19 across these societies, not to make direct comparisons between them. This is because of the inherent differences between the five markets, as well as the varying data collection methods.

For example, the total economic costs in Taiwan are ~45% that of Australia because, despite similar population sizes, average monthly wages in Taiwan are ~40% of those in Australia, meaning the value of productivity losses from lost work are proportionally less. One must also allow for the fact that healthcare costs are lower in Taiwan.

By contrast, the total economic costs in South Korea are ~60% higher than in Australia because the volume of infections is more than twice that of Australia (reflecting relative population sizes), and the mandated quarantine period remains seven days in South Korea (as of early 2023), whereas there is no longer a mandated quarantine period in Australia. Together, these mean a larger volume of people are becoming unwell in South Korea and the duration of work missed is also greater per person. Offsetting this is the fact that average monthly wages are lower, so the value of that lost work per unit time is ~35% less.

Our estimates of the economic costs imposed by COVID-19 using the cost-of-illness approach are detailed in Sections 3 (Australia), 4 (Taiwan), 5 (South Korea), 6 (Singapore), and 7 (Hong Kong) below.

Exhibit 1: Total economic costs due to COVID-19 as a percentage of GDP

	Singapore	Taiwan	Australia	Hong Kong	South Korea
Cost per capita, USD	**~$480**	**~$320**	**~$660**	**~$707**	**~$530**
Cost per infection, USD	**~$820**	**~$381**	**~$854**	**~$611**	**~$530**
GDP, USD billion	~$424	~$830	~$1,725	~$369	~$1,734
Average monthly wage, USD	~$3,850	~$1,408	~$3,545	~$2,385	~$2,292
Population, millions	5.6	23.6	25.7	7.5	51.7
Infections, per capita	0.58	0.84	0.77	1.16	1.00

GDPs are nominal, 2022 figures.

2.1.1 Three epidemiological scenarios

Epidemiological scenarios help us to consider the potential courses that the COVID-19 pandemic may take in the future, providing a mechanism with which to anchor cost estimates to real-world conditions. Cost estimates can then be adjusted based on potential changes in these conditions.

While the price of medical services or the value of lost work in each cohort affected by COVID-19 is relatively straightforward to establish, other factors are contingent on the course of the pandemic. For example, a novel and more contagious strain may result in a greater number of infected individuals, unlike an earlier variant to which the population has already acquired a reasonably high level of immunity.

Three epidemiological scenarios have been developed:

- Normal 2.0: A lower estimate scenario, with more favorable conditions
- Base case: A middle estimate scenario, where current conditions prevail
- Pandemic 2.0: A higher estimate scenario, with more severe conditions

These scenarios are defined by two key features:

- Infection volume (driven by contagiousness and measured by cases per million population per year), and;
- Case severity (driven by a prevailing strain's virulence and measured by the resulting hospitalization rate).

These features allow low, base, and high scenarios to be used in cost estimates that reflect real-world conditions, improving their applicability to support decision-making. Estimates of the economic costs of COVID-19 using the cost-of-illness approach are detailed in Sections 3 (Australia), 4 (Taiwan), 5 (South Korea), 6 (Singapore), and 7 (Hong Kong) below.

To note, this report leverages Institute for Health Metrics and Evaluation (IHME)'s 2022 Reference Scenario data (last updated 18 November 2022) to inform the 'base case' for each of the markets in focus. The IHME is an independent global health research centre at the University of Washington. IHME aggregates real-time COVID-19 data and projects future scenarios for a number of markets, using a hybrid modelling approach incorporating statistical and disease transmission models.

This dataset includes:

- Historical actuals for daily confirmed cases and daily deaths
- Estimates of daily infections (not just those confirmed by a positive test) based on the SEIR disease transmission model that leverages data from seroprevalence surveys, daily cases, daily deaths, and daily hospitalisations where possible

IHME draws datasets from local and national authorities, hospital networks and associations, the World Health Organisation, and other sources / aggregators such as Johns Hopkins University and Our World in Data.

3. Economic Cost of COVID-19 in Australia

In Australia, the future economic cost of COVID-19 could range from AUD ~17 billion p.a. (~0.6% of GDP) to AUD ~56 billion p.a. (~2.2% of GDP), depending on the scenario that evolves. These costs are far greater than commonly recognized. COVID-19 not only inflicts health losses through illness and death but also imposes substantial economic costs, including direct costs on the healthcare system and productivity losses from missed work.

Living with ongoing transmission of the virus and the burden of disease it incurs is a reality that nations have had to come to terms with. However, there is an opportunity to better leverage tools available to reduce this burden. To better inform the ongoing discussion on COVID-19's impacts and how we could benefit from addressing these impacts, it is important to understand the full range of economic costs imposed by COVID-19.

There is a range of potential epidemiological scenarios for how the COVID-19 pandemic may evolve. This is reflected in the wide range of existing estimates for the economic costs due to COVID-19 (which also vary due to interventions studied and the scope of costs included).[23] Possible epidemiological scenarios include a base case, where current conditions prevail, and alternative scenarios that differ in the rate of infections and their severity (driven by, for example, the interplay between variants and the level of immunity maintained in the population).

In the base case scenario, total economic costs could be AUD ~25 billion p.a. (equivalent to ~1.0% of GDP), assuming a transmission rate that results in ~20 million infections p.a. and ~193,000 admissions p.a.[24] (including ~109,000 inpatient admissions and ~84,000 home care program admissions), with:

- The majority of costs (AUD ~22.5 billion p.a., ~90%) are due to productivity losses (indirect costs) through missed work by both working-age adults and elderly in the workforce, either during their own illness or while caring for dependents (children and over 65-year-olds) affected by COVID-19, and
- A further cost (AUD ~2.8 billion p.a., ~10%) is borne by the health system (direct costs), in both admissions (AUD ~1.3 billion p.a.) and outpatient (AUD ~1.5 billion p.a.) settings.

23. Australian Bureau of Statistics [Internet]. Economic gains and losses over the COVID-19 pandemic. 2022 Jul 9. Available from: https://www.abs.gov.au/articles/economic-gains-and-losses-over-covid-19-pandemic

24. Includes ~109k inpatient admissions and ~84k admissions to COVID home care programs nationwide (such as 'virtual hospitals' in NSW and the COVID Positive Pathways program in Victoria). Inpatient admissions figures are sourced from the Institute of Health Metrics and Evaluation's (IHME; used with permission) mean estimate of annual inpatient admissions in Australia in 2022, and may differ from other sources.

- Local currencies have been used in this Section, reflecting the use and findings of local data sources. The below exchange rates were used in all local currency conversions to USD in this report. USD currency exchange rate conversions via Google Finance as of 28 February 2023 (USD1 = AUD 1.4861 = HKD 7.8493 = KRW 1,322 = SGD 1.3484 = TWD 30.6608): https://www.google.com/finance/markets/currencies?hl=en

In a Pandemic 2.0 scenario, economic costs could reach as high as AUD ~56 billion p.a. (~2.2% of GDP). This assumes transmission rates that result in ~26 million infections per year (instead of ~20 million in the base case), and a severity that results in ~130,000 inpatient hospitalizations (compared with ~109,000 in the base case). In contrast, at the lower end of the spectrum, a Normal 2.0 scenario might feature ~14 million infections over the course of a year with only ~45,000 inpatient hospitalizations, translating to direct and indirect costs of AUD ~17 billion p.a. (~0.6% of GDP).

These economic costs are unevenly distributed. The health and logistics workforces, those affected by long COVID, and vulnerable populations are likely to be disproportionately impacted. For example, COVID-19 illness in vulnerable populations contributes AUD ~12.4 billion p.a. in the base case scenario, of which AUD ~3.1 billion p.a. (~25%) is borne by individuals eligible for oral antivirals. Separately, the health workforce is impacted by high levels of absenteeism and a risk of infection that is around 3 times that of the general population, both carrying consequences for health system capacity and quality of care. Economic costs arising from these disruptions to the health workforce total AUD ~2.3 billion p.a. in the base case scenario. Those affected by long COVID (see Section 3.4.6) are impacted most significantly, with the value of lost work and health system utilization totaling AUD ~8.6 billion p.a. or ~34% of all economic costs.

Fortunately, a range of countermeasures remains available that may mitigate the economic costs of COVID-19 (see Section 8), including vaccination, therapeutics, and community measures (i.e., non-pharmaceutical interventions). Strengthening these countermeasures may allow Australia to mitigate the potentially high economic costs of the continuing pandemic.

3.1 Context: The Situation In Australia

Today, Australia is relatively free of restrictive measures. Most of the community measures employed earlier in the pandemic, such as lockdowns and mandatory isolation, have been pared back. In their place, Australia has wide availability and uptake of vaccines and therapeutics such as antivirals. Concerning antivirals, these are available in line with their indication, under the Pharmaceutical Benefits Scheme (PBS) to a subset of the Australian population, based on traditional health technology assessments.

However, in early December 2022, Australia was experiencing its fourth wave of infections arising from the Omicron variant. With ~80,000 new infections per day and an effective transmission number[25] of ~1.05, infection volumes did not peak until later in December.[26] By contrast, in January 2021, before the Delta or Omicron variants emerged, there were ~60 infections per day, when most of the nation was subject to international and domestic border closures, rolling metropolitan lockdowns, and social distancing measures. The change in Australia's pandemic response approach is both a reaction to the volume of infections, as well as a driver of subsequent infections.

25. The number of people a single case will infect, on average.
26. As a point of comparison, as Australia's first Omicron wave began to subside in January 2022, there were ~100,000 infections per day and an effective transmission number of ~0.90; Institute of Health Metrics and Evaluation (IHME; used with permission).

Australia's initial measures were effective at containment and then suppression of the virus, while imposing significant economic costs. By international standards, the countermeasures employed during the first phase (2020 to 2021) were largely successful. The number of reported cases (~400,000) and deaths (~2,200) were among the lowest in the OECD.[27] However, these border closures, domestic travel restrictions, lockdowns, social-distancing requirements (including limiting the number of people allowed in indoor spaces), and mask-wearing imposed significant hardships on the community. The successful rollout of vaccines[28] afforded an easing of many restrictions, although the immunity conferred was found to wane over time. This waning immunity necessitated third (and ultimately fourth and fifth) doses, while novel variants capable of immune evasion, such as Omicron, emerged.

Oral antivirals have been added to Australia's response toolkit. As restrictive community measures are only accomplishable in the short-term, whereas COVID-19 continues to pose a health threat in the longer-term, Australia had to broaden its approach to include oral antivirals, which became available via the PBS in March 2022.[29]

Nevertheless, the health and economic outcomes of the reopening phase have been mixed. The vast majority (~92%) of Australia's infections to date occurred in 2022.[30] While infections were not as severe as early in the pandemic, the sheer volume led to the busiest of the pandemic yet for the hospital system, with ~300 admissions per day on average, compared to ~23 in 2021 and just ~10 in 2020.[31] This translated into the number of deaths increasing significantly, from 1,332 in 2021 and 909 in 2020, to 14,783 in 2022. It is worth noting that COVID-19 has potentially contributed to excess mortality (that is, additional deaths relative to pre-pandemic mortality) both due to deaths caused by COVID-19 and deaths that may have arisen as a second- order impact of COVID-19 on health system capacity. In August 2022 alone, excess mortality was ~10% (+1,700 deaths).[32]

The high volume of infections has also wrought an economic impact, both in costs borne directly by the health system in addressing COVID-19, and the economic losses borne indirectly by society in the form of absenteeism and productivity losses. These will be explored in detail in Sections 3.3.1 and 3.3.2. Australia's reopening experience has illustrated that the costs of COVID-19 borne by Australian society extend beyond the value of health losses captured by traditional health technology assessments. Indeed, productivity losses driven by infections across all age groups constitute a major economic cost.

A better understanding of the economic costs of COVID-19 may better inform the assessment of the costs and benefits of various measures to address COVID-19. Indeed, despite the ongoing burden of COVID-19 on society, vaccination coverage remains incomplete. While 96% of Australians have received two doses of a COVID-19 vaccine, 72% have received three doses and just 44% have received four.[33] This can be compared, for example, to South Korea (~80%) and Japan (100%) where third-dose coverage is higher. While the use of antivirals has tracked infection waves,[34] their use remains relatively uncommon at a prescription rate of ~3% of all infections.

27. Our World in Data [Internet]. Cumulative confirmed COVID-19 cases. Available from: https://ourworldindata.org/explorers/coronavirus-data-explorer?time=earliest..2021-12-30&facet=none&Metric=Confirmed+cases&Interval=Cumulative&Relative+to+Population=false&Color+by+test+positivity=false&country=~AUS
28. As in many international jurisdictions, a vaccine rollout strategy was adopted in 2021 as a conduit for an easing of various restrictions. The resulting population-wide vaccination program (excluding ineligible children) delivered a double-dose national vaccination rate of >90% by November 2021. As of December 2022, 95.9% of people aged 16 and above have had two COVID-19 vaccine doses. Uptake waned somewhat after the second dose, with the third dose reaching only 72.3%. Australian Government Department of Health and Aged Care [Internet]. Vaccination numbers and statistics. 2023 Mar 31. Available from: https://www.health.gov.au/our-work/covid-19-vaccines/vaccination-numbers-and-statistics.
29. Oral antivirals are currently available to all COVID-19-positive patients over the age of 70 or those over the age of 50 presenting with two or more additional risk factors (e.g., comorbidities such as diabetes, obesity, or heart failure).
30. There have been ~30 million infections in Australia this year, compared to ~2 million in 2021 and ~100,000 in 2020.
31. Institute of Health Metrics and Evaluation [Internet]. COVID-19 estimates reference scenario. 2022 Dec 16. Available from: https://www.healthdata.org/covid/data-downloads
32. COVID-19 Mortality Working Group [Internet]. Excess mortality continues in August 2022 Actuaries Digital. 2022 December 7. Available from: https://www.actuaries.digital/2022/12/07/covid-19-mortality-working-group-excess-mortality-continues-in-august-2022/
33. Commonwealth of Australia, Department of Health and Aged Care [Internet]. Vaccination numbers and statistics. 2023 Mar 31. Available from: https://www.health.gov.au/our-work/covid-19-vaccines/vaccination-numbers-and-statistics
34. Prescriptions peaked in July at ~35,000 per week, subsiding to ~6,000 per week in early October and increasing again to ~30,000 per week by the end of November as the fourth Omicron wave emerged.

3.2 Key Assumptions In The Australian Context

A range of informed assumptions is used to derive the estimates of economic costs in Australia as a result of COVID. Exhibit 2 illustrates how these assumptions are used and provides a list of key assumptions used, while a full list of assumptions is given in the Appendix section.

Exhibit 2: Use of assumptions in the Australian context

A | Epidemiological scenarios

Scenario	Infections (mn) p.a.	Inpt. admiss. (k)
Normal 2.0	~14	~45
Base	~20	~109
Pandemic 2.0	~26	~130

→

B | Direct costs: borne by the health system

Key Base Case Assumptions	
# Ward admissions p.a.	~104,000
# ICU admissions p.a.	~5,500
% Infections that visit a GP	3-12%
% Infections prescribed OAVs	3%
# Long COVID cases p.a.	~990,000

+

C | Indirect costs: economic productivity losses borne by society

Key Base Case Assumptions	
Working-age infections as proportion of total	67%
Proportion of working-age infections that can work	98.85%
Proportion of working-age infections that can work from home	61%
Average number of working days lost due to acute illness in working-age population	~6
Average daily salary	AUD 173

=

D | Total economic cost to society

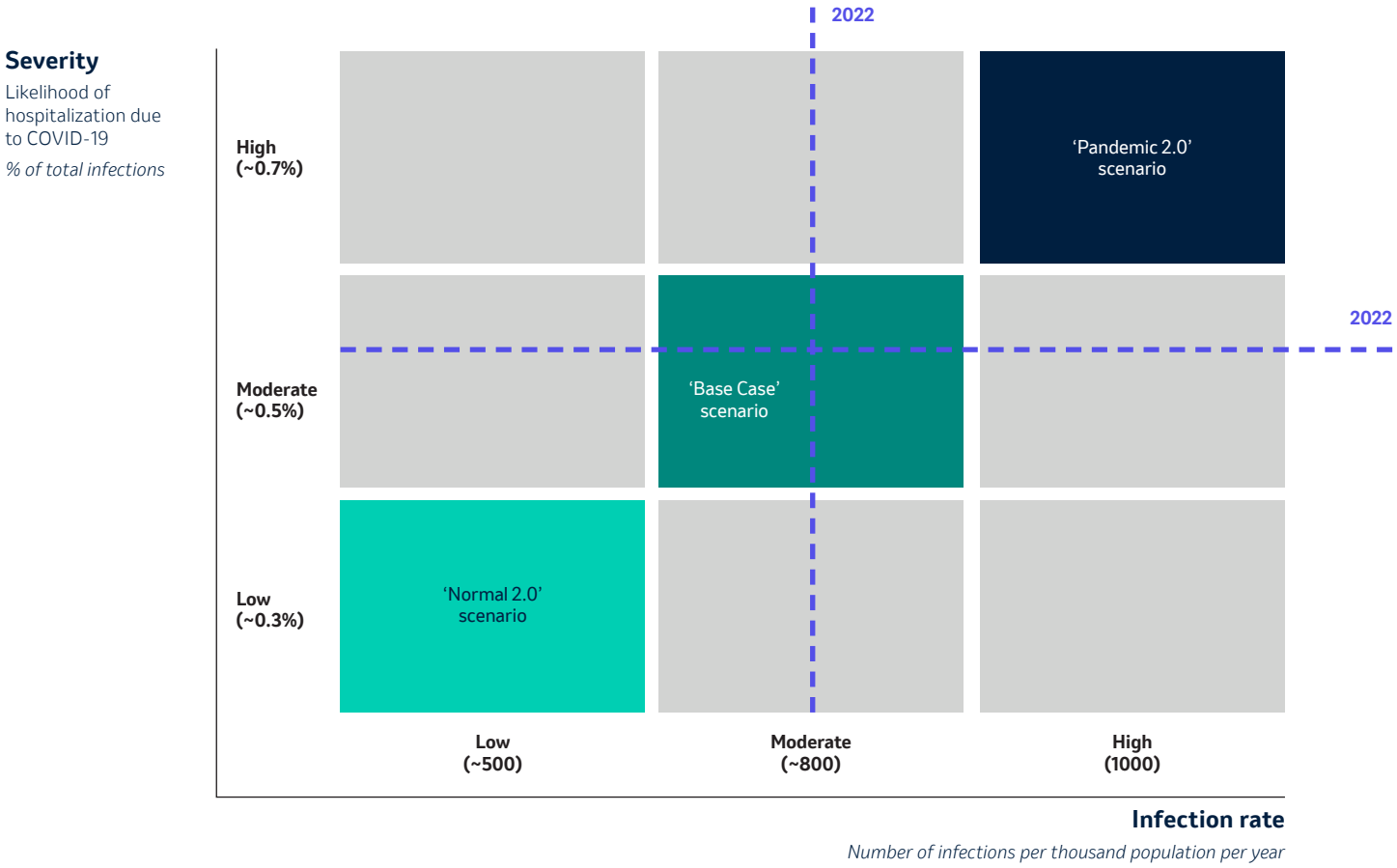
- **Total direct and indirect costs,** broken down by patient/demographic group
- **Costs per person** in each patient/ demographic group

  - E.g., if total admissions costs are $1bn, and 75,000 patients are admitted, the cost per person is ~ $13,000

A full list of assumptions is given in the appendix.

3.3 Future:
Scenario-Based Estimates Of The Economic Costs Of COVID-19 In Australia

Exhibit 3: Potential epidemiological scenarios



Scenarios are indicative only and based on the observed epidemiology of COVID-19 in Australia in 2022.

Scenarios help us to consider and envisage the potential courses that the COVID-19 pandemic may take in the future. One way to express scenarios is in the form of low (Normal 2.0), base case, and high (Pandemic 2.0) epidemiological trajectories.

As Exhibit 3 illustrates, in the Australian context this might mean:

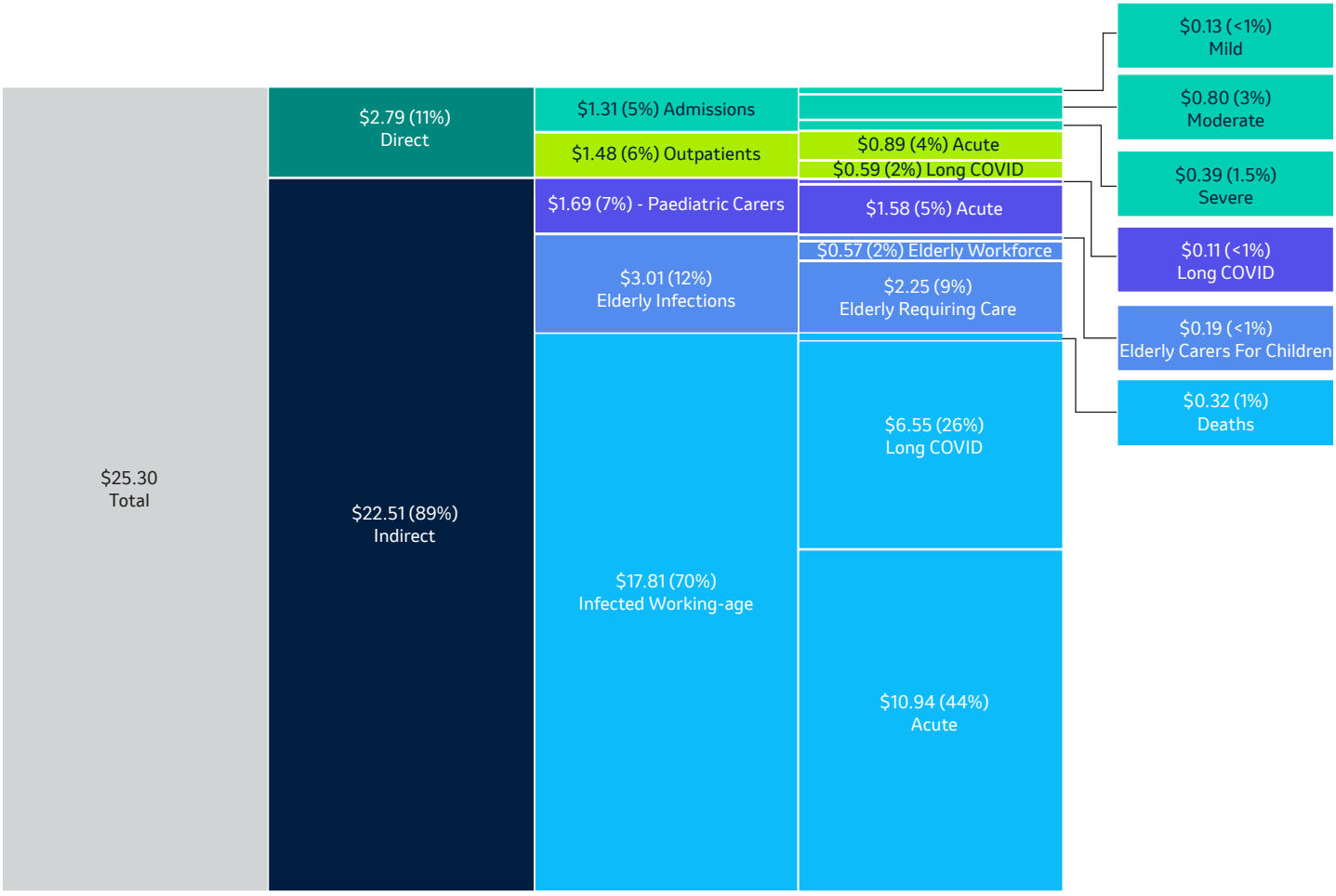
- A base case, with an economic cost of AUD ~25 billion p.a. (~1.0% of GDP and in addition to the value of lost health, such as that already considered in HTAs), which assumes a rate of infection (e.g., ~750,000 infections per million population annually) and a viral severity driving ~193,000 admissions annually,[35] similar to that seen over the course of 2022. This is the scenario shown in Exhibit 4 below and described in the direct (3.3.1) and indirect (3.3.2) costs Sections below.

35. Includes ~109k inpatient admissions and ~84k admissions to COVID home care programs nationwide (such as 'virtual hospitals' in NSW and the COVID Positive Pathways program in Victoria). Inpatient admissions figures are sourced from the Institute of Health Metrics and Evaluation's (IHME; used with permission) mean estimate of annual inpatient admissions in Australia in 2022, and may differ from other sources.

- **A high or Pandemic 2.0 case, with an economic cost of AUD ~56 billion p.a. (~2.2% of GDP)** which assumes a higher rate of infection (e.g., 1 million infections per million population per year) and a higher viral severity driving ~285,000 hospitalizations annually, similar to what was seen during the first Omicron wave in early 2022.

- **A low or Normal 2.0 case, with an economic cost of AUD ~17 billion p.a. (~0.6% of GDP)** which assumes a lower rate of infection (e.g., ~500,000 infections per million population per year) and a viral severity driving ~47,000 hospitalizations, similar to what was seen in mid to late 2022.

Exhibit 4: Direct and indirect costs of COVID-19 to Australia's economy in a base case scenario, AUD billion p.a.

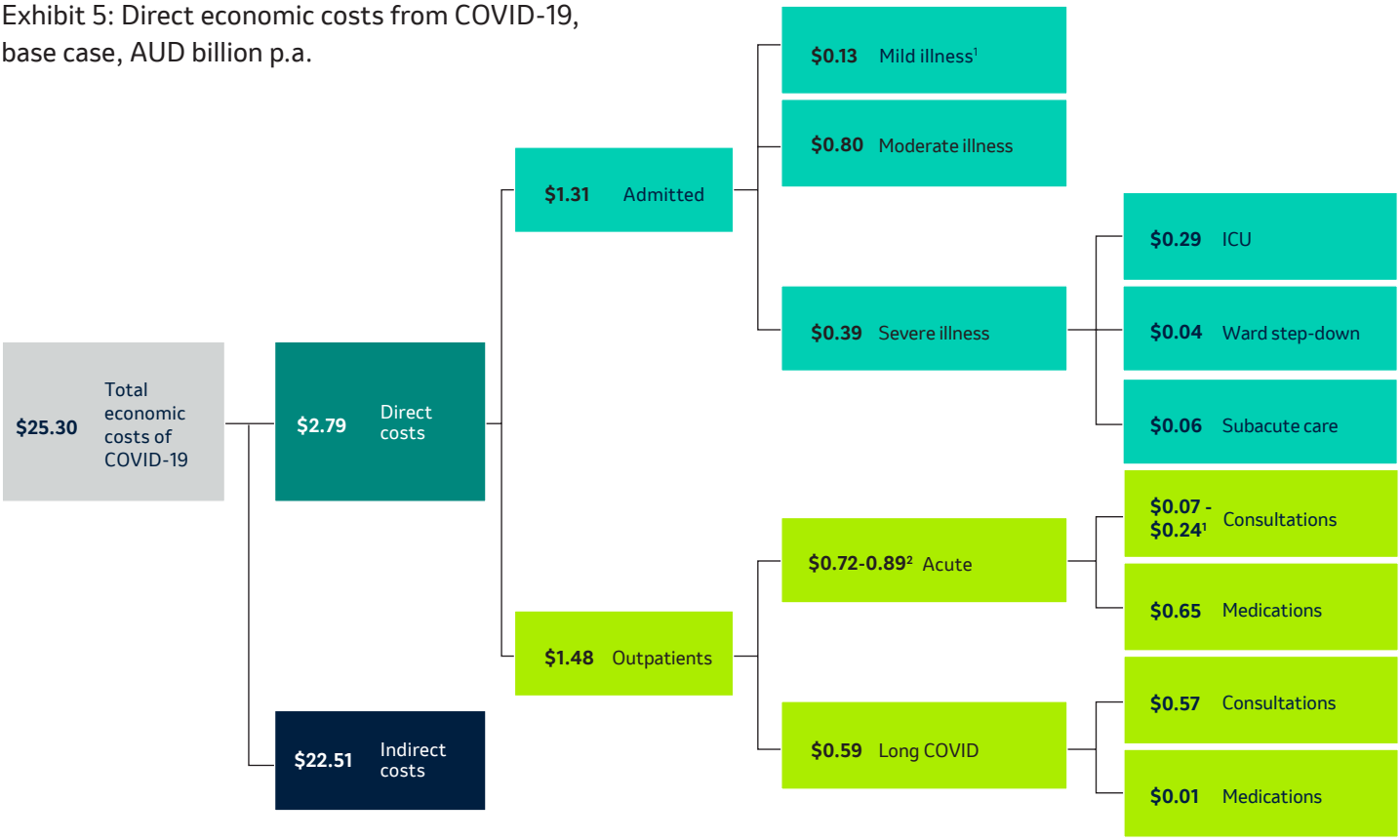


Costs are indicative only and based on the distribution of COVID-19 infections between cohorts in Australia in 2022.

As Exhibit 4 illustrates, the base case scenario is designed to reflect a continuation of recent conditions. To design a base case scenario, infection volumes and the prevailing hospitalization rate from 2022 have been drawn from the Institute of Health Metrics and Evaluation (IHME; used with permission) model of COVID-19.

3.3.1 Direct costs to the health system

Exhibit 5: Direct economic costs from COVID-19, base case, AUD billion p.a.



Note: Totals may not sum due to rounding
1. Patients with mild illness are admitted to COVID-19 home care programs, as distinct from hospital inpatient admissions. Patients with moderate illness are admitted to hospital as admissions.
2. A range is given for acute consultations to reflect the range of possible values for the number of GP consultations for COVID-19 assessment and treatment.

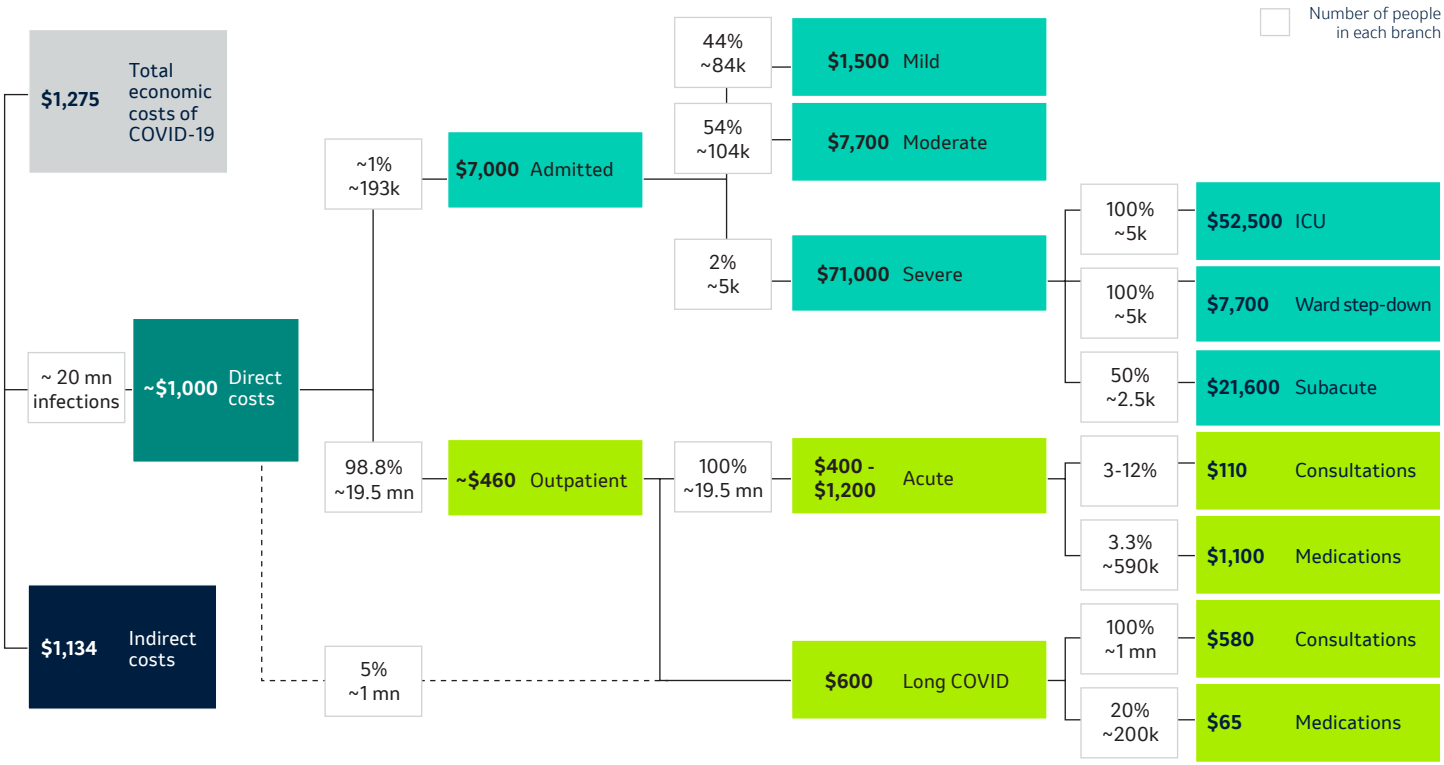
'Mild illness' requires home-based care, 'Moderate illness' requires ward-based admissions care, and 'Severe illness' requires ICU-level care; 'Acute illness' refers to all infections not included in admissions care; Long COVID refers to a small subset (~5%) of total infections and represents infections with symptoms lasting 12 weeks or more.

With ~109,000 inpatient admissions[36] (including ~5,500 to the ICU) and ~1 million cases of long COVID in the base case scenario, preventing hospital and ICU admissions, reducing lengths of stay, recovery time, and the incidence of long COVID are steps needed to reduce the direct costs imposed on the health system. Given that those over 65 are over-represented in the COVID-19 admissions population, preventing severe illness in this cohort would likely be particularly impactful in reducing direct costs.[37]

In this scenario, as displayed in Exhibit 5, COVID-19 could cost the Australian health system AUD ~2.8 billion p.a. This is a significant expense, equating to ~0.1% of Australia's GDP, and alone would constitute ~1.4% of total health expenditure in FY19-20.[38] Despite the magnitude of this figure, direct costs are still a minority of the overall economic impact of COVID-19 in Australia, accounting for ~10% of the total. The remaining ~90% are in the form of indirect costs and are discussed below in Section 3.3.2.

36. Inpatient admissions figures are sourced from the Institute of Health Metrics and Evaluation's (IHME; used with permission) mean estimate of annual inpatient admissions in Australia in 2022 and may differ from other sources.
37. Those over 65 represent ~14% of infections but ~40% of COVID-19 inpatient admissions. Australian Institute of Health and Welfare [Internet]. Admitted patient activity 2020-21. Available from: https://www.aihw.gov.au/reports-data/myhospitals/intersection/activity/apc
38. Australian Institute of Health and Welfare [Internet]. Health expenditure Australia 2019-20. 2021 Dec 17. Available from: https://www.aihw.gov.au/reports/health-welfare-expenditure/health-expenditure-australia-2019-20/contents/about

Exhibit 6: Direct economic costs from COVID-19, per person, base case, AUD p.a.



Costs per person for each segment are calculated by dividing the total cost of that segment by the number of individuals in that segment that utilize a health service; 'Mild illness' requires home-based care, 'Moderate illness' requires ward-based admissions care, and 'Severe illness' requires ICU-level care; 'Acute illness' refers to all infections not included in admissions care, where 3-12% visit a GP and 3% are prescribed medication; Long COVID refers to a small subset (~5%) of total infections and represents infections with symptoms lasting 12 weeks or more.

Despite their relatively lower significance in the wider scheme of COVID-19's economic impact, direct costs remain significant on a per-infection basis. As illustrated in Exhibit 6, each infection that uses some form of health service could impose an average cost of AUD ~1,000. This is concentrated in the costs of admissions care, where a single ward admission could cost AUD ~7,700 and a single ICU admission (with subsequent ward and rehabilitation stays) could cost AUD ~71,000.

As indicated in Exhibits 5 and 6 direct costs are incurred in two major settings:

- Admissions care (AUD ~1.3 billion p.a.; 45%; AUD ~7,000 per person)
- Outpatient (primarily GP-based) care (AUD ~1.5 billion p.a.; 55%; AUD ~460 per person)

The profile of costs of admissions suggests that ameliorating the severity of illness acquired could have a substantial impact on cost. Particularly in a reopened economy, where individuals at risk of severe disease are less protected from infection by community measures, the extent of ongoing costs to the health system underscores the importance of continuing to prevent, test for, and treat the disease.

Costs in this category comprise those arising from mild infections requiring home-based care (AUD ~0.13 billion p.a.; AUD ~1,500 per person), moderate infections requiring ward-based care (AUD ~0.8 billion p.a.; AUD ~7,700 per person), and severe infections requiring ICU admission (AUD ~0.39 billion p.a.; AUD ~71,000 per person). The more costly care for moderate infections is driven largely by length of stay in the ward (~11 days on average), while the cost of care for severe infections is driven mostly by very high bed day costs (AUD ~5,250 per day in ICU), followed by substantial periods of admissions rehabilitation.

Limiting the incidence, duration, and severity of long COVID-19 would have a substantial impact on outpatient care costs. Outpatient care for COVID-19 infections adds AUD ~1.5 billion p.a. to the total economic costs incurred due to COVID-19. While seemingly less resource-intensive, outpatient infections that use health services are also expensive on a per-person basis, each costing AUD ~460.

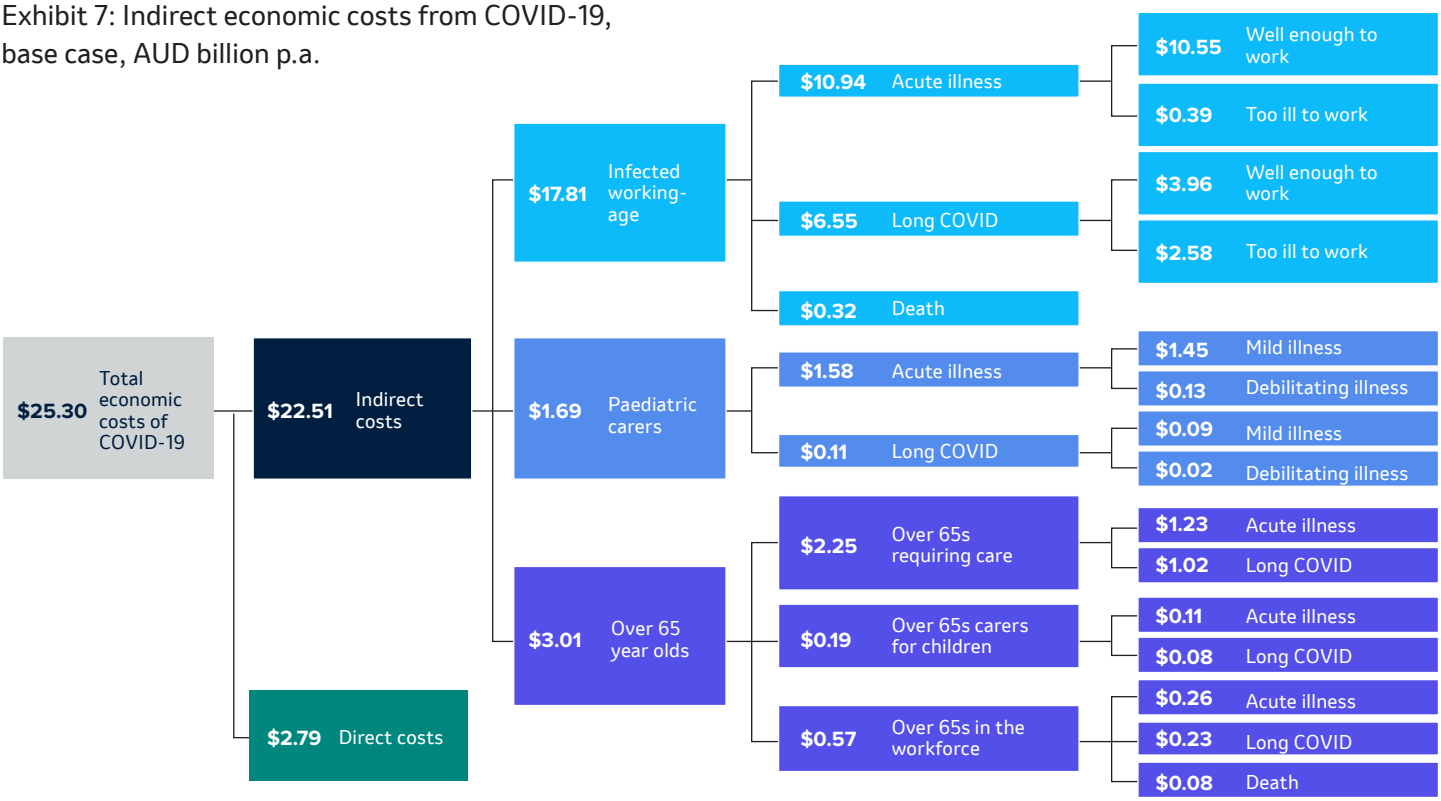
Outpatient costs can be separated into acute outpatient care (consultations and medications; AUD ~0.9 billion p.a.) and chronic outpatient or long COVID care (consultations and medications; AUD ~0.6 billion p.a.; see also Section 3.4.6).

While the cost of acute outpatient care is driven largely by the cost of medications (such as oral antivirals, AUD ~650 million), this equates to just ~2.5% of all direct and indirect costs. Medications represent a small investment towards partially reducing substantial additional costs (AUD ~25.3 billion p.a.). Visits to GPs account for the remainder of outpatient costs, which could total more than 2 million consultations per year if ~10% of those infected seek the care of their regular doctor. While the cost of these services is low compared to admissions costs (AUD ~240 million p.a.), it is not insignificant, and the patient volume represents a substantial additional burden on the primary care system.

Together, direct costs from the admissions and outpatient cohorts amount to AUD ~2.8 billion p.a. or 0.1% of Australia's GDP. While significant on their own, these costs are in addition to indirect costs to Australia's economy (discussed below in Section 3.3.2), the value of lost health they represent, and the flow-on effects to the health system (such as its workforce) or other critical industries.

3.3.2 Indirect costs to the economy

Exhibit 7: Indirect economic costs from COVID-19, base case, AUD billion p.a.



Note: Totals may not sum precisely due to rounding to 2 decimal places

Indirect costs arise from productivity losses incurred due to infection with COVID-19; 'Well enough to work' refers to those who can continue working while infected, albeit with reduced productivity; 'Too ill to work'' refers to those who cannot work, at least for a portion of the time, while infected; 'Acute illness' refers to all infections not included in admissions care; Long COVID refers to a small subset (~5%) of total infections and represents infections with symptoms lasting 12 weeks or more.

Reducing the sheer volume of COVID-19 infections and the duration of illness and/or time to recovery for working-age adults, children, and the older population would have a significant impact on the economic and societal costs of COVID-19.

In the base case scenario, and as Exhibit 7 illustrates, COVID-19 could cost the Australian economy AUD ~23 billion p.a. in productivity losses if current epidemiological conditions and response settings continue.[39] This estimate accounts for the removal of mandatory quarantine requirements in Australia, and thus would likely be significantly larger were this requirement still in place. As with direct costs to the health system, this is a significant expense, equating to ~0.9% of GDP and ~11% of Australia's total expenditure on health in 2019-20.[40] While these costs are significant, as with direct costs, they still do not account for the value of health lost due to COVID-19, nor the ripple effects on critical industries and vulnerable populations such as the health workforce.

As illustrated in Exhibit 7, indirect costs result from productivity losses borne by three major groups:

- **Infections in working-age adults (19 to 64-year-olds) – AUD ~17.8 billion p.a.** (~79%; AUD ~1,340 per person)
- **Infections in the older population (>65-year-olds) – AUD ~3.0 billion p.a.** (~13%; AUD ~1,260 per person)
- **Infections in children and adolescents (18 years old and under) – AUD ~1.7 billion p.a.** (~8%; AUD ~390 per person)

Infections in working-age adults impose a significant economic burden on Australia, through productivity losses valued at AUD ~17.8 billion p.a., a significant figure that equates to ~0.7% of Australia's GDP. This burden highlights the impact that an illness that is mild for most but significant enough to last ~12 days – and impair productivity by ~35% for a quarter of them – can have on the broader economy.[41]

Productivity losses incurred by the working-age group can be considered in two ways:

- Acute illness (AUD ~10.9 billion p.a.), chronic illness or long COVID (AUD ~6.6 billion p.a.) and deaths (AUD ~0.3 billion p.a.), or
- Infected adults with mild illness who are still well enough to work but with reduced capacity (AUD ~14.5 billion p.a.), and infected adults who are too ill to work (i.e., are hospitalized) (AUD ~3.0 billion p.a.)

Taking these together, acute illness in those who can still work but at reduced capacity accounts for ~50% (AUD ~10.6 billion) of all productivity losses incurred across the age groups. These figures illustrate that, despite the mildness of the illness for most, when modest reductions in working capacity are multiplied across a multi-day illness affecting ~13 million Australians, the cost impact is substantial.

Infections in the older population impose AUD ~3 billion p.a. in costs from productivity losses on the Australian economy, which highlights that productivity losses are not limited to those borne by working-age adults.

Older people that incur productivity losses due to COVID-19 fall into three categories:

- **Older people with COVID-19 who require care from a working-age person** – ~2.3 million working-age carers each incurring an AUD ~994 productivity loss – resulting in a total impact of AUD ~2.2 billion p.a.
- **Older people who directly participate in Australia's labor force** – estimated to be 15% of over-65s, 50% of whom work full-time. Infections in this group result in AUD ~570 million in productivity losses.
- **Older people (e.g., grandparents) who care for children to enable parents to work** – one survey found that 64% of grandparents providing care for grandchildren did so to enable parents to work. When this work-enabling care is disrupted, the productivity loss amounts to AUD ~190 million.

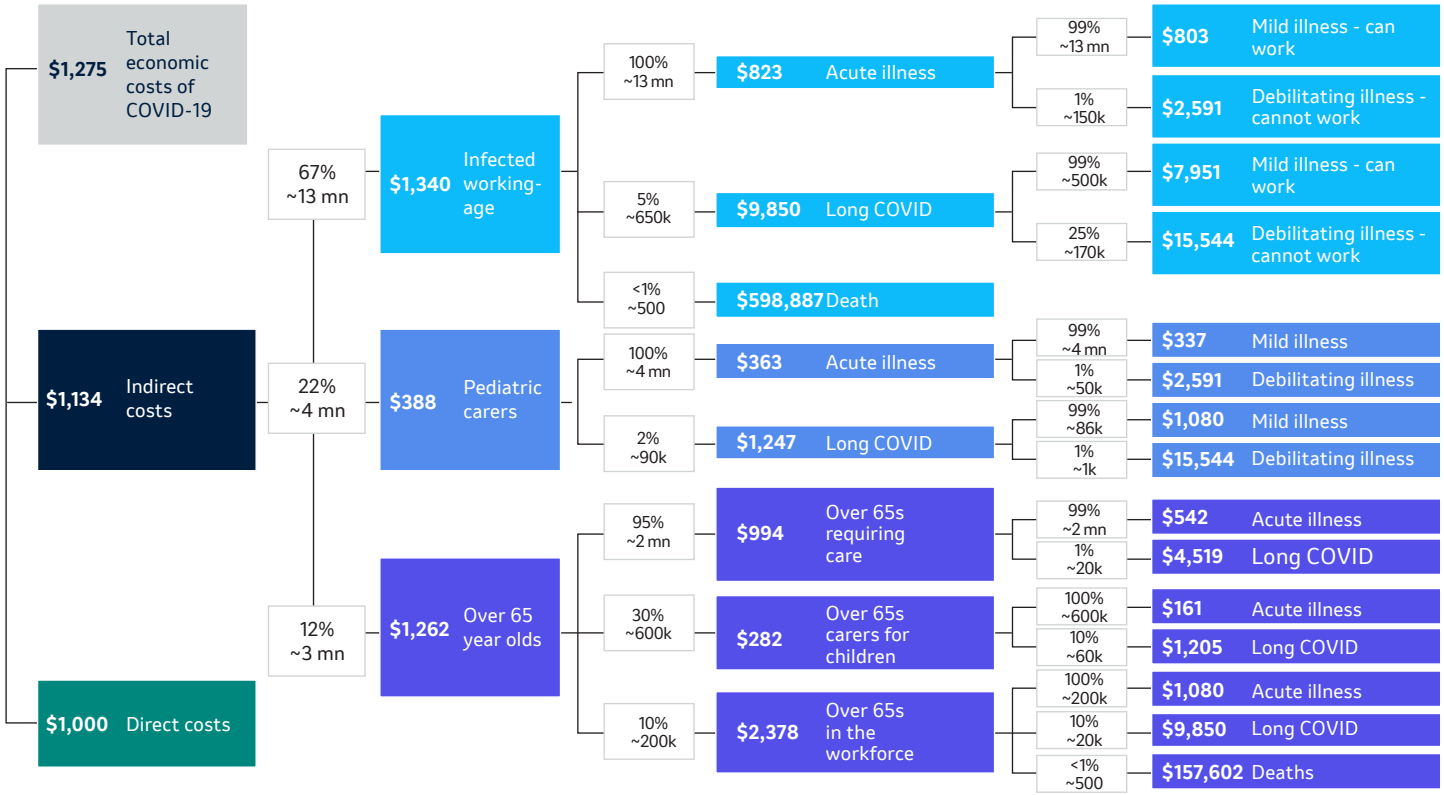
39. Based on a median weekly earnings figure of $1,209. Australian Bureau of Statistics [Internet]. Employee Earnings and Hours, Australia. 2022 Jan 19. Available from: https://www.abs.gov.au/statistics/labour/earnings-and-working-conditions/employee-earnings-and-hours-australia/latest-release#industry
40. Australian Institute of Health and Welfare [Internet]. Health Expenditure Australia 2019-20. 2021 Dec 17. Available from: https://www.aihw.gov.au/reports/health-welfare-expenditure/health-expenditure-australia-2019-20/contents/about
41. Johnsen S et al. European Respiratory Journal [Internet]. Descriptive analysis of long COVID sequelae identified in a multidisciplinary clinic serving hospitalised and non-hospitalised patients. 2021 Apr 20. Available: https://openres.ersjournals.com/content/erjor/7/3/00205-2021.full.pdf

Infections in the older population account for AUD ~3.2 billion p.a., or ~13% of all direct and indirect costs combined, serving as a stark reminder of the need to address costly infections in cohorts adjacent to working-age adults.

Finally, infections in children impose an additional economic cost of AUD ~1.7 billion p.a. owing to productivity losses borne by adults who are absent from or less productive at work while caring for children. As with those from the older population, productivity losses arising from infections in children can be difficult to recognize in advance but are significant when they emerge.

Productivity losses arising from infections in children are predominantly driven by adults caring for children with acute, mild illness. The cohort of infected children, which constitutes the majority (~92%) of productivity losses in adults caring for children with acute illness, is worth AUD ~1.5 billion p.a. This cost is driven by care for ~2.1 million mild infections in children, who despite having a mild illness require one parent to care for them at home. The remaining ~8% is driven by productivity losses from caring for children with debilitating infections. For parents who can work from home (~60%), productivity is estimated to halve, while all productivity is foregone from parents who cannot (~40%). This is a substantial cost driven more by lost work than the illness itself, reiterating that substantial costs imposed by productivity losses are not limited to infections in working-age adults.

Exhibit 8: Indirect economic costs from COVID-19, per person, base case, AUD p.a.



Costs per person for each segment are calculated by dividing the total cost of that segment by the number of individuals in that segment; Indirect costs arise from productivity losses incurred due to infection with COVID-19; 'Well enough to work' refers to those who can continue working while infected, albeit with reduced productivity; 'Too ill to work' refers to those who cannot work, at least for a portion of the time, while infected; 'Acute illness' refers to all infections not included in admissions care; Long COVID refers to a small subset (~5%) of total infections and represents infections with symptoms lasting 12 weeks or more.

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Despite the seeming reduction in resource intensiveness compared to direct healthcare costs, the magnitude of productivity losses imposed by COVID-19 means indirect costs are nearly as expensive on a per-person basis (as indicated in Exhibit 8 above), with each infection costing AUD ~1,130 on average. This is concentrated in productivity losses resulting from infections in the working-age (AUD ~1,340 per person) and the older population (AUD ~1,260 per person).

Together, economic costs arising from productivity losses in these cohorts amount to AUD ~23 billion p.a. or ~0.9% of Australia's GDP and are in addition to the value of lost health and direct costs to Australia's health system. Although already substantial, these costs are likely to underestimate the entirety of the burden imposed on society by COVID-19. These costs do not account for second-order impacts on health system capacity and flow-on effects on the health workforce, supply chains, as well as other aspects of critical industry, which all add to directly measurable economic impacts.

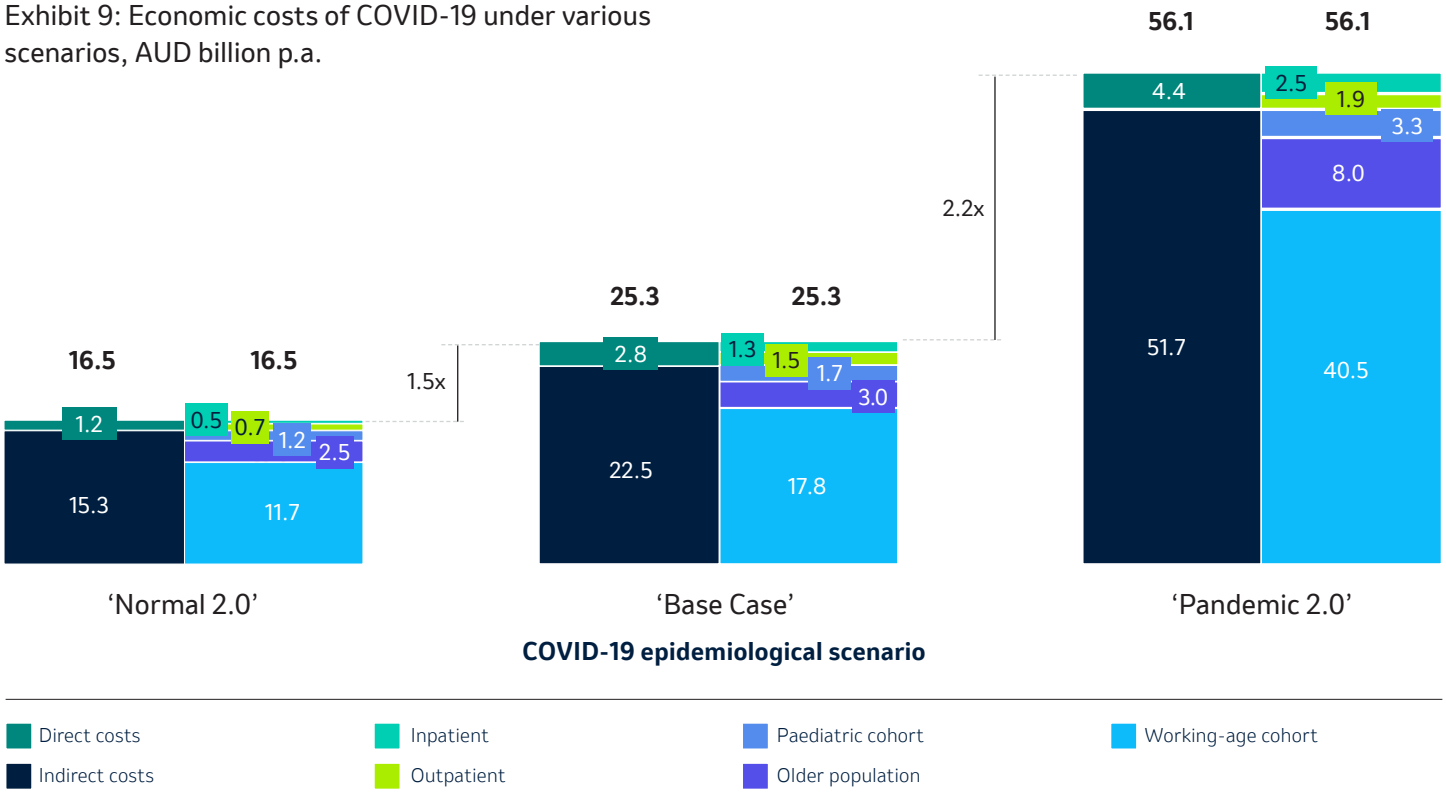
The entirety of the economic burden imposed by COVID-19 also needs to be understood in the context of the prevailing epidemiological scenario, as the impacts and costs described can significantly increase under plausible scenarios where novel variants emerge. Such scenario variations are described below.

3.3.3 Alternative scenarios: costs of Pandemic 2.0 and Normal 2.0

In addition to the base case, two further scenarios have been considered, as illustrated in Exhibit 9:

In a Pandemic 2.0 scenario, total economic costs could reach AUD ~56 billion p.a. Conversely, in the Normal 2.0 scenario, economic costs could decrease to AUD ~17 billion p.a.

Exhibit 9: Economic costs of COVID-19 under various scenarios, AUD billion p.a.



Normal 2.0 refers to a scenario featuring ~500,000 infections per million population and ~47,000 hospitalizations, reflecting conditions observed in mid-late 2022; Pandemic 2.0 refers to a scenario featuring ~1 million infections per million population and ~285,000 hospitalizations, reflecting conditions observed in early 2022.

The two example scenarios represent divergent epidemiological outcomes that are both plausible as the pandemic evolves. Each theoretical scenario is designed with attention to two key features:

- Infection volume (driven by contagiousness; measured by cases per million population per year), and
- Case severity (driven by a prevailing strain's virulence factors; measured by the resulting hospitalization rate)

A Pandemic 2.0 scenario would feature a case volume of ~1 million cases per million population per year (i.e., the entire population is infected once, on average) and a case severity that drives ~130,000 inpatient admissions. This compares to the base case scenario of a case volume of ~750,000 infections per million population and ~109,000 inpatient admissions. These thresholds represent epidemiological conditions very similar to those observed in Australia in late 2022.

In this scenario, economic impacts from COVID-19 could increase to AUD ~56 billion p.a., equating to ~2.2% of GDP and AUD ~2,175 per person. In this scenario, direct costs could be AUD ~4.4 billion p.a. (a 1.6 times increase of AUD ~1.6 billion p.a.) and indirect costs could reach AUD ~52 billion p.a. (a 2.3 times increase of AUD ~29 billion p.a.). These increases would be driven by increased hospitalization rates, longer lengths of stay, and augmented productivity losses from an increased incidence of debilitating illness and longer periods of missed work.

The magnitude of the cost increases that could result from a plausible epidemiological Pandemic 2.0 scenario demonstrates the need for a range of preparedness settings that include options to limit impacts at all junctures.

In addition to economic impacts, a high-demand scenario such as this can also impose 'second order' impacts on health system capacity such as disruptions to elective surgery services and the displacement of care that these disruptions entail. For example, ~200,000 fewer elective surgeries were performed by the public health system across 2019-22, cumulatively, versus a pre-pandemic baseline (2018-19).[42] The largest cumulative volume of displaced care was in general surgery, followed by orthopedics, ophthalmology, and ENT, but there were cumulative deficits in every specialty. Moreover, the annual rate of care displacement appears to be deteriorating rather than improving, with the greatest number of displacements occurring in 2022.

Separate data from the Medicare Benefits Schedule (MBS) demonstrates that these foregone procedures were not picked up by the private system, suggesting that care was genuinely displaced. The volume of (~12.8 million p.a.) and benefits paid (AUD ~2.1 billion p.a.) for surgical procedures in the private system remained flat across 2020 through to Q2, 2022, compared to pre-pandemic levels in 2019. Therefore, this trend represents a reduction against forecast volumes (especially given their pre-COVID growth trajectory), in contrast to an expected small increase if public elective surgery volumes were conducted in the private system.

Over the three-year course of the pandemic to date, a cumulative ~42,000 fewer elective orthopedic procedures took place compared to the 2018-19 baseline, primarily due to the impact of COVID-related disruptions. This suggests that ~4,600 waitlisted total hip replacements and ~6,200 total knee replacements were not performed.[43] With most of these cases due to osteoarthritis, displaced orthopedic care indicates a significant burden of morbidity and disability has been imposed on these patients due to COVID-19 disruptions, as well as an ongoing burden on the health system in managing patients with advanced, complex diseases.[44]

42. Australian Institute of Health and Welfare [Internet]. Elective surgery waiting times 2021-2022. Available from: https://www.aihw.gov.au/getmedia/6348652f-959a-447a-93a5-c8081c085106/Elective-surgery-waiting-times-2021-22.xlsx.aspx
43. THRs accounted for 11% of FY22 case volume and TKRs 15%. Australian Institute of Health and Welfare [Internet]. Elective surgery waiting times 2021-22. Available from: https://www.aihw.gov.au/getmedia/6348652f-959a-447a-93a5-c8081c085106/Elective-surgery-waiting-times-2021-22.xlsx.aspx
44. Johns Hopkins Medicine [Internet]. Osteoarthritis 2022.. Available from: https://www.hopkinsmedicine.org/health/conditions-and-diseases/arthritis/osteoarthritis

Conversely, while a relatively small number of procedures in children were not performed (~680), these still carry a significant impact. Common elective procedures in children, such as tonsillectomies and hernia repairs, can lead to sleep, learning, and behavioral difficulties as well as potential pain and intestinal damage if left untreated.[45] Care displacement of this nature serves as one example of the far-reaching impact the ongoing COVID-19 pandemic could have on both patients and the health system in a high-demand scenario.

A Normal 2.0 scenario would feature a case volume of ~500,000 cases per million population per year and ~45,000 inpatient admissions. These thresholds represent the lowest recorded levels for each measure observed in Australia during the pandemic. Under a Normal 2.0 scenario, economic impacts from COVID-19 could reduce to AUD ~16.5 billion p.a., equating to ~0.6% of GDP and AUD ~1,185 per person. Direct costs could decrease to AUD ~1.2 billion p.a. and indirect costs to AUD ~15.3 billion p.a. Decreases in costs would be driven by lower hospitalization rates and diminished productivity losses owing to reduced periods of missed work.

While scenarios help us to consider potential courses that the COVID-19 pandemic may take in the future, their scope is largely restricted to quantifiable economic cost considerations. Equally important to consider are the second-order impacts that COVID-19 could have on health system capacity and ripple effects on vulnerable populations and critical industries.

45. Connecticut Children's Hospital [Internet]. Growing Healthy—Topics you care about 2023. Available from: www.connecticutchildrens.org

3.4 Considerations For Particular Cohorts And Industries

The economic costs of COVID-19 described will impact different populations and industries disproportionately. This includes those that play a critical economic or social role (e.g., health care workers), those that are particularly vulnerable to severe disease (e.g., people with comorbidities), and those that go on to develop long COVID.

Interventions that protect health and productivity losses in these critical industries and populations may yield corresponding disproportionate economic returns. Disruptions to these groups also cause significant economic and societal concern and may be worthy of additional focus when considering countermeasure approaches to mitigate the impacts of COVID-19.

3.4.1 Critical workers and industries

As outlined above, some critical industries experience disproportionate workforce productivity losses that generate significant public concern. Here, the focus is on three industries in particular – healthcare, logistics, and travel and tourism.

The economic costs of COVID-19 borne by critical industries and their stakeholders may increase under a Pandemic 2.0 scenario. In this scenario, these workforces, which are largely unable to work from home, may be required to isolate while they recover. The resulting loss of productive time can be 30% greater (the equivalent of one to two workdays) than individuals in desk-based jobs.

3.4.2 Healthcare

Australia's health system serves as the country's first and last line of defense against COVID-19 and other health threats. The AUD ~202.5 billion industry employs ~650,000 healthcare practitioners.[46,47]

At a potential minimum cost of AUD ~2.3 billion p.a. (~9% of the combined total cost),[48] healthcare workers who become infected with COVID-19 represent a disproportionate contributor to the impacts on the economy. However, this also likely significantly underestimates the total impact on the Australian economy and citizens' welfare, due to flow-on effects on patient outcomes.

Health services experience higher rates of absenteeism due to COVID-19 compared to other industries. Employers reported a 25% to 47% rate of COVID-19 sick leave in 2022, with some hospitals experiencing rostering gaps of up to ~40%.[49,50] Healthcare workers' increased exposure to, and risk of, COVID-19 infection in the workplace is estimated at three times greater than the general population.[51] Productivity losses are not only incurred by sick workers but also by the remaining workers who are required to take up additional responsibilities. The extra workload reduces time to complete additional tasks other than patient care and contributes to exhaustion, reduced empathy, and an increased risk of workplace errors.

The flow-on economic impact of COVID-19-related absenteeism among healthcare workers is significant. COVID-19 exacerbates (pre-existing) workforce shortages, resulting in poorer quality and safety of healthcare provision. Even recently, shortages have contributed to emergency department wait-times of up to 12 hours and record delays in 'lights and sirens' (Code 1) ambulance responses.[52,53] Such reductions in the availability and timeliness of medical care may subsequently lead to prolonged illness or recovery times for patients, who in turn accumulate their own, additional productivity losses.

Additionally, the COVID-19 pandemic has witnessed unprecedented levels of workforce burnout and attrition.[54] Although the initial impact of the pandemic has subsided, global talent shortages and mobility limitations are ongoing challenges.

A countermeasure approach that targets healthcare workers is essential in mitigating overall economic costs as well as COVID-19 impacts on public health. This urgency is backed by the disproportionate costs of COVID-19 infections among healthcare workers against the backdrop of an increasingly constrained talent market.

3.4.3 Logistics

COVID-19 has caused unprecedented disruption to Australia's transport and logistics sector, which delivers vital goods and services across the nation. It is an AUD ~120 billion industry, with a growing workforce of over 550,000 people.[55] During the pandemic, the sector experienced a disproportionate impact of productivity loss from workers, which has snowballed to disrupt local and global supply networks.

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46. Australian Institute of Health and Welfare [Internet]. Health Expenditure Australia 2019-20. 2021 Dec 17. Available from: https://www.aihw.gov.au/reports/health-welfare-expenditure/health-expenditure-australia-2019-20/contents/about
47. Australian Institute of Health and Welfare [Internet]. Health workforce. 2022 Jul 7. Available from: https://www.aihw.gov.au/reports/workforce/health-workforce
48. Based on a median weekly earnings figure of $1,287. Australian Bureau of Statistics [Internet]. Employee Earnings and Hours, Australia. 2022 Jan 19. Available from: https://www.abs.gov.au/statistics/labour/earnings-and-working-conditions/employee-earnings-and-hours-australia/latest-release#industry
49. Australian Bureau of Statistics [Internet]. Staff absent in 22% of businesses due to COVID-19. 2022 Feb 11. Available from: https://www.abs.gov.au/media-centre/media-releases/staff-absent-22-businesses-due-covid-19
50. Thompson, H. WA Today [Internet]. $40K for 10 days' work: Doctors offered huge pay to fill in at Geraldton Hospital. 2022 Jan 19. Available from: https://www.watoday.com.au/national/western-australia/40k-for-10-days-work-doctors-offered-huge-pay-to-fill-in-at-geraldton-hospital-20220118-p59p4s.html
51. Quigley, A.L. et al. Elsevier Public Health Emergency Collection [Internet]. Estimating the burden of COVID-19 on Australian healthcare workers and health system during the first six months of the pandemic. 2020 Oct 29. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7598370/
52. McMillan A, Schelle C. The Age [Internet]. Ambulance Victoria code red called after 'lights and sirens' delay. 2022 Dec 3. Available from: https://www.theage.com.au/national/victoria/ambulance-victoria-code-red-called-after-lights-and-sirens-delay-20221203-p5c3c9.html
53. Dow A, Sambul N. The Age [Internet]. 'Incredibly challenging': All hands on deck as children's hospital faces 12-hour emergency queue. 2022 Dec 6. Available from: https://www.theage.com.au/national/victoria/royal-children-s-hospital-advises-patients-to-go-elsewhere-20221205-p5c3v7.html
54. Willis K, Maple J, Bismark M, Smallwood N. The Conversation [Internet]. A burnt-out health workforce impacts patient care. 2022 May 5. Available from: https://theconversation.com/a-burnt-out-health-workforce-impacts-patient-care-180021#:~:text=This%20review%20cites%20studies%20finding,increased%20mortality%20in%20one%20study
55. Australian Industry Standards [Internet]. Transport and Logistics Industry Outlook 2021. Available from: https://www.australianindustrystandards.org.au/industries/transport-and-logistics/

Australia's transport operators and distribution centers have experienced significant workforce shortages due to COVID-19 illness. Among this workforce are warehouse staff, forklift drivers, unpack crews, and technicians, who are unable to fulfill work obligations at home while ill, isolating, or caring for others who have been infected with COVID-19. While absenteeism across all industries has reached peaks of ~10%,[56] reductions in the logistics sector have increased from 20% to half of the available labor.[57,58] Subsequently, these businesses struggle to retain other employees who are required to work longer hours to compensate for the lost labor.

Workforce shortages also have downstream consequences for end-point retailers, users, and customers. In June 2022, over 40% of businesses faced COVID-related supply chain disruptions, and almost half of those to a 'great' extent (e.g., major delays and impacts to revenue). Disruptions have the dual effect of driving inflation in the costs of goods and services and impeding the ability of businesses, and their workers, to deliver them. Among these goods are necessities of particular public importance such as food, life-altering medicines, oil, and gas.

The impact of workforce shortages may point to an incremental opportunity for targeted COVID-19 countermeasures to support Australia's logistics industry, as it grapples with the multitude of challenges (including geopolitical tensions) at the heart of today's supply chain crisis.

3.4.4 Travel and tourism

Despite a strong economic recovery, Australia's travel and tourism sector continues to face headwinds due to workforce shortages. One of the highest-yielding destinations in the world prior to the COVID-19 pandemic, the sector contributed ~2.5% to the national economy and supported ~5% of the national workforce.[59] The pandemic led to a steep decline in tourism revenue due to border closures, lockdowns, and hesitancy to travel.

COVID-19-related absenteeism has wreaked havoc across industries, from airports to accommodation services. Some employers saw staff shortages rise to 25% overnight.[60] In July 2022, Qantas and Virgin Airlines recorded their worst on-time performances,[61] with flight disruptions impeding corporate travelers' productivity and holidaymakers' spending.

Countermeasures targeted at Australia's travel and tourism workforce are needed to help these industries recover from the COVID-19 pandemic.

3.4.5 Vulnerable populations

COVID-19 illness in Australia's vulnerable populations represents a minimum impact of AUD ~12.4 billion p.a. to Australia's economy. These populations are at greater risk of severe COVID-19 disease and are more heavily reliant on the healthcare system than others. Populations that have received particular attention throughout the pandemic include those over 65 years old, those with comorbidities, and Indigenous Australians.

COVID-19 illness in Australia's older population (65 years and over) could have an economic impact of AUD ~3.2 billion p.a. (~13% of the combined annual impact), a significant AUD ~1,430 per person. Despite representing just ~12% of confirmed cases, the older population represents over 40% of COVID-19 hospitalizations.[62] This figure is not surprising when

56. Whelan S. The Load Star [Internet]. Staff shortages from COVID heighten chronic Australian supply chain delays. 2022 Jan 31. Available from: https://theloadstar.com/staff-shortages-from-covid-heighten-chronic-australian-supply-chain-delays/
57. Whelan S. The Load Star [Internet]. Omicron outbreak in Australia wreaking havoc with supply chains. 2022 Jan 7. Available from: https://theloadstar.com/omicron-outbreak-in-australia-wreaking-havoc-with-supply-chains/
58. Butler B. The Guardian; [Internet]. Australia's supply chain issues likely to continue despite drop in Covid cases. 2022 Feb 13. Available from: https://www.theguardian.com/australia-news/2022/feb/13/australias-supply-chain-issues-likely-to-continue-despite-drop-in-covid-cases
59. Tourism Research Australia [Internet]. National Tourism Satellite Account 2020-21. Available from: https://www.tra.gov.au/data-and-research/reports/national-tourism-satellite-account-2020-21
60. Wiggins J. Australian Financial Review [Internet]. Airports say jobs shortages 'could persist'. 2022 Jun 23. Available from: https://www.afr.com/companies/infrastructure/airports-say-jobs-shortages-could-persist-20220623-p5aw0f
61. Magennis M. 7 News [Internet]. Major airlines on track to record worst ever performances amid staff shortage crisis. 2022 Jul 12. Available from: https://7news.com.au/sunrise/major-airlines-on-track-to-record-worst-ever-performances-amid-staff-shortage-crisis--c-7490084
62. Admitted patient activity. Australian Institute of Health and Welfare [Internet]. Available from: https://www.aihw.gov.au/reports-data/myhospitals/intersection/activity/apc

considering the high prevalence of comorbidities such as high blood pressure, cancer, and diabetes in this age group, which affect ~65% of those over 70 years old.[63]

Comorbidities in the younger, working-age (19–64-year-old) population could also have a disproportionate impact of AUD ~9.0 billion p.a. Just one comorbidity doubles the risk of severe COVID-19,[64] subsequently increasing the likelihood of hospitalization and prolonging time off work to recover. This could be a reality for at least 50% of 45–64-year-olds in Australia.[65]

COVID-19 continues to exacerbate the health gap between Indigenous and non-Indigenous Australians. The Indigenous community has high rates of chronic illness and faces inequalities in access to health services which heightens their susceptibility to severe COVID-19. In addition, the pandemic has amplified disparities in the social determinants of health, which account for one-third of the health gap. These include employment, hours worked, the completion of schooling, and household incomes – all of which decline when individuals become ill or need to care for loved ones.[66]

Given that almost 50% of combined direct and indirect costs are borne by these vulnerable populations, countermeasures that reduce the duration of illness and/or time to recover for this group alone could significantly mitigate the costly impacts of COVID-19. Countermeasures may include ongoing vaccination, community interventions, or the use of oral antivirals. Although oral antivirals are only available to a smaller subset of vulnerable populations, this subset already accounts for AUD ~3.1 billion p.a. in economic costs or ~12% of the total economic costs to Australia.

3.4.6 Long COVID

Long COVID[67] has a potential minimum impact of AUD ~8.6 billion p.a. on Australia's economy. Individuals who develop this condition experience prolonged productivity losses (increasing indirect costs) and reliance on health services (increasing direct costs).

Direct costs due to long COVID collectively amount to at least AUD ~590 million (AUD ~593 per person), largely driven by consultations. When the incidence, relative complexity, and duration (90 days) of long COVID illness are factored in, ~6 million healthcare consultations are required for this cohort alone.[68,69] Long COVID, therefore, represents a substantial burden on the health system, both in terms of required capacity and economic costs.

Productivity losses from long COVID could amount to AUD ~8.0 billion p.a. (AUD ~8,058 per person and ~35% of all indirect costs). The largest contributor, by a significant margin, is productivity losses arising from long COVID in the working-age population (AUD ~6.5 billion p.a. or ~82%). To illustrate this further, an adult with long COVID, despite being well enough to work, could still lose the equivalent of 46 workdays over a three-month period of illness, due to impairments to productivity.[70]

Given the large share (~32%) of total economic costs that long COVID imposes on the Australian economy, any countermeasure that is able to reduce the incidence and/or duration of this condition would contribute a great deal to mitigating economic costs associated with the pandemic. Conservative estimates place the incidence and duration of long COVID at 5% and 90 days respectively. However, as an emerging field, the full scope of long COVID might still be underestimated.

63. Roy Morgan [Internet]. 1.8 million Australians aged 70+ have a 'comorbidity' condition that puts them at higher risk from COVID-19. 2020 Apr 28. Available from: https://www.roymorgan.com/findings/1-8-million-australians-aged-70-have-a-comorbidity-condition-that-puts-them-at-higher-risk-from-covid-19
64. Liu B, Spokes P, He W, Kaldor J. High risk groups for severe COVID-19 in a whole of population cohort in Australia. BMC Infectious Diseases [Internet]. 2021 Jul 16. Available from: https://bmcinfectdis.biomedcentral.com/articles/10.1186/s12879-021-06378-z
65. Australian Institute of Health and Welfare [Internet]. Chronic conditions and multimorbidity. 2022 Jul 7. Available from: https://www.aihw.gov.au/reports/australias-health/chronic-conditions-and-multimorbidity
66. Australian Institute of Health and Welfare [Internet]. Determinants of health for Indigenous Australians. 2022 Jul 7. Available from: https://www.aihw.gov.au/reports/australias-health/social-determinants-and-indigenous-health
67. Also commonly described as 'post-COVID-19 syndrome', long COVID describes the prolonged duration of COVID-19 symptoms beyond twelve weeks after the initial infection.
68. Inquiry into Long COVID and Repeated COVID Infections. Parliament of Australia [Internet]. Available from: https://www.aph.gov.au/longandrepeatedcovid
69. Each case could require 6 consultations on average over the 90-day period of long COVID illness.
70. Based on an average of 9 days of sick leave and reported reductions in productivity while working, due to long COVID

4. Economic Cost of COVID-19 in Taiwan

In Taiwan, the future economic cost of COVID-19 could range from TWD ~91 billion p.a. (~0.4% of GDP) to TWD ~573 billion p.a. (~2.3% of GDP) depending on the scenario that evolves. These costs are far greater than commonly recognized. COVID-19 not only inflicts health losses through illness and death but also imposes substantial economic costs including direct costs on the healthcare system and productivity losses from missed work.

Living with ongoing transmission of the virus and the burden of disease it incurs is a reality that markets have had to come to terms with. However, there has been an incomplete uptake of the tools available to reduce this burden. To better inform the ongoing discussion on COVID-19's impacts and how we could benefit from addressing these impacts, it is important to understand the full range of economic costs imposed by COVID-19.

There is a range of potential epidemiological scenarios for how the COVID-19 pandemic may evolve.[71] This is reflected in the wide range of existing estimates for the economic costs due to COVID-19 (which also vary due to interventions studied and the scope of costs included). Possible epidemiological scenarios include a base case, where current conditions prevail, and alternative scenarios that differ in the volume of infections and their severity (driven by, for example, the interplay between variants and the level of immunity maintained in the population).

In the base case scenario, total economic costs could be TWD ~233 billion p.a. (~0.9% of GDP), with:

- The majority (TWD ~200 billion p.a., ~86%) due to productivity losses (indirect costs) through missed work by both working-age adults and elderly in the workforce, either during their own illness or while caring for dependents (children and over 65-year-olds) affected by COVID-19.
- A minority (TWD ~33 billion p.a., ~14%) borne by the health system (direct costs), in both inpatient (TWD ~9.5 billion p.a.) and outpatient (TWD ~23.5 billion p.a.) settings.

In a Pandemic 2.0 scenario, economic costs could reach as high as TWD ~573 billion p.a. (~2.3% of GDP). This assumes transmission rates that result in ~24 million infections per year (instead of ~20 million in the base case) and a severity that results in ~110,000 hospitalizations

71. Institute of Health Metrics and Evaluation [Internet]. Institute of Health Metrics and Evaluation. 2022 Nov, used with permission. Taiwan, 2022 Nov, used with permission. Institute of Health Metrics and Evaluation (IHME) [Internet]. COVID-19 Results Briefing, Taiwan. 2022 Dec 15. Available from: https://www.healthdata.org/sites/default/files/covid_briefs/8_briefing_Taiwan_Province_of_China.pdf

- Local currencies have been used in this Section, reflecting the use and findings of local data sources. The below exchange rates were used in all local currency conversions to USD in this report. USD currency exchange rate conversions via Google Finance as of 28 February 2023 (USD1 = AUD 1.4861 = HKD 7.8493 = KRW 1,322 = SGD 1.3484 = TWD 30.6608): https://www.google.com/finance/markets/currencies?hl=en

(compared with ~77,000 in the base case). In contrast, at the lower end of the spectrum, a Normal 2.0 scenario might feature ~6.7 million infections over the course of a year with only ~30,000 hospitalizations, which would translate to direct and indirect costs of TWD ~91 billion p.a.

These economic costs are unevenly distributed. The health and logistics workforces, those affected by long COVID, and vulnerable populations are likely to be disproportionately impacted. For example, economic costs in the health workforce total TWD ~15.9 billion p.a. (~0.1% of GDP). This is driven by high levels of absenteeism and a likelihood of infection that is twice as high as that of the general population, with consequences for health system capacity and quality of care. Those affected by long COVID are impacted most significantly, with the value of lost work and health system utilization totaling TWD ~73 billion p.a. (~0.3% of GDP) or ~32% of all economic costs. Finally, COVID-19 illness in vulnerable populations contributes TWD ~118 billion p.a. (~0.5% of GDP; see Section 4.4.5).

Fortunately, a range of countermeasures remains available that may mitigate the economic costs of COVID-19 (see Section 8), including vaccination, therapeutics, and community measures (i.e., non-pharmaceutical interventions). Strengthening these countermeasures may allow Taiwan to mitigate the potentially high economic costs of the continuing pandemic.

4.1 Context: The Situation In Taiwan

Today, Taiwan is relatively free of restrictive measures. Most of the community measures employed earlier in the pandemic, such as border closures and sophisticated contact tracing, have been pared back. These measures have now been replaced by the widespread availability and uptake of vaccines. Therapeutics such as antivirals have also been made available to a subset of the Taiwanese population that meets eligibility criteria indicating they are at high risk of developing severe disease.

As of early December 2022, Taiwan was experiencing a reduction in the volume of infections following its second Omicron wave. With ~40,000 new infections per day, and an effective transmission number[25] of ~0.99, infection volumes were stabilizing. Just two months earlier, however, in October 2022, at the height of this second wave, there were ~120,000 new infections per day. By contrast, in January 2022 there were just ~700 infections per day.[72] This occurred when wide-ranging response measures were still in place and the Omicron variant had not yet emerged. The change in Taiwan's pandemic response approach is both a reaction to the volume of infections and a driver of the subsequent infection volume.

72. Institute of Health Metrics and Evaluation [Internet]. COVID-19 estimates, 2022 reference scenario, Taiwan. 2022 Dec. Available from: https://ihmecovid19storage.blob.core.windows.net/archive/2022-12-16/data_download_file_reference_2022.csv

Taiwan's initial measures were very effective at containment and suppression of the virus while managing to limit economic costs. By international standards, the countermeasures employed during the first phase (2020 to 2021) were very successful. The number of reported cases (~17,000) and deaths (~1,000) were among the lowest in the OECD.[73] In addition, Taiwan managed to avoid negative economic growth in each of the pandemic's three years, an outcome matched neither by the G20 nor by other comparable OECD markets.[74] However, border closures, social-distancing requirements, strict contact tracing, and mask-wearing mandates still imposed significant hardships on the community. The successful rollout of vaccines[75] afforded an easing of many restrictions in April 2022, although the immunity conferred was found to wane over time. This waning immunity necessitated third (and ultimately fourth) doses. However, the emergence of novel variants such as Omicron continued to reduce population immunity in general.

Oral antivirals have been added to Taiwan's response toolkit. The necessarily short-term nature of restrictive community measures and the remaining health threat posed by COVID-19 led Taiwan to broaden its approach to include oral antivirals, which became available in Taiwan in January 2022.[76]

Nevertheless, the health and economic outcomes of the reopening phase have been mixed. The vast majority (>99%) of Taiwan's infections occurred in 2022.[77] While infections were not as severe as early in the pandemic, the high volume of infections led to the busiest year of the pandemic yet for the hospital system, with an average of ~200 hospital admissions per day, compared to ~9 in 2021 and just ~2 in 2020.

The high volume of infections also had an economic impact, both directly through costs borne by the health system in addressing COVID-19, and indirectly by society through absenteeism and productivity declines. These will be explored in detail in Sections 4.3.1 and 4.3.2. Taiwan's reopening experience has illustrated that the costs of COVID-19 borne by Taiwanese society extend beyond the value of health losses captured by conventional health technology assessments. Indeed, productivity losses driven by infections across all age groups constitute a major economic cost.

A better understanding of the economic costs of COVID-19 may better inform the assessment of the costs and benefits of various measures to address COVID-19. Indeed, despite the ongoing burden on society, while vaccination coverage has been widespread, the use of antivirals tends to track infection waves, and use remains relatively uncommon at a prescription rate of ~3% of all infections.[78]

73. Cumulative confirmed COVID-19 cases. Our World in Data [Internet]. Available from: https://ourworldindata.org/explorers/coronavirus-data-explorer?time=earliest..2021-12-30&facet=none&Metric=Confirmed+cases&Interval=Cumulative&Relative+to+Population=false&Color+by+test+positivity=false&country=~AUS Cumulative confirmed COVID-19 cases. Our World in Data [Internet]. Available from: https://ourworldindata.org/explorers/coronavirus-data-explorer?time=earliest..2021-12-30&facet=none&Metric=Confirmed+cases&Interval=Cumulative&Relative+to+Population=false&Color+by+test+positivity=false&country=~AUS
74. National Statistics Republic of China (Taiwan) [Internet]. Economic Growth Rate. Available from: https://eng.stat.gov.tw/Point.aspx?sid=t.1&n=4200&sms=11713
75. As in many international jurisdictions, a vaccine rollout strategy was adopted in 2021 as a conduit for an easing of various restrictions. The resulting population-wide vaccination program (which excluded ineligible children) delivered a double-dose national vaccination rate of >90% by November 2021. As of December 2022, 94% of the eligible population have had two COVID-19 vaccine doses. Uptake waned somewhat after the second dose, with the third 'booster' only reaching 74%. Taiwan National Centre for High-performance Computing [Internet]. Vaccination Dashboard. 2023 Apr 7. Available from: https://covid-19.nchc.org.tw/dt_002-csse_covid_19_daily_reports_vaccine_city2.php?language=en
76. Oral antivirals are currently available to all COVID-19 positive patients over the age of 12 who are at high risk of severe disease, to be taken within 5 days of symptom onset.
77. There have been ~8 million COVID-19 infections in Taiwan this year, compared to ~17,000 in 2020-21. Institute of Health Metrics and Evaluation. COVID-19 projections. 2022 Nov 18. Available from: https://www.healthdata.org/covid/data-downloads
78. Based on a tendered volume of doses ordered by Taiwanese authorities (~700,000), divided by the projected annual number of infections (~20 million). Taiwan Centers for Disease Control [Internet]. 公開招標公告 (Tender documents for 700,000 doses of Paxlovid). 2022 Dec 6. Available from: https://www.cdc.gov.tw/Uploads/files/b16f6eed-8d74-4531-a826-a1b9202c1ec3.pdf

4.2 Key Assumptions In The Taiwan Context

A range of informed assumptions is used to derive the estimates of economic costs in Taiwan as a result of COVID. Exhibit 10 illustrates how these assumptions are used and provides a list of key assumptions used, while a full list of assumptions is given in the Appendix section.

Exhibit 10: Use of assumptions in the Taiwanese context

A | Epidemiological scenarios

Scenario	Infections (mn) p.a.	Inpt. admiss. (k)
Normal 2.0	~7	~30
Base	~20	~77
Pandemic 2.0	~26	~111

→

B | Direct costs: borne by the health system

Key Base Case Assumptions	
# Ward admissions p.a.	~70,000
# ICU admissions p.a.	~7,000
% Infections that visit a GP	3-12%
% Infections prescribed OAVs	3.3%
# Long COVID cases p.a.	~990,000

+

C | Indirect costs: economic productivity losses borne by society

Key Base Case Assumptions	
Working-age infections as proportion of total	67%
Proportion of working-age infections that can work	99.6%
Proportion of working-age infections that can work from home	63%
Average number of working days lost due to acute illness in working-age population	~6
Average daily salary	TWD 1,433

=

D | Total economic cost to society

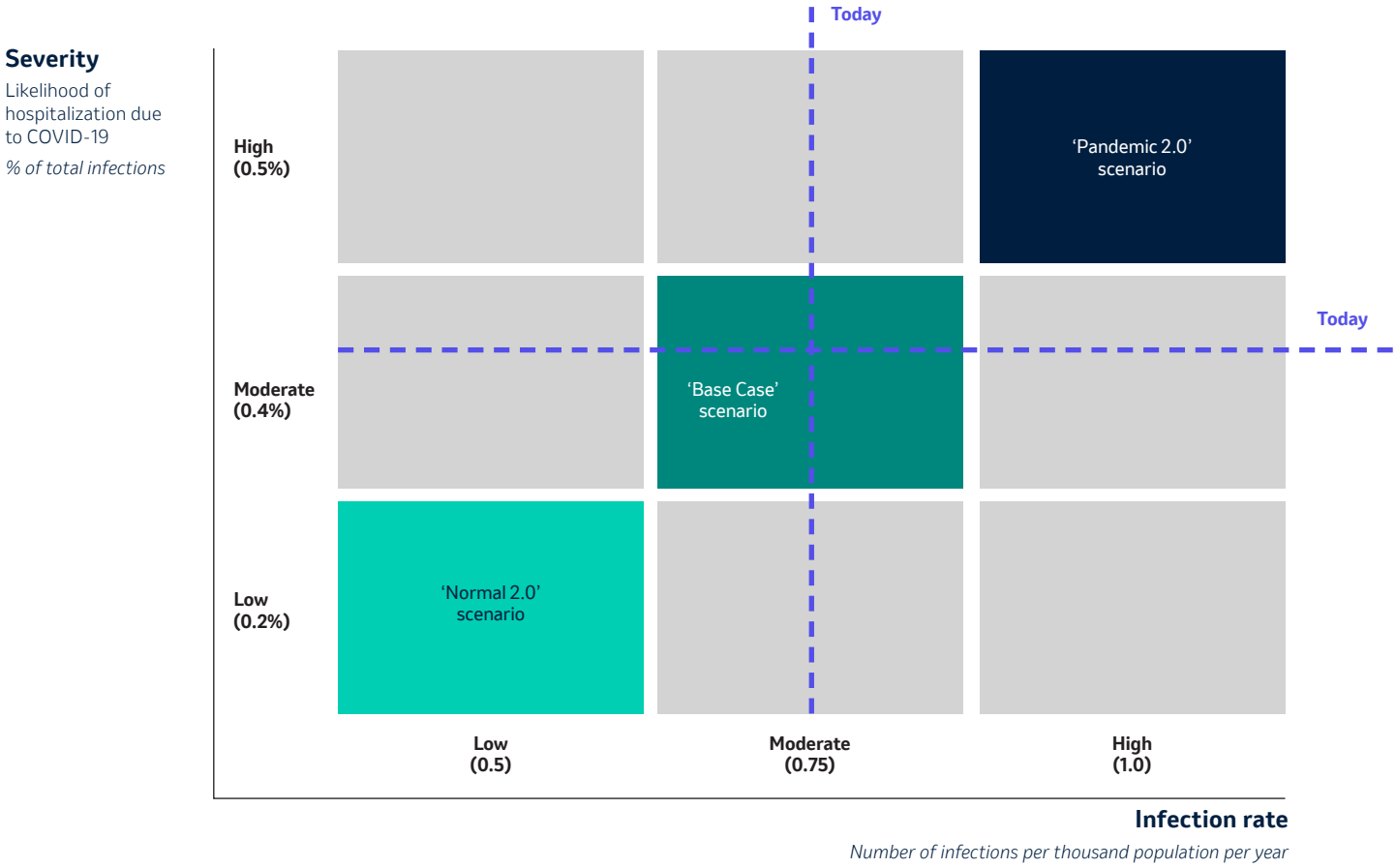
- **Total direct and indirect costs,** broken down by patient/demographic group
- **Costs per person** in each patient/ demographic group

  - E.g., if total inpatient costs are $1bn, and 75,000 patients are admitted, the cost per person is ~ $13,000

A full list of assumptions is given in the appendix.

4.3 Future:
Scenario-Based Estimates Of The Economic Costs Of COVID-19 In Taiwan

Exhibit 11: Potential epidemiological scenarios



Scenarios are indicative only and based on the observed epidemiology of COVID-19 in Taiwan in 2022..

Scenarios help us to consider and envisage the potential courses that the COVID-19 pandemic may take in the future. One way to express scenarios is in the form of low (Normal 2.0), base case, and high (Pandemic 2.0) epidemiological trajectories.

As Exhibit 11 illustrates, in the Taiwan context this might mean:

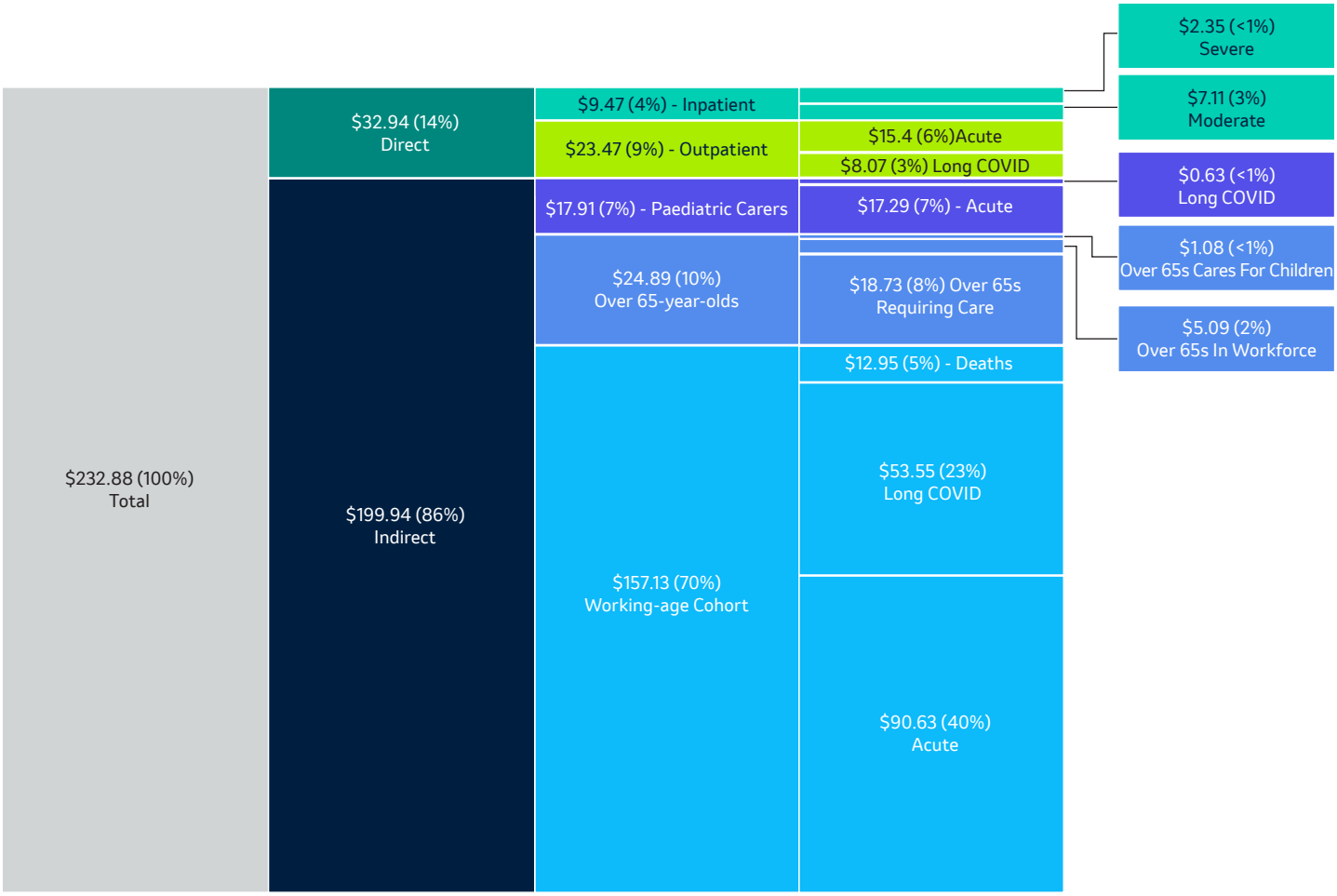
- A base case, with a total economic cost of TWD ~233 billion p.a. (~0.9% of GDP), (in addition to the value of lost health, such as that already considered in HTAs), which assumes a rate of infection (e.g., ~840,000 infections per million population annually) and a viral severity driving ~77,000 hospital admissions annually, similar to what was seen in August 2022.[79] This is the scenario shown in Exhibit 12 below and described in the direct (4.3.1) and indirect (4.3.2) costs Sections below.

79. Infection numbers and hospitalization rates are sourced from modeling of COVID-19 infections in Taiwan by the Institute of Health Metrics and Evaluation (IHME; used with permission). In Taiwan, infection numbers are twice the number of reported cases, recognizing the volume that is not detected by the testing process.

- **A low or Normal 2.0 case, with an economic cost of TWD ~91 billion p.a. (~0.4% of GDP)** which assumes a lower rate of infection (e.g., ~290,000 infections per million population per year) and a viral severity driving ~30,000 hospitalizations, reflecting reported case numbers from November 2022.[80] As this scenario is based on reported case numbers, it should be noted that 'actual' COVID-19 infection volumes could be up to ~2 times higher.

- **A high or Pandemic 2.0 case, with an economic cost of TWD ~573 billion p.a. (~2.3% of GDP)** which assumes a higher rate of infection (e.g., 1 million infections per million population per year) and a higher viral severity driving ~110,000 hospitalizations annually, reflecting a scenario where each individual contracts the virus once per year.

Exhibit 12: Direct and indirect costs of COVID-19 to Taiwan's economy in a base case scenario, TWD billion p.a.



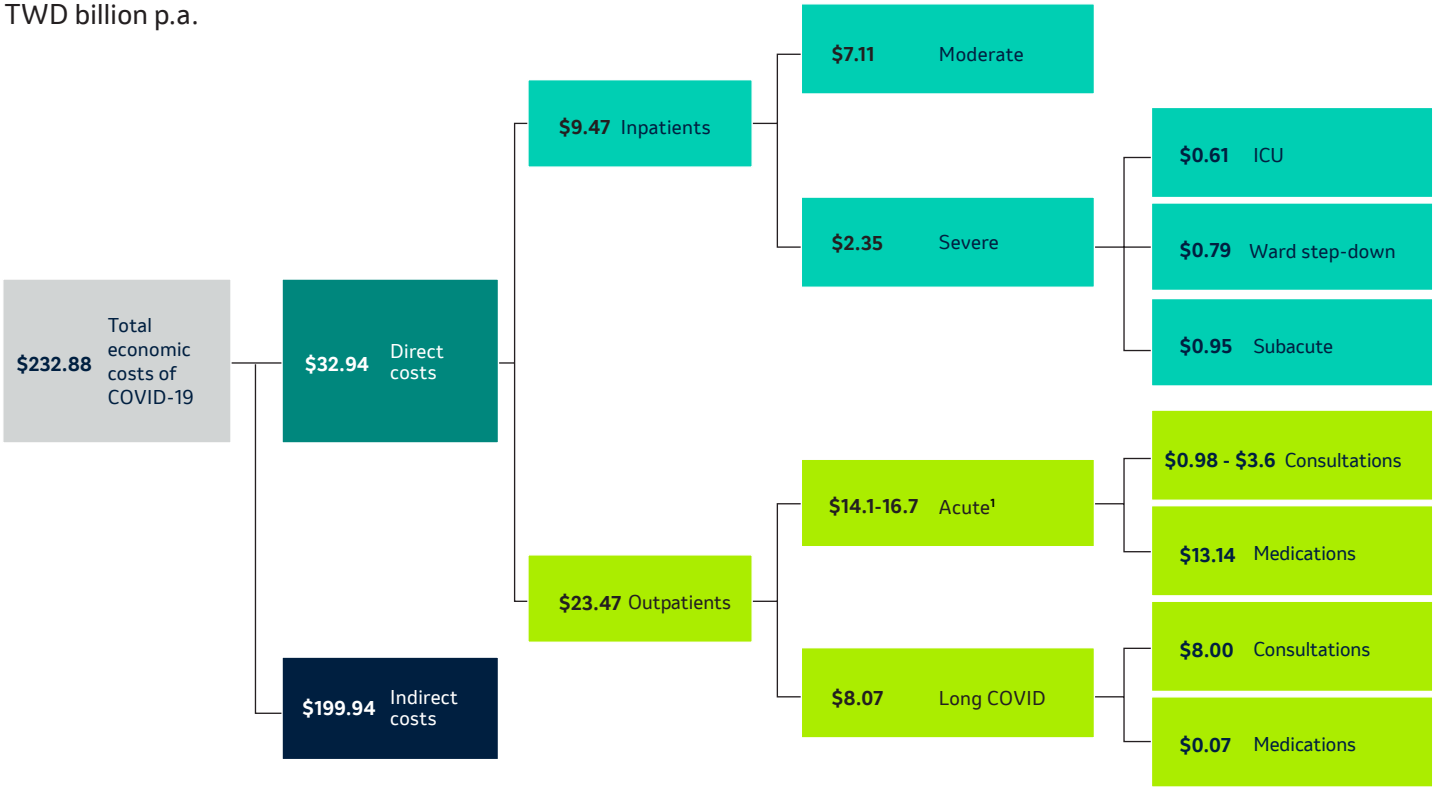
Costs are indicative only and based on the distribution of COVID-19 infections between cohorts in Taiwan in 2022.

As Exhibit 12 illustrates, the base case scenario is designed to reflect a continuation of recent conditions. To do this, infection volumes and the prevailing hospitalization rate from Q3 in 2022 have been drawn from the Institute of Health Metrics and Evaluation (IHME; used with permission) model of COVID-19 and annualized.

80. Case volumes reflect an annualized figure based on total reported cases in November 2022. COVID-19 statistics. Available from: https://sites.google.com/cdc.gov.tw/2019ncov/taiwan. Our World in Data [Internet]. COVID-19 Data Explorer. Available from: https://ourworldindata.org/explorers/coronavirus-data-explorer?facet=none&uniformYAxis=0&Interval=Cumulative&Relative+to+Population=false&Color+by+test+positivity=false&country=~TWN&Metric=Confirmed+cases

4.3.1 Direct costs to the health system

Exhibit 13: Direct economic costs from COVID-19, TWD billion p.a.



Note: Totals may not sum due to rounding
1. A range is given for acute consultations to reflect the range of possible values for the number of GP consultations for COVID-19 assessment and treatment.

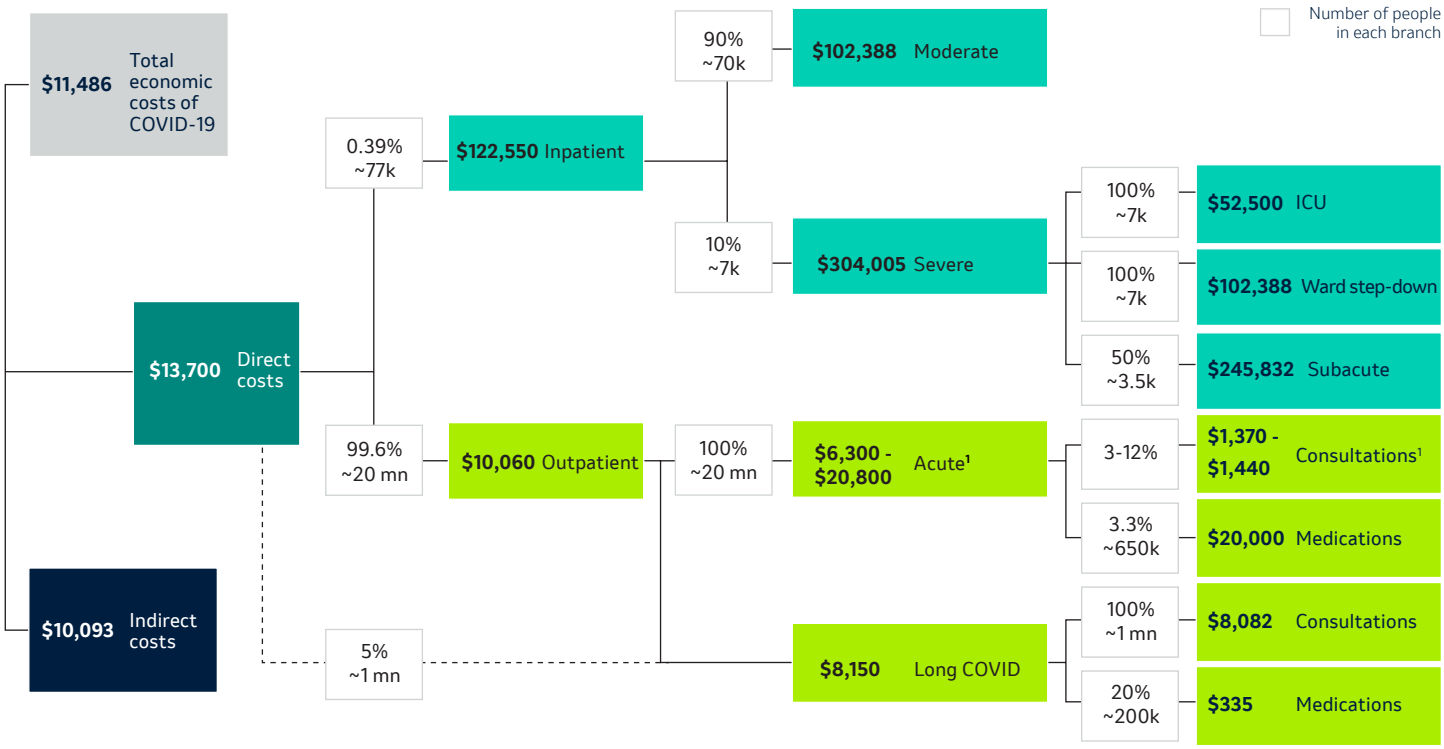
Moderate illness requires ward-based inpatient care, and 'Severe illness' requires ICU-level care; 'Acute illness' refers to all infections not included in inpatient care; Long COVID refers to a small subset (~5%) of total infections and represents infections with symptoms lasting 12 weeks or more.

With ~77,000 hospital admissions (including ~7,000 to the ICU) and ~1 million cases of long COVID in the base case scenario, preventing admissions (including to ICU), reducing lengths of stay, time to recovery, and/or the incidence of long COVID would have a significant impact on reducing the direct costs imposed by COVID-19 on the health system.

In this scenario, as displayed in Exhibit 13, COVID-19 could cost the Taiwan health system TWD ~32.9 billion p.a. This is a significant expense, equating to ~0.1% of Taiwan's GDP. Despite the magnitude of this figure, direct costs are still a minority of the total economic costs of COVID-19 in Taiwan, accounting for ~14% of the total. Indirect costs, comprising productivity losses due to missed work, account for the remainder and could be TWD ~200 billion p.a. These are discussed further in Section (4.3.2). While combined, these direct and indirect costs amount to a significant expense, they still do not account for the value of health lost due to COVID-19, nor the ripple effects on critical industries and vulnerable populations such as the health workforce.

Despite their relatively lower significance in the wider scheme of COVID-19's economic impact, direct costs remain significant on a per-infection basis. As illustrated in Exhibit 14, each infection that uses some form of health service could impose an average cost of TWD ~13,700. This is concentrated in the costs of inpatient care, where

Exhibit 14: Direct economic costs from COVID-19, per person, TWD p.a.



Costs per person for each segment are calculated by dividing the total cost of that segment by the number of individuals in that segment that utilize a health service; 'Moderate illness' requires ward-based inpatient care, and 'Severe illness' requires ICU-level care; 'Acute illness' refers to all infections not included in inpatient care; Long COVID refers to a small subset (~5%) of total infections of which symptoms last 12 weeks or more.

a single ward admission could cost TWD ~102,400 and a single ICU admission (with subsequent ward and rehabilitation stays) could cost TWD ~304,000.

As indicated in Exhibits 13 and 14: direct costs are incurred in two major settings:

- Inpatient (hospital-based) care (TWD ~9.47 billion p.a.; 30%; TWD ~122,550 per person)
- Outpatient (primarily clinic-based) care (TWD ~23.47 billion p.a.; 70%; TWD ~10,060 per person)

The profile of inpatient care costs suggests that ameliorating the severity of illness acquired could have a significant impact on cost. Particularly in a reopened economy, where individuals at risk of severe disease are less protected from infection by community health measures, the extent of ongoing costs to the health system underscores the importance of continuing to test for and treat the disease.

Costs in this category comprise those arising from moderate infections requiring ward-based care (TWD ~7.1 billion p.a.; TWD ~102,400 per person) and severe infections requiring ICU admission (TWD ~2.35 billion p.a.; TWD ~304,000 per person). The more costly care for moderate infections is driven largely by length of stay in the ward (~11 days on average), while the cost of care for severe infections is driven mostly by higher bed day costs (TWD ~11,200 per day in ICU), followed by substantial periods of inpatient rehabilitation (with a median stay of 24 days.)[81]

The profile of outpatient care costs indicates that limiting the incidence, duration, and/or severity of long COVID would have a substantial impact on this portion of the cost burden. Outpatient care for COVID-19 infections adds TWD ~23.47 billion p.a. to the

81. National Health Insurance Administration [Internet]. Annual Statistical Report 2021. Available from: https://www.nhi.gov.tw/Content_List.aspx?n=82BE88F79016A334&topn=23C660CAACAA159D

total economic costs incurred due to COVID-19. While seemingly less resource-intensive, outpatient infections are not inexpensive on a per-person basis, each costing TWD ~10,060.

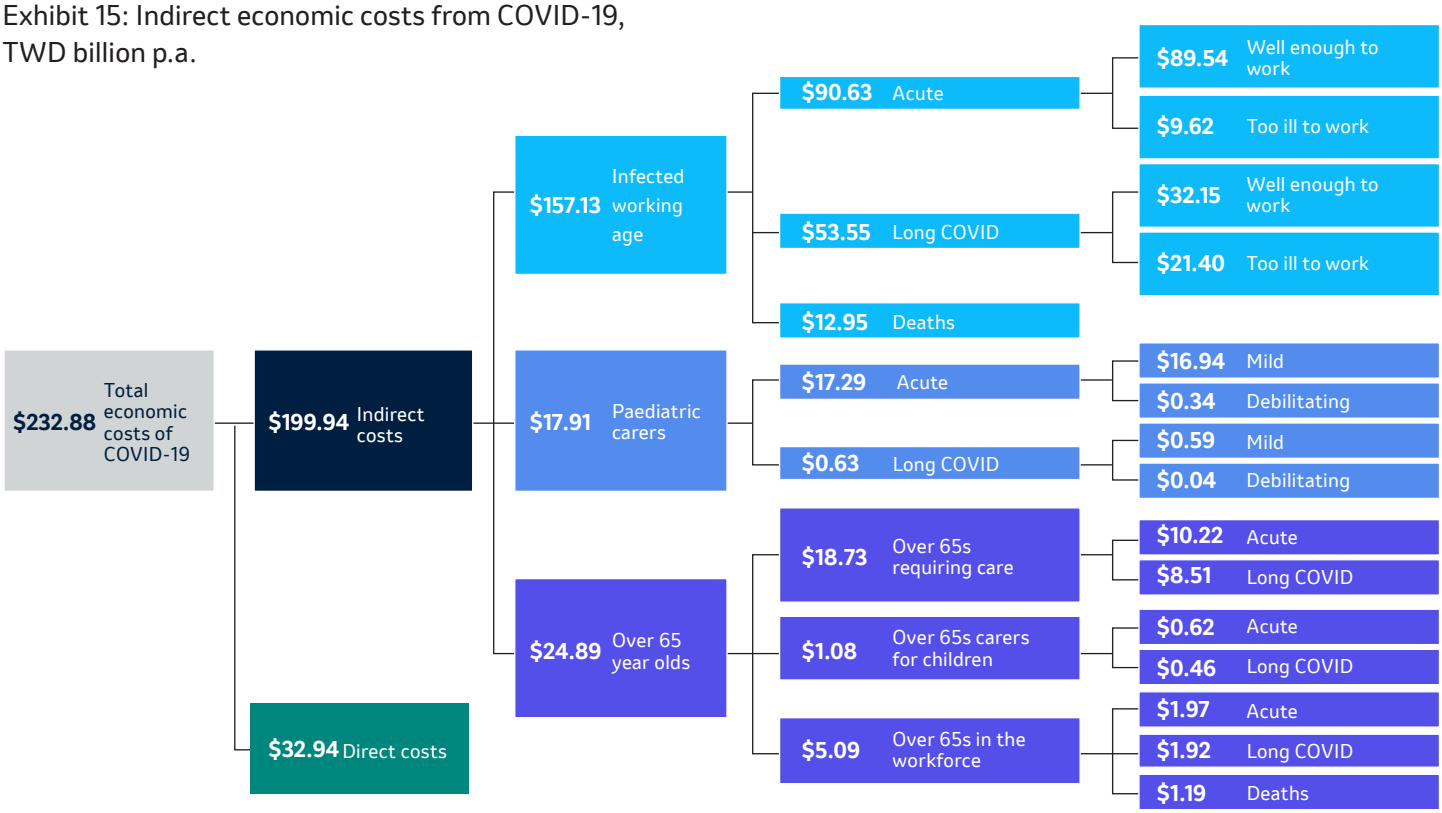
Outpatient costs can be separated into acute outpatient care (consultations and medications; TWD ~15.4 billion p.a.) and chronic outpatient or long COVID care (consultations and medications; TWD ~8 billion p.a.; see also Section 4.4.6).

The cost of acute outpatient care is driven largely by the cost of medications (such as oral antivirals, TWD ~13 billion p.a.) which, equating to ~6% of total economic costs, represents a small investment towards partially reducing a large burden of direct and indirect costs (TWD ~233 billion p.a.). In addition to this, it is important to recognize healthcare labor costs associated with prescribing medications. For example, if a complex treatment is chosen that requires additional checks or reviews, every additional 10-minute period of healthcare labor is worth TWD ~44,[82] without accounting for the opportunity cost of servicing other patients, which is imposed by the additional burden. Aggregate consultation costs in this cohort are lower because there are fewer of them – it is estimated that 2% of all infected patients visit a clinic (~395,000 visits p.a.).[83]

The combined direct costs from the inpatient and outpatient cohorts amount to TWD ~32.9 billion p.a. or ~0.1% of Taiwan's GDP. While significant on their own, these costs are in addition to indirect costs to Taiwan's economy (discussed below in Section 4.3.2), the value of lost health they represent, and flow-on effects to the health system (such as its workforce) and other critical industries.

82. Based on a median weekly earnings figure of $14,934. Statista [Internet]. Average monthly earnings of employees in Taiwan in 2022, by industry. 2023 Feb 27. Available from: https://www.statista.com/statistics/1293585/taiwan-average-monthly-wage-by-industry/
83. Goldstein EV, Seiber EE et al. Journal of Primary Care & Community Health [Internet]. Early Data on Predictors of COVID-19 Treatment Frequency at Community Health Centers. 2021 Dec 23. Available from: https://journals.sagepub.com/doi/full/10.1177/21501319211069473

Exhibit 15: Indirect economic costs from COVID-19, TWD billion p.a.



Note: Totals may not sum precisely due to rounding to 2 decimal places

Indirect costs arise from productivity losses incurred due to infection with COVID-19; 'Well enough to work' refers to those who can continue working while infected, albeit with reduced productivity; 'Too ill to work'' refers to those who cannot work, at least for a portion of the time, while infected; 'Acute illness' refers to all infections not included in inpatient care; Long COVID refers to a small subset (~5%) of total infections and represents infections with symptoms lasting 12 weeks or more.

4.3.2 Indirect costs to the economy

Reducing the sheer volume of COVID-19 infections, the duration of illness, and recovery time for working-age adults, children, and the older population would considerably reduce the economic and societal costs of COVID-19 in Taiwan.

In the base case scenario, and as illustrated by Exhibit 15: COVID-19 could cost the Taiwan economy TWD ~200 billion p.a. in productivity losses if current epidemiological conditions and response settings continue.[84] As with direct costs to the health system, this is a significant expense, equating to ~0.8% of GDP. While these costs are significant, as with direct costs, they still do not account for the value of health lost due to COVID-19, nor the flow-on effects to critical industries and vulnerable populations such as the health workforce.

As illustrated in Exhibit 15 indirect costs resulting from productivity losses are borne by three major groups:

- **Infections in working-age adults (19 to 64-year-olds) – TWD ~157 billion p.a.** (~78%; TWD ~11,800 per person)
- **Infections in the older population (65-year-olds and above) – TWD ~24.9 billion p.a.** (~12%; TWD ~10,470 per person)
- **Infections in children and adolescents (18 years old and younger) – TWD ~17.9 billion p.a.** (~9%; TWD ~4,300 per person)

Infections in working-age adults impose a significant economic burden on Taiwan, through productivity losses valued at ~TWD 157 billion p.a., a significant figure that alone equates to ~0.6% of Taiwan's GDP. This burden highlights the impact that an illness that is mild for most but significant enough to last ~12 days – and impair productivity by ~35% for a ~fifth of them – can have on the broader economy.

Productivity losses incurred by the working-age group can be considered in two ways:

- Acute illness (TWD ~90.6 billion p.a.), chronic illness or long COVID (TWD ~53.6 billion p.a.), and deaths (TWD ~13.0 billion p.a.), or
- Infected adults still well enough to work, but with reduced capacity (TWD ~121.7 billion p.a.), and infected adults who are too ill to work (i.e., are hospitalized) (TWD ~31.0 billion p.a.)

Taking these together, acute illness in those who can still work but at reduced capacity accounts for ~45% (TWD ~89.5 billion) of all productivity losses incurred across the age groups. The magnitude of this cost illustrates that, despite the mildness of the illness for most when modest reductions in working capacity are multiplied across a multi-day illness affecting ~13 million people in Taiwan, a cost impact of substantial proportions results.

Infections in the older population impose TWD ~24.9 billion p.a. (~0.1% of GDP) in costs from productivity losses on the Taiwan economy, adding to the burden from working-age adults. This highlights that productivity losses are not limited to those borne by the working-aged and that adjacent age cohorts are also of proportional importance.

Older people that incur productivity losses due to COVID-19 fall into three categories:

- **Older people with COVID-19 who require care from a working-age person** – ~2.4 million working-age incurring a TWD ~8,000 productivity loss[85] – resulting in a total impact of TWD ~18.7 billion p.a.
- **Older people who directly participate in Taiwan's labor force** – ~10% of over-65s.[86] Infections in this group result in TWD ~5.1 billion p.a. of productivity losses.

84. Based on a median weekly earnings figure of TWD ~10,033. 全台平均月薪43K，但難以追上通膨！實體薪資幾乎零成長 (The average monthly salary in Taiwan is 43K, but it is difficult to catch up with inflation! Physical salary growth is almost zero) Business Next [Internet]. 2022 Sep 8. Available from: https://www.bnext.com.tw/article/71613/salary--average-22

85. ~99% of Taiwan's 65+ population do not receive long-term care services (either in facilities or home-based). This proportion is assumed to be consistent in the 65+ cohort that becomes infected with COVID-19. 行政院主計總處 (Directorate General of Budgeting, Accounting, and Statistics) [Internet]. 2022 Nov 30. Available from: https://ws.dgbas.gov.tw/Download.ashx?u=LzAwMS9VcGxvYWQvNDYzL3JlbGZpbGUvMTA5ODAvMjMwMTYyL2M5NWE5ZWU5LWI1OTEtNGNkMS04YzAwLTI3NTkyYjJhOGRlNC5wZGY%3d&n=MTA55bm05Lq65Y%2bj5Y%2bK5L2P5a6F5pmu5p%2bI57i95aCx5ZGK57Wx6KiI57WQ5p6cLeaWsOiBnueovy5wZGY%3d

86. National Statistics Republic of China (Taiwan) [Internet]. Statistical Tables. Available from: https://eng.stat.gov.tw/News.aspx?n=2401&sms=10889

- **Older people (e.g., grandparents) who care for children to enable parents to work** – one survey found that ~20% of grandparents (including in multi- and single-generation households) provided care for grandchildren.[87] When this work-enabling care is disrupted, the productivity loss amounts to TWD ~1.1 billion p.a.

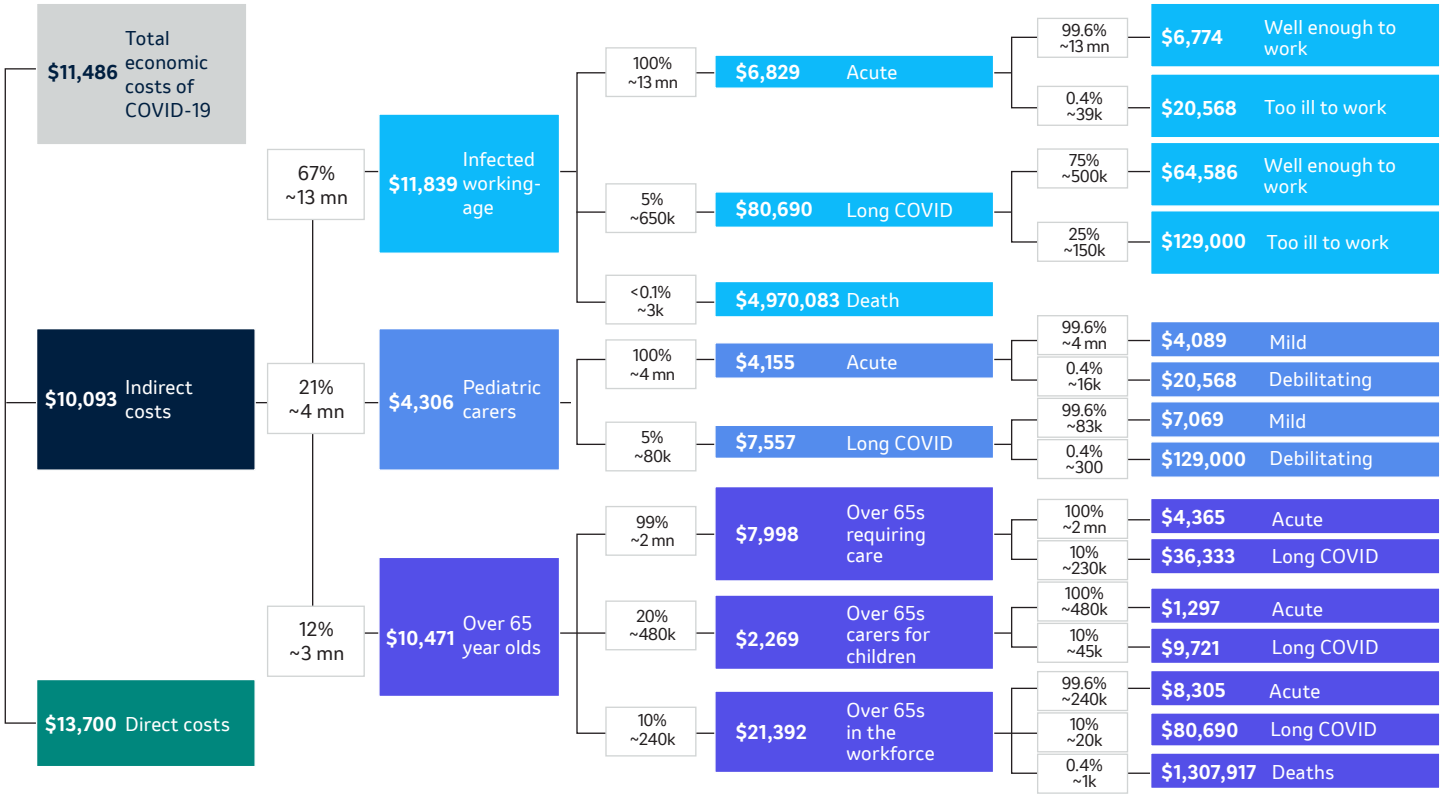
Infections in the older population account for TWD ~29 billion p.a., or ~13% of all direct and indirect costs combined, serving as a stark reminder of the need to address costly infections in cohorts adjacent to working-age adults.

Finally, infections in children impose an additional economic cost of TWD ~17.9 billion p.a. (~0.07% of GDP) owing to productivity losses borne by adults who are absent from or less productive at work while caring for children. Along with those from the older population, productivity losses arising from infections in children can be difficult to recognize in advance but are significant when they emerge.

Productivity losses arising from infections in children are predominantly driven by adults caring for children with acute, mild illness. The cohort of infected children, which constitutes the majority (98%) of productivity losses in adults caring for children with acute illness, is worth TWD ~16.9 billion p.a. This cost is driven by care for ~3.3 million mild but symptomatic infections in children, who despite having a mild illness require one parent to care for them at home. The remaining ~2% is driven by productivity losses from caring for

87. Ku LE, Stearns SC, Van Houtven CH, Lee SD, Dilworth Anderson E, Konrad TR. The Journals of Gerontology: Series B [Internet]. Impact of Caring for Grandchildren on the Health of Grandparents in Taiwan. 2013 Sep 21; 68(6): 1009-21. Available from: https://academic.oup.com/psychsocgerontology/article/68/6/1009/658299?login=false

Exhibit 16: Indirect economic costs from COVID-19, per person, TWD p.a.



Costs per person for each segment are calculated by dividing the total cost of that segment by the number of individuals in that segment; Indirect costs arise from productivity losses incurred due to infection with COVID-19; 'Well enough to work' refers to those who can continue working while infected, albeit with reduced productivity; 'Too ill to work' refers to those who cannot work, at least for a portion of the time, while infected; 'Acute illness' refers to all infections not included in inpatient care; Long COVID refers to a small subset (~5%) of total infections and represents infections with symptoms lasting 12 weeks or more.

children with debilitating infections. For parents who can work from home (~63%), productivity is estimated to halve, while all productivity is foregone from parents who cannot work from home (~37%).[88] This is a substantial cost driven more by lost work than the illness itself, reiterating that substantial costs imposed by productivity losses are not limited to infections in working-age adults.

Despite the seeming reduction in resource intensiveness compared to direct healthcare costs, the magnitude of productivity losses imposed by COVID-19 means indirect costs are actually more expensive on a per-person basis (as indicated in Exhibit 16), with each infection costing TWD ~10,100 (versus TWD ~21,100 for direct costs) on average. This is concentrated in productivity losses resulting from infections in the working-age (TWD ~11,800 per person) and the older population (TWD ~10,470 per person).

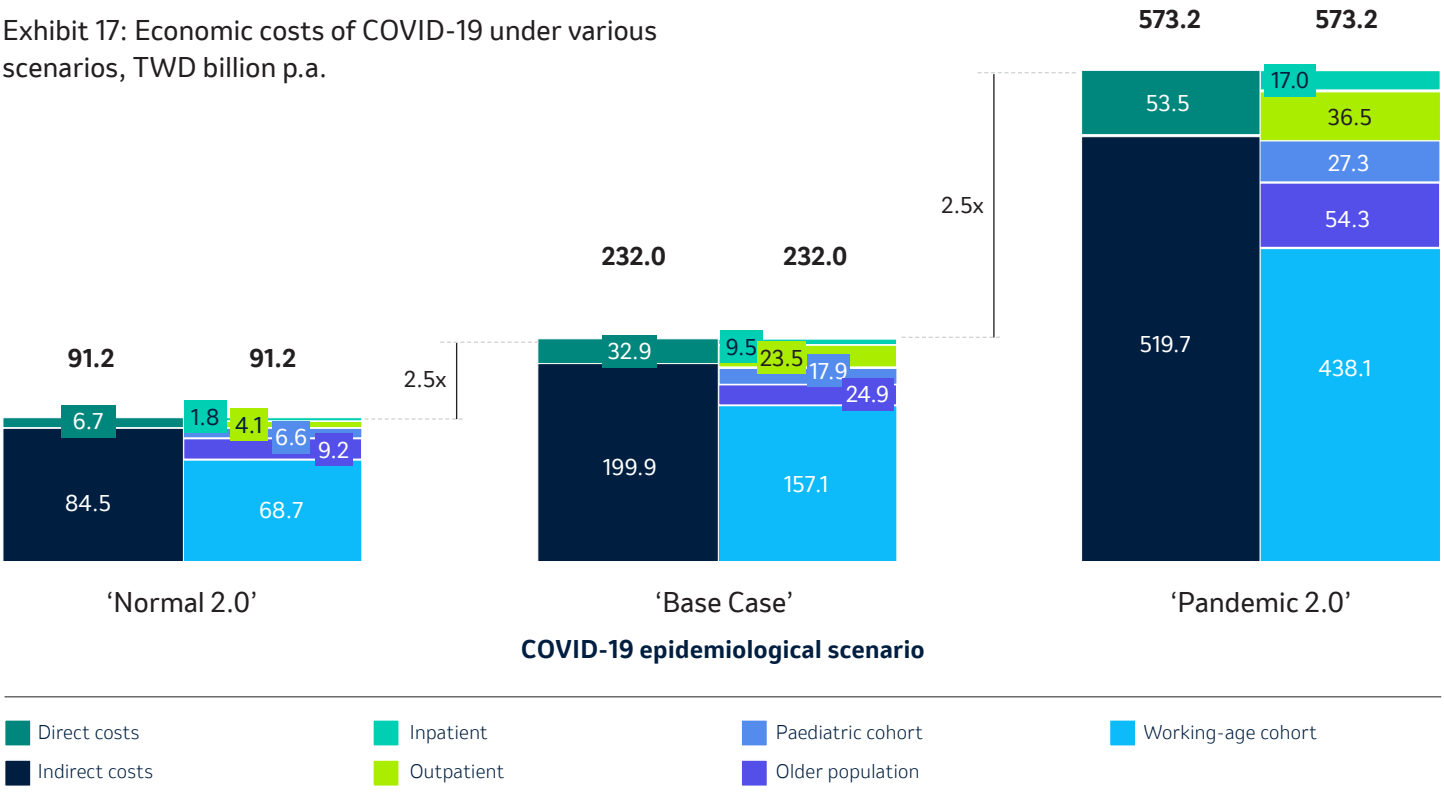
88. Taipei Times [Internet]. Companies consider reinstating work from home amid spike in COVID-19. 2022 Apr 16. Available from: https://www.taipeitimes.com/News/biz/archives/2022/04/16/2003776668

Together, indirect economic costs arising from productivity losses in these groups amount to TWD ~200 billion p.a. or ~0.8% of Taiwan's GDP and are in addition to the value of lost health and direct costs to Taiwan's health system. Although already substantial, these costs are likely to underestimate the entirety of the burden imposed on society by COVID-19, as second-order impacts on health system capacity and flow-on effects to the health workforce, supply chains, and other aspects of critical industry are all additive to directly measurable economic impacts.

The entirety of the economic burden imposed by COVID-19 also needs to be understood in the context of the prevailing epidemiological scenario, as the impacts and costs described can significantly increase under plausible scenarios where novel variants emerge. Such scenario variations are described below.

4.3.3 Alternative scenarios: costs of Pandemic 2.0 and Normal 2.0

Exhibit 17: Economic costs of COVID-19 under various scenarios, TWD billion p.a.



Normal 2.0 refers to a scenario featuring ~500,000 infections per million population and ~47,000 hospitalizations, reflecting conditions observed in mid-late 2022; Pandemic 2.0 refers to a scenario featuring ~1 million infections per million population and ~285,000 hospitalizations, reflecting conditions observed in early 2022.

In addition to the base case, two further scenarios are considered, as illustrated in Exhibit 17:

In a Pandemic 2.0 scenario, total economic costs could reach TWD ~573 billion p.a. Conversely, in the Normal 2.0 scenario, economic costs could decrease to TWD ~91 billion p.a.

The two example scenarios represent divergent epidemiological outcomes that are both plausible as the pandemic evolves. Each theoretical scenario is defined by two key features:

- Infection volume (driven by contagiousness; measured by cases per million population per year), and
- Case severity (driven by a prevailing strain's virulence factors; measured by resulting hospitalization rate)

A Normal 2.0 scenario would feature a case volume of ~290,000 cases per million population per year and ~30,000 hospitalizations.[89] These thresholds represent reported case numbers prevalent in Taiwan in November 2022, annualized. Under a Normal 2.0 scenario, economic impacts from COVID-19 could decrease to TWD ~91 billion p.a., equating to ~0.4% of GDP and TWD ~13,570 per person. Direct costs could decrease to TWD ~6.7 billion p.a. and indirect costs to TWD ~85 billion p.a. Decreases in costs would be driven by lower hospitalization rates and diminished productivity losses owing to reduced periods of missed work.

By contrast, a Pandemic 2.0 scenario would feature a case volume of ~1 million cases per million population per year (i.e., the entire population is infected once, on average) and a case severity that drives ~111,000 hospitalizations. This compares to the base case scenario featuring a case volume of ~840,000 infections per million population and ~77,000 hospitalizations.[90]

In this scenario, economic impacts from COVID-19 could increase to TWD ~573 billion p.a., equating to ~2.3% of GDP and TWD ~24,300 per person. In this scenario, direct costs could be TWD ~53.5 billion p.a. (a 1.7 times increase of TWD ~21 billion p.a.) and indirect costs could reach TWD ~520 billion p.a. (a 2.6 times increase of TWD ~320 billion p.a.). These increases would be driven by increased hospitalization rates, longer lengths of stay, and augmented productivity losses from an increased incidence of debilitating illness and longer periods of missed work.

The magnitude of the cost increases that could result from a plausible epidemiological scenario such as described above demonstrates the need for a range of preparedness settings that include options to limit impacts at all junctures.

While scenarios help us to consider potential courses that the COVID-19 pandemic may take in the future, their scope is largely restricted to the consideration of quantifiable economic costs. Equally important to consider are the 'second-order' impacts that COVID-19 could have on health system capacity and flow-on effects to vulnerable populations and critical industries, demonstrating its broad reach in economic and societal impact.

89. Case volumes reflect an annualized figure based on total reported cases in November 2022. Taiwan Centre for Disease Control [Internet]. COVID-19 statistics. Available from: https://sites.google.com/cdc.gov.tw/2019ncov/taiwan

    Our World in Data [Internet]. COVID-19 Data Explorer. Available from: https://ourworldindata.org/explorers/coronavirus-data-explorer?facet=none&uniformYAxis=0&Interval=Cumulative&Relative+to+Population=false&Color+by+test+positivity=false&country=~TWN&Metric=Confirmed+cases

90. Infection numbers and hospitalization rates are sourced from modeling of COVID-19 infections in Taiwan by the Institute of Health Metrics and Evaluation (IHME; used with permission). In Taiwan, infection numbers are ~twice the number of reported cases, recognizing the volume that is not detected by the testing process.

4.4 Considerations For Critical Cohorts And Industries

The economic costs of COVID-19 described will impact different populations and industries disproportionately. This includes cohorts that play a critical economic or societal role (e.g., logistics workers, health care workers), those that are particularly vulnerable to severe disease (e.g., people with comorbidities), and those that go on to develop long COVID. These groups may be worthy of additional focus when considering countermeasure approaches to mitigate the impacts of COVID-19.

Specifically, interventions that protect health and productivity losses in these critical industries and populations may yield corresponding disproportionate economic returns.

4.4.1 Critical workers and industries

As outlined above, some critical industries experience disproportionate indirect costs (i.e., productivity losses) that generate significant public concern. Here, the focus is on three industries in particular – healthcare, logistics, and travel and tourism.

The economic costs of COVID-19 borne by critical industries and their stakeholders may increase under a Pandemic 2.0 scenario. In this scenario, workforces that are largely unable to work from home may be required to isolate while they recover. The resulting loss of productive time can be 30% greater (up to the equivalent of one to two workdays) than that of individuals in desk-based jobs who are able to perform work tasks in their home environment.

4.4.2 Healthcare

Taiwan's health system serves as its first and last line of defense against COVID-19 and other health threats. National healthcare expenditure is TWD ~1.3 trillion and the industry employs ~350,000 healthcare practitioners.[91,92]

At a potential minimum cost of TWD ~15.9 billion p.a. (~0.06% of GDP; ~7% of combined total cost),[93] healthcare workers who become infected with COVID-19 represent a disproportionate slice of the impact of this disease on the economy. However, this is likely to significantly underestimate the total impact on the Taiwanese economy and citizens' welfare, due to flow-on effects on patient outcomes.

Health services typically experience higher rates of COVID-19-related absenteeism compared to other industries. A root cause of these inflated figures is healthcare workers' increased risk of exposure to COVID-19 infection in the workplace, estimated at almost twice that of the general population.[94] Productivity losses are not only incurred by sick workers but also by the remaining workers who are required to take up additional responsibilities. Taking Chi Mei Hospital as an example, an infection rate of 20% among medical staff meant others were caring for seven, instead of five, patients.[95] The extra workload reduces time to complete tasks in addition to patient care and contributes to exhaustion, reduced empathy, and an increased risk of workplace errors.[96]

91. Ministry of Health and Welfare; [Internet]. 國民醫療保健支出(NHE) (National Health Care Expenditure Statistical Table). (cited 2021). Available from: https://dep.mohw.gov.tw/DOS/cp-5071-66025-113.html
92. Ministry of Health and Welfare [Internet]. [統計指標(人口、死亡率、醫療設施等) (Statistical indicators [population, death rate, medical facilities, etc.]) cited 2021. Available from: https://dep.mohw.gov.tw/DOS/lp-5083-113.html
93. Based on a median weekly earnings figure of TWD ~14,934. Statista [Internet]. Average monthly earnings of employees in Taiwan in 2022, by industry. Available from: https://www.statista.com/statistics/1293585/taiwan-average-monthly-wage-by-industry/
94. 工會估2.6萬醫護曾染疫，僅465人申請職災給付：院方阻撓刁難，要求證明「因公確診」(The trade union estimates that 26,000 medical staff have been infected with the epidemic, and only 465 people applied for occupational benefits) [Internet]. The New Lens; 2022 Jul 15. Available from: https://www.thenewslens.com/article/169683
95. The Reporter [Internet]. Omicron疫情下的急診室，醫師說：20年來最恐怖！(In the emergency room under the Omicron epidemic, the doctor said: the scariest in 20 years!) 2022 Jul 22. Available from: https://www.twreporter.org/a/emergency-overstrain-2022-situation
96. Shiu C, Chen W, Hung C, Huang EP, Lee TS. Journal of the Formosan Medical Association [Internet]. COVID-19 stigma associates with burnoutamong healthcare providers: Evidence from Taiwanese physicians and nurses. 2021 Sep 30; 121(2022): 1384. Available from: https://escholarship.org/content/qt8kg630k1/qt8kg630k1_noSplash_f126cba31894e48fa5f96c1ef9d7ce2d.pdf

The economic ripple effects of COVID-19-related absenteeism among healthcare workers are significant. COVID-19 has exacerbated pre-existing workforce shortages, resulting in poorer quality and safety of healthcare provision. Even recently, shortages have contributed to two- to three-fold increases in emergency department wait times in some hospitals.[97] These wait times apply to, among others, patients with myocardial infarction, respiratory failure, or septic shock. Such reductions in the availability and timeliness of medical care may lead to prolonged illness or delayed recovery for patients, who incur their own productivity losses as a result.

Additionally, the COVID-19 pandemic has seen unprecedented levels of workforce burnout and attrition.[98] Although the initial response to the COVID-19 pandemic has subsided, global talent shortages and mobility limitations are ongoing challenges.

A countermeasure approach that targets healthcare workers is essential in mitigating overall economic costs as well as COVID-19's impact on public health. This is demonstrated by the disproportionate costs of COVID-19 infections among healthcare workers against the backdrop of an increasingly constrained talent market.

4.4.3 Logistics

COVID-19 has caused unprecedented disruption to Taiwan's transport and logistics sector, which delivers vital goods and services across the nation. It is a TWD ~1.7 trillion industry, with a growing workforce of ~300,000 people.[99,100] During the pandemic, the sector was disproportionately impacted by productivity losses from workers, which snowballed into local and global supply network disruptions.

Taiwan's transport operators and distribution centers have experienced significant workforce shortages due to COVID-19 illness. This workforce includes warehouse staff, forklift drivers, unpack crews, and technicians, who are unable to fulfill work obligations at home while ill, isolating, or caring for others who have been infected with COVID-19. Subsequently, these businesses struggle to retain other employees who are required to work longer hours to compensate for the lost labor.

Workforce shortages have downstream consequences for end-point retailers, users, and customers. Disruptions have the dual effect of driving inflation in the costs of goods and services, as well as impeding the ability of businesses and their workers to deliver them. Among these goods are necessities of public importance such as food, life-altering medicines, gas, and oil.[101]

The impact of workforce shortages may point to an incremental opportunity for targeted COVID-19 countermeasures to support Taiwan's logistics industry workforce, as it grapples with the multitude of challenges (including geopolitical tensions) at the heart of today's 'supply chain crisis'.

97. The Reporter [Internet]. Omicron疫情下的急診室，醫師說：20年來最恐怖！(In the emergency room under the Omicron epidemic, the doctor said: the scariest in 20 years!) 2022 Jul 22. Available from: https://www.twreporter.org/a/emergency-overstrain-2022-situation
98. Public Television Service Foundation (PTS) [Internet].; 2至5月近800護理人員離職 衛福部否認有護理人員離職潮 (Nearly 800 nursing staff resigned from February to May, 2021) 2021 Jun 5. Available from: https://news.pts.org.tw/article/529444. Institute of Health Metrics and Evaluation [Internet]. Worldwide shortage of health workers threatens effective health coverage 2022 May 23. Available from: https://www.healthdata.org/news-release/worldwide-shortage-health-workers-threatens-effective-health-coverage. Turton M. Taipei Times [Internet]. Does Taiwan's nursing problem have a cure? 2022 Feb 21. Available from: https://www.taipeitimes.com/News/feat/archives/2022/02/21/2003773473
99. Taiwan Ministry of Transportation and Communication [Internet]. Taiwan Services Trade Information Platform. Available: https://www.taiwanservices.com.tw/internet/en/index.aspx?cat=9&istop=1#
100. National Statistics, R.O.C. (Taiwan) [Internet]. 國情統計通報 (National Statistical Bulletin). Available from: https://www.stat.gov.tw/News.aspx?n=2661&sms=11020&_CSN=588
101. Kang R. HKTDC Research [Internet]. Taiwanese Industries Struggle to Weather Global Commodity Price Hike. 2021 Oct 20. Available from: https://research.hktdc.com/en/article/ODcwMDk4NTg0

4.4.4 Travel and tourism

Despite a strong recovery since re-opening borders in October last year, Taiwan's travel and tourism sector continues to face headwinds due to workforce shortages. Prior to the COVID-19 pandemic, Taiwan's tourism sector contributed ~4.4% to the national economy and supported 1 in 11 jobs nationwide.[102] However, the pandemic led to steep declines (up to ~50%) in visitor numbers and tourism spending due to border restrictions, isolation orders, and hesitancy to travel.[103]

Absenteeism linked to COVID-19 has wreaked havoc across industries such as airports and accommodation services. Unexpected staff shortages due to illness exacerbate a labor gap already at ~13%.[104] This is contributing to flight disruptions that can impede corporate travelers' productive work time and impact holidaymakers' spending.

Countermeasures targeted at Taiwan's travel and tourism workforce are needed to help these industries recover from the COVID-19 pandemic.

4.4.5 Vulnerable populations

COVID-19 illness in Taiwan's vulnerable populations represents a minimum impact of TWD ~118 billion p.a. (~0.5% of GDP) on Taiwan's economy. These populations are at greater risk of severe COVID-19 disease and are more heavily reliant on the healthcare system than others. Vulnerable populations that have received particular attention throughout the pandemic include those over 65 years old, those with comorbidities, and Taiwan's indigenous peoples.

COVID-19 illness in Taiwan's older population (65 years and older) could have an economic impact of TWD ~29 billion p.a. (~13% of the combined annual impact), a significant TWD ~12,370 per person. Despite representing just ~12% of confirmed cases, the older population represents ~20% of COVID-19 hospitalizations.[105] This figure is not surprising considering the high prevalence of comorbidities such as high blood pressure, cancer, and diabetes in this age group, which affect ~80% of those over 65 years old.[106]

Comorbidities in the younger, working-age (19-64 years) population could also have a disproportionate impact of TWD ~88 billion p.a. (~0.4% of GDP). Just one comorbidity doubles the risk of severe COVID-19,[107] subsequently increasing the likelihood of hospitalization and prolonging time off work to recover. This could be a reality for at least ~50% of 40-64-year-olds in Taiwan.[108]

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102. World Travel and Tourism Council [Internet]. Taiwan, China 2022 Annual Research: Key Highlights. Available from: https://wttc.org/DesktopModules/MVC/FactSheets/pdf/704/242_20220613171216_Taiwan,%20China2022_.pdf
103. Kang R. HKTDC Research [Internet]. Taiwan's Tourism Sector Readies Itself for Visitor Spike as Borders Re-Open. 2022 Oct 14. Available from: https://research.hktdc.com/en/article/MTE4NDYxMjg5Ng
104. Xue Y, Wu J. Public Television Service Foundation (PTS) [Internet]. 邊境解封地勤人力不足 民航局坦言缺員6、7百人 (Insufficient manpower for ground staff due to unsealed borders). 2022 Oct 17. Available from: https://news.pts.org.tw/article/6047800
105. Calculated based on age distribution of respiratory diseases. Statistics on the total number of outpatient and inpatient visits. 2021NHI Statistics on Taiwan Healthcare [Internet]. 2022 Dec.
106. The figure represents the percentage of those aged 65 and older who have one or more chronic illnesses or comorbidities. It excludes chronic mental health conditions and hip fractures which account for 8% of chronic conditions among those aged 65 and older. Health Promotion Administration [Internet]. Long-term follow-up survey on the physical and social living conditions of middle-aged elderly peoples of the Republic of China. 2022. Available from: https://apps.who.int/iris/bitstream/handle/%2010665/194271/9789241509312_eng.pdf
107. Liu B, Spokes P, He W, Kaldor J. BMC Infectious Diseases [Internet]. High risk groups for severe COVID-19 in a whole of population cohort in Australia. 2021 Jul 16; 21(685). Available from: https://bmcinfectdis.biomedcentral.com/articles/10.1186/s12879-021-06378-z
108. Approximately ~57% of 54-59year-olds and ~69% of 60-64-year-olds have 1 or more chronic illnesses (excluding mental health conditions and hip fractures). Hypertension (high blood pressure) is the most prevalent COVID-19 comorbidity affecting ~26.76% of 40-64-year-olds. Therefore, a conservative estimate of a ~50% severe illness risk among 40-64-year-olds has been made. Ministry of Health and Welfare [Internet]. Health Promotion Administration. Available from: https://www.hpa.gov.tw/Home/Index.aspx

COVID-19 continues to exacerbate the health gap between Indigenous and non-Indigenous Taiwanese peoples. The Indigenous community has high rates of chronic illness and faces inequalities in access to health services which heightens their susceptibility to severe COVID-19. In addition, the pandemic has amplified the social determinants of health, which account for one-third of the health gap. These determinants include employment, hours worked, the completion of schooling, and household incomes – all of which decline when individuals become ill or need to care for loved ones.[109,110]

Vulnerable populations bear ~50% of the combined direct and indirect costs of COVID-19. Countermeasures that reduce the duration of illness and/or speed up recovery time among these populations could significantly mitigate the pandemic's impact. Countermeasures may include ongoing vaccination for individuals aged five years and older,[111] community interventions, or the use of oral antivirals.[112] Oral antivirals were introduced in Taiwan in the second quarter of 2022 to strengthen the suite of countermeasures in the market.

4.4.6 Long COVID

Long COVID[113] has a potential minimum impact of TWD ~73 billion p.a. (~0.3% of GDP; TWD ~73,867 per person) on Taiwan's economy. Individuals who develop this condition experience prolonged productivity losses (increasing indirect costs) and reliance on health services (increasing direct costs).

The direct costs of long COVID, largely driven by consultations, collectively amount to at least TWD ~8.1 billion (TWD ~8,150 per person). When the incidence, complexity, and duration (90 days) of long COVID are factored in, this could mean ~6 million healthcare consultations[114] are required for this cohort alone.[115] Long COVID, therefore, represents a substantial burden on the health system, both in terms of required capacity and economic costs.

Indirect costs or productivity losses resulting from long COVID could amount to at least TWD ~65 billion p.a. (TWD ~66,079 per person and ~32% of all indirect costs). Long COVID productivity losses among the working-age population contribute the bulk of this figure (TWD ~53.5 billion p.a. or ~82%). An adult with long COVID, for instance, could lose up to 45 workdays over a three-month period in reduced productivity.[116]

Long COVID contributes a large share (~32%) of total economic costs, economy. and therefore countermeasures to reduce the incidence and duration of this condition would greatly mitigate pandemic-associated costs. Conservative estimates place the incidence and duration of long COVID at 5% and 90 days respectively. However, as studies on long COVID are still evolving, the full scope of long COVID might still be underestimated.

109. 行政院 (Executive Yuan) [Internet]. 改善原鄉健康不平等 (Improve health inequalities in origin). 2022 Jul 31. Available from: https://www.ey.gov.tw/Page/5A8A0CB5B41DA11E/dcef57a2-e619-40fa-b992-455260a27a23
110. United News Network [Internet].每4人就有1人確診 全台染疫率最高鄉鎮為何在原民部落?(1 out of every 4 people is diagnosed. Why is the town with the highest infection rate in Taiwan located in an aboriginal tribe?) 2022 Jun 9. Available from: https://udn.com/news/story/6841/6375217
111. Taiwan Centers for Disease Control, Ministry of Health and Welfare [Internet]. Pfizer-BioNTech COVID-19 Vaccine Information Sheet for Student Immunization (ages 5-17). 2022 Sep 12. Available from: https://www.cdc.gov.tw/Uploads/394492b5-0a4d-46a6-9b13-4d816d969f80.pdf
112. Oral antivirals are indicated for over18-year-olds with COVID-19 confirmed with severe risk factors within 5 days of onset. Risk factors include being over 65 years of age, or having cardiovascular disease, high blood pressure, and disease. Taiwan Centers for Disease Control [Internet]. 醫療照護人員用藥說明 (Medication Instructions for Healthcare Providers). 2022 May 4. Available from: https://www.cdc.gov.tw/File/Get/aIO8-5_jjbjkqVr42heVUA
113. Also commonly described as 'post-COVID 19 syndrome', long COVID describes the prolonged duration of COVID-19 symptoms beyond twelve weeks after the initial infection.
114. Due to limited data availability, statistics in this report have been assumed as applicable to the Taiwanese context. Commonwealth of Australia House of Representatives, Standing Committee on Health, Aged Care and Sport [Internet]. Impacts of Long COVID and repeated COVID infections. 2022 Oct. Available from: https://www.aph.gov.au/longandrepeatedcovid
115. Each case could require 6 consultations on average over a 90-day period of long COVID illness.
116. Based on an average of 7.2 days of sick leave and reported reductions in working hours due to long COVID.

5. Economic Cost of COVID-19 in South Korea

In South Korea, the future economic cost of COVID-19 could range from KRW ~7 trillion p.a. (~0.3% of GDP) to KRW ~122 trillion p.a. (~5.5% of GDP), depending on the scenario that evolves. These are far greater costs than commonly recognized. COVID-19 not only inflicts health losses through illness and death but also imposes substantial economic costs, including a direct strain on the healthcare system and productivity losses from missed work.

As a society, South Korea has largely accepted the reality of living with ongoing transmission of the virus and the disease burden this incurs. However, the tools available to reduce this burden have been taken up incompletely. To better inform the ongoing discussion on COVID-19's impacts and the benefits of addressing them, it is fruitful to understand the full range of economic costs imposed by COVID-19.

There is a variety of potential epidemiological scenarios for how the COVID-19 pandemic may evolve.[117] This is reflected in the wide range of existing estimates for the economic costs resulting from COVID-19 (which also vary depending on the types of interventions studied and the scope of costs included). Possible epidemiological scenarios include a base case, where current conditions prevail, and alternative scenarios that differ in the volume of infections and their severity (driven, for example, by the interplay between variants and the level of immunity maintained in the population).

In the base case scenario, total economic costs could be KRW ~36 trillion p.a. (~1.6% of GDP), with:

- The majority (KRW ~35 trillion p.a., ~96%) due to productivity losses (indirect costs) through missed work by both working-age adults and elderly in the workforce, either during their own illness or while caring for dependents (children and over 60-year-olds) affected by COVID-19;
- A minority (KRW ~1.5 trillion p.a., ~4%) borne by the health system (direct costs), in both the inpatient (KRW ~540 billion p.a.) and outpatient (KRW ~1 trillion p.a.) settings.

In a Pandemic 2.0 scenario, economic costs could reach as high as KRW ~122 trillion p.a. (~5.5% of GDP). (This assumes transmission rates that result in ~103 million infections per year (instead of ~52 million in the base case) and a severity that results in ~1,000,000 hospitalizations (compared with ~155,000 in the base case). In contrast, at the lower end of the spectrum, a Normal 2.0 scenario could result in just ~12 million infections over the course of a year with only ~23,000 hospitalizations, which would translate to direct and indirect costs of KRW ~7 trillion p.a.

117. Institute of Health Metrics and Evaluation [Internet]. COVID-19 Results Briefing - The Western Pacific Region. 2022 Nov 17. Available from: https://www.healthdata.org/sites/default/files/files/Projects/COVID/2022/44568_briefing_the_Western_Pacific_Region_8.pdf

- Local currencies have been used in this Section, reflecting the use and findings of local data sources. The below exchange rates were used in all local currency conversions to USD in this report. USD currency exchange rate conversions via Google Finance as of 28 February 2023 (USD1 = AUD 1.4861 = HKD 7.8493 = KRW 1,322 = SGD 1.3484 = TWD 30.6608): https://www.google.com/finance/markets/currencies?hl=en

These economic costs fall unevenly. The health and logistics workforces, those affected by long COVID, and vulnerable populations are likely to be disproportionately impacted. For example, economic costs in the health workforce total KRW ~1 trillion p.a. This is driven by high levels of absenteeism and a likelihood of infection that is higher than the wider community, with consequences for health system capacity and quality of care. Those affected by long COVID are impacted most significantly, with the value of lost work and health system utilization totaling KRW ~12.5 trillion p.a. (~0.6% of GDP) or a third of all economic costs. Finally, COVID-19 in vulnerable populations contributes KRW ~18 trillion p.a. (~0.8% of GDP). Almost all of the costs in this category (KRW ~17.4 trillion p.a.; ~48% of total economic costs and ~0.8% of GDP) result from infections in individuals who are eligible for oral antivirals.[118,119]

Fortunately, a range of countermeasures remains available that may mitigate the economic costs of COVID-19 (see Section 8), including vaccination, therapeutics, and community measures (i.e., non-pharmaceutical interventions). Strengthening these countermeasures may allow South Korea to mitigate the potentially high economic costs of the continuing pandemic.

118. Assumes ~19.5% infections are >60 and eligible; assumes ~57.4% infections are aged 19-60 years, of which ~36.5% have a comorbidity and are eligible.
119. Eul H. Journal of Health Informatics [Internet]. Analysis of multiple chronic disease characteristics in South Koreans by age groups using association rules analysis. Journal of Health Informatics [Internet]. 2022 Jan 17. Available from: https://journals.sagepub.com/doi/full/10.1177/14604582211070208#bibr5-14604582211070208

5.1 Context: The Situation In South Korea

Today, South Korea is relatively free of restrictive measures. Most of the community measures employed earlier in the pandemic, such as case isolation, lockdowns, and social distancing have been pared back. In their place, South Korea now has wide vaccine availability and uptake, while other therapeutics such as antivirals are also being used, having been made available to a subset of the South Korean population deemed to be at high risk of developing severe disease, based on their age or other eligibility criteria.

As of early December 2022, South Korea experienced a reduction in the volume of infections following its second Omicron wave. With ~20,000 new infections per day on average, and an effective transmission number[25] of ~0.97, infection volumes have been stabilizing. At the height of South Korea's Omicron wave in March 2022, however, there were ~385,000 new infections per day on average and an effective transmission number of ~1.43 in the month preceding this. By contrast, in October 2021 there were just ~5,300 infections per day,[120] at a time when the nation was still subject to wide-ranging response measures, and before the emergence of the Omicron variant. The

120. Directional estimates based on Institute of Health Metrics and Evaluation (IHME; used with permission), 2022 Reference Scenario. Available from: https://www.healthdata.org/covid/data-downloads

change in South Korea's pandemic response is both a reaction to the volume of infections, as well as a driver itself of the subsequent infection volume.

South Korea's initial measures were very effective at containment and suppression of the virus. By international standards, the countermeasures employed during the first phase of the pandemic (2020 to 2021) were successful. The number of reported cases (~635,000) and deaths (~5,720) were among the lowest in the OECD.[121] However, border closures, social-distancing requirements, strict contact tracing, and mask-wearing mandates still imposed significant hardships on the community and the economy. The successful rollout of vaccines[122] afforded a gradual easing of many restrictions from February 2022 onwards, although the immunity conferred was found to wane over time.

Oral antivirals have been added to South Korea's response toolkit. The short-term nature of restrictive community measures and the remaining health threat from COVID-19 led South Korea to broaden its approach to include oral antivirals, which became available in South Korea in January 2022.[123]

Nevertheless, the health and economic outcomes of the reopening phase have been mixed. The vast majority (>98%) of South Korea's infections occurred in 2022.[124] While the severity of infections remained relatively mild compared to that seen early in the pandemic, the high volume of infections nevertheless made 2022 the busiest year for the hospital system during the pandemic so far, with an average of ~362 hospital admissions per day, compared to 76 in 2021 and just 26 in 2020. This also translated into the number of deaths increasing significantly, to ~25,770 in 2022 compared to ~4,708 in 2021 and just 917 in 2020.[125]

The high volume of infections has also wrought an economic impact, both in direct costs borne by the health system in addressing COVID-19, and indirect economic losses borne by society in the form of absenteeism and productivity declines. While vaccination coverage has remained widespread, the use of antivirals has tended to track infection waves, with overall usage remaining relatively uncommon at a prescription rate of ~1.9% of all infections.

Direct and indirect costs will be explored in detail in Sections 5.3.1 and 5.3.2. South Korea's reopening experience has illustrated that the costs of COVID-19 borne by South Korean society extend beyond the value of health losses calculated merely by traditional health technology assessments. Indeed, productivity losses driven by infections across all age groups constitute a major economic cost.

A better understanding of the economic costs of the pandemic may allow for a more accurate assessment of the costs and benefits of various measures to address COVID-19.

121. Mathieu E, Ritchie H, Rodés-Guirao L, Appel C, Gavrilov D, Giattino C et al. Our World in Data [Internet]. South Korea: Coronavirus Pandemic Country Profile. 2023 Apr 13. Available from: https://ourworldindata.org/coronavirus/country/south-korea

122. As in many international jurisdictions, a vaccine rollout strategy was adopted in 2021 as a conduit for an easing of various restrictions. The resulting population-wide vaccination program (excluding ineligible children) delivered a double-dose national vaccination rate of >80% by January 2022. Lim S, Sohn M. The Lancet Regional Health Western Pacific [Internet]. How to cope with emerging viral diseases: lessons from South Korea's strategy for COVID-19. 2022 Sep 4. Available from: https://www.thelancet.com/journals/lanwpc/article/PIIS2666-6065(22)00196-1/fulltext

123. They are currently available for all COVID-19 positive patients over the age of 12 who are at high risk of severe disease, to be taken within 5 days of symptom onset.

124. There have been ~28 million infections in Korea this year, compared to ~635,000 in 2020-21.

125. Mathieu E, Ritchie H, Rodés-Guirao L, Appel C, Gavrilov D, Giattino C et al. Our World in Data [Internet]. South Korea: Coronavirus Pandemic Country Profile. 2023 Apr 13. Available from: https://ourworldindata.org/coronavirus/country/south-korea

5.2 Key Assumptions In The South Korean Context

A range of informed assumptions is used to derive estimates for the economic costs in South Korea as a result of COVID. Exhibit 18 illustrates how these assumptions are used and provides a list of key assumptions used, while a full list of assumptions is given in the Appendix section.

Exhibit 18: Use of assumptions in the South Korean context

A | Epidemiological scenarios

Scenario	Infections (mn) p.a.	Hosp. rate (%)
Normal 2.0	~12	0.20
Base	~52	0.30
Pandemic 2.0	~103	1.00

→

B | Direct costs: borne by the health system

Key Base Case Assumptions	
# Ward admissions p.a.	~14,000
# ICU admissions p.a.	~15,000
% Infections that visit a GP	2%
% Infections prescribed OAVs	~1.9%
# Long COVID cases p.a.	~2.6 million

+

C | Indirect costs: economic productivity losses borne by society

Key Base Case Assumptions	
Working-age infections as proportion of total	57%
Proportion of working-age infections that can work	99.7%
Proportion of working-age infections that can work from home	32%
Average number of working days lost due to acute illness in working-age population	8.5
Average daily salary	KRW 99,000

=

D | Total economic cost to society

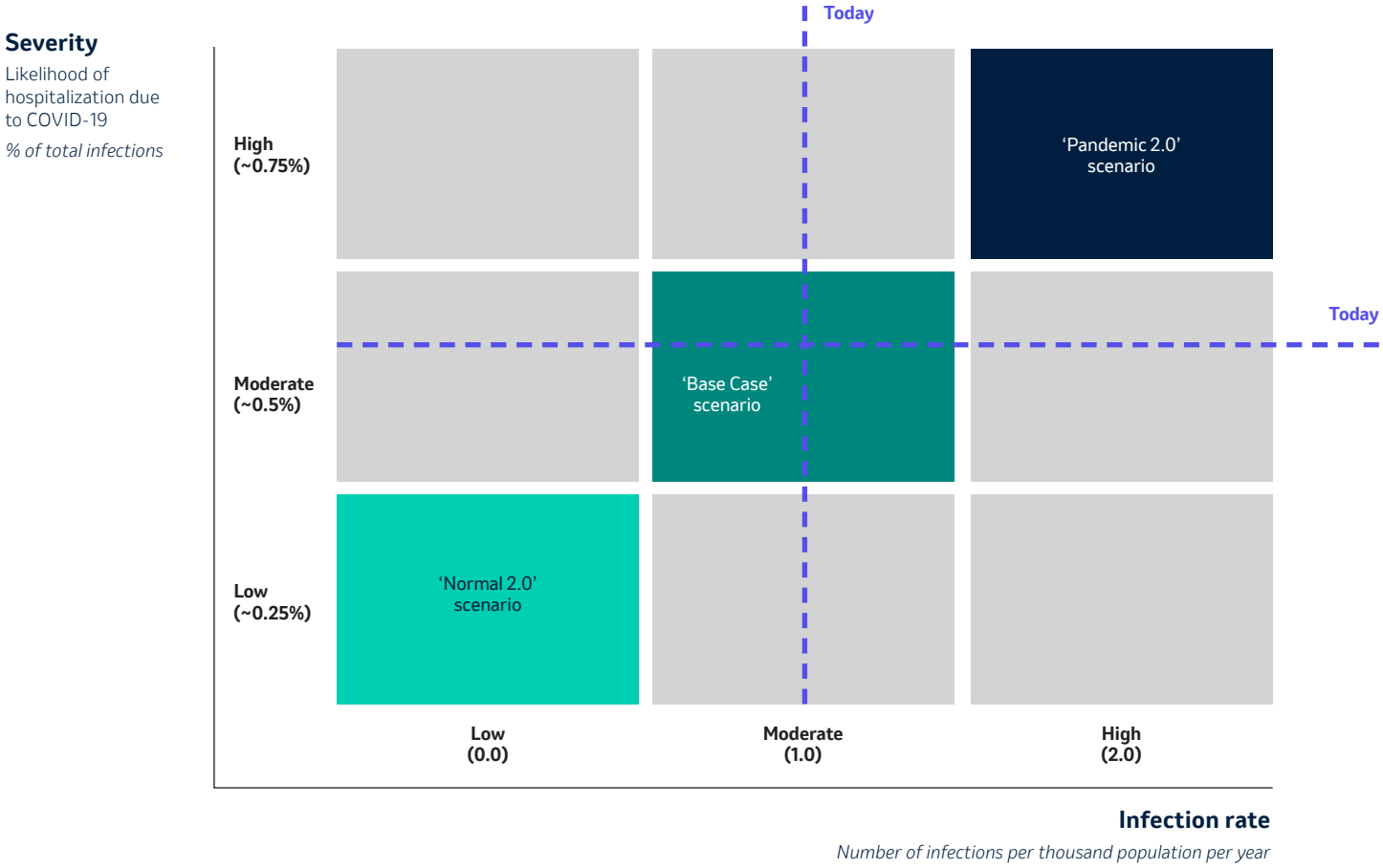
- **Total direct and indirect costs,** broken down by patient/demographic group
- **Costs per person** in each patient/ demographic group

  - E.g., if total inpatient costs are KRW ~540bn and 156,000 patients are admitted, the cost per person is KRW ~3.5mn

A full list of assumptions is given in the appendix.

5.3 Future:
Scenario-Based Estimates Of The Economic Costs Of COVID-19 In South Korea

Exhibit 19: Potential epidemiological scenarios



Scenarios are indicative only and based on the observed epidemiology of COVID-19 in South Korea in 2022.

Scenarios help us to consider and envisage the potential courses that the COVID-19 pandemic may take in the future. One way to express scenarios is in the form of low (Normal 2.0), base case, and high (Pandemic 2.0) epidemiological trajectories.

As illustrated by Exhibit 19, in the South Korean context this could mean:

- A base case, with an economic cost of KRW ~36 trillion p.a. (~1.6% of GDP, and in addition to the value of lost health, such as that already considered in HTAs), which assumes a rate of infection and a viral severity similar to that seen in Q3-4 2022, i.e., ~1,000,000 infections per million population annually, driving ~155,000 hospital admissions.[126] This is the scenario shown in Exhibit 20 below and described in the direct (5.3.1) and indirect (5.3.2) costs Sections below.

126. Infection numbers and hospitalization rates are sourced from modelling of COVID-19 infections in Korea by the Institute of Health Metrics and Evaluation (IHME; used with permission). In Korea, infection numbers are ~twice the number of reported cases, recognizing the volume that is not detected by the testing process.

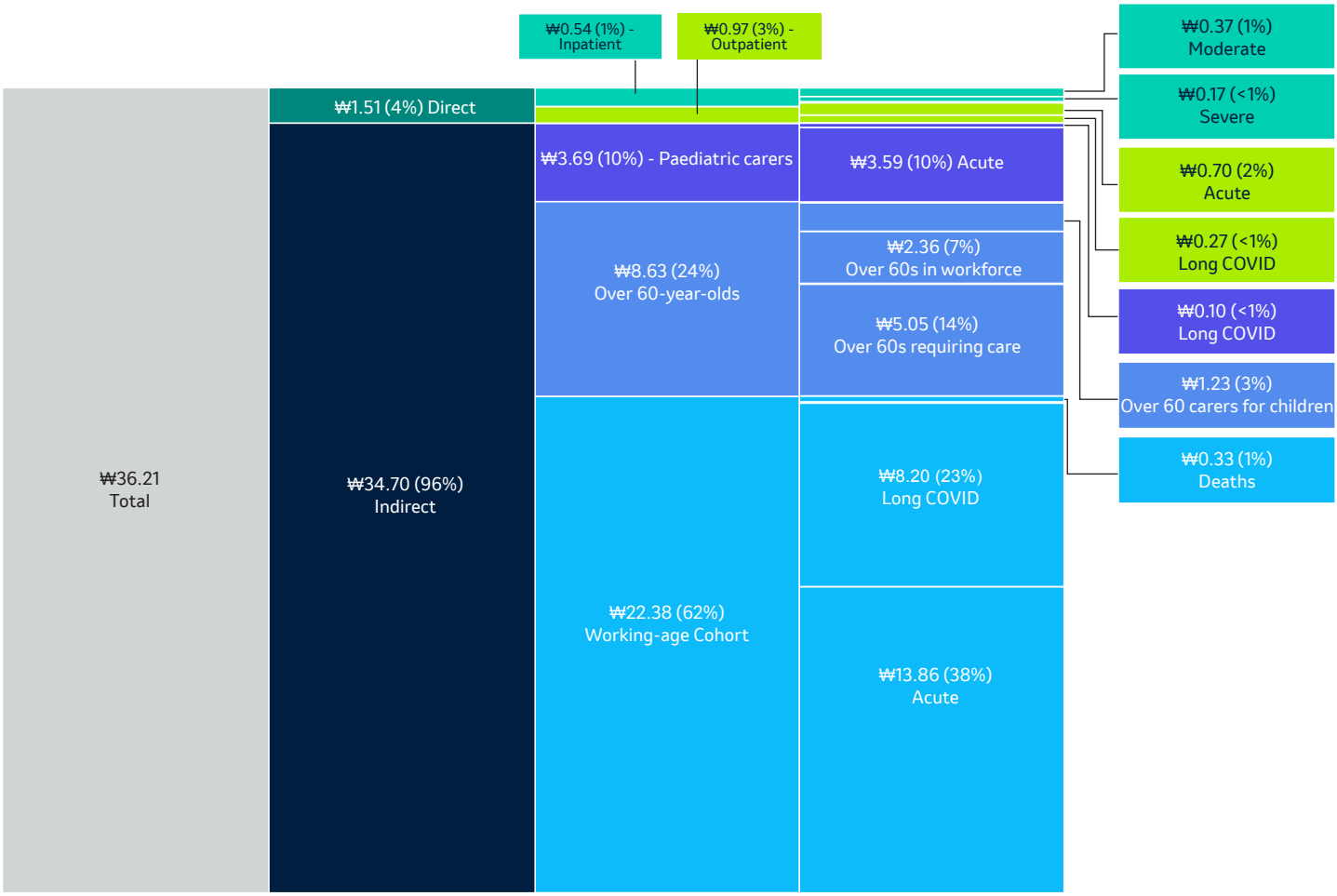
This base case scenario reflects the current COVID-19 isolation mandate of 7 days. If this assumption were to be reduced to just 3 days, the economic impact would be KRW ~32 trillion p.a. (an ~11% reduction).

- A high or Pandemic 2.0 case, with an economic cost of KRW ~122 trillion p.a. (~5.5% of GDP), which assumes a higher rate of infection and a higher viral severity, reflecting a scenario where each individual contracts the virus twice per year, i.e., 2 million infections per million population per year, driving ~1,000,000 hospitalizations annually.

- A low or Normal 2.0 case, with an economic cost of KRW ~7 trillion p.a. (~0.3% of GDP) which assumes a lower rate of infection and lower viral severity, similar to that seen in June 2022, whereby ~230,000 infections per million population per year result in ~23,000 hospitalizations.

As illustrated in Exhibit 20, the base case scenario is designed to reflect a continuation of recent conditions. To do this, infection volumes and the prevailing hospitalization rate from Q4 2022 have been drawn from the Institute of Health Metrics and Evaluation (IHME; used with permission) model of COVID-19 and annualized.

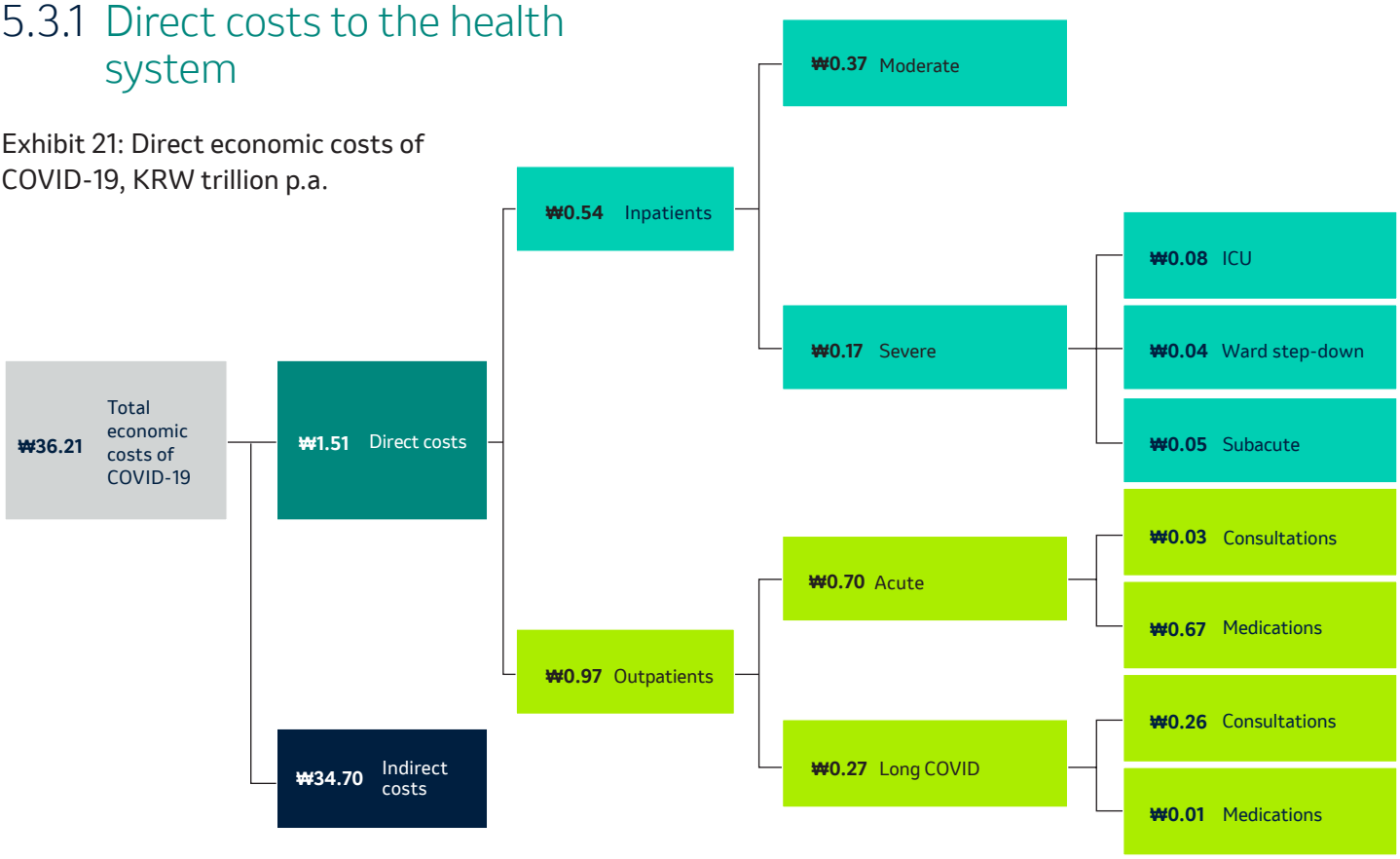
Exhibit 20: Direct and indirect costs of COVID-19 to South Korea's economy in a base case scenario, KRW trillion p.a.



Costs are indicative only and based on the distribution of COVID-19 infections between certain cohorts in South Korea in 2022.

5.3.1 Direct costs to the health system

Exhibit 21: Direct economic costs of COVID-19, KRW trillion p.a.



Note: Totals may not sum precisely due to rounding to 2 decimal places

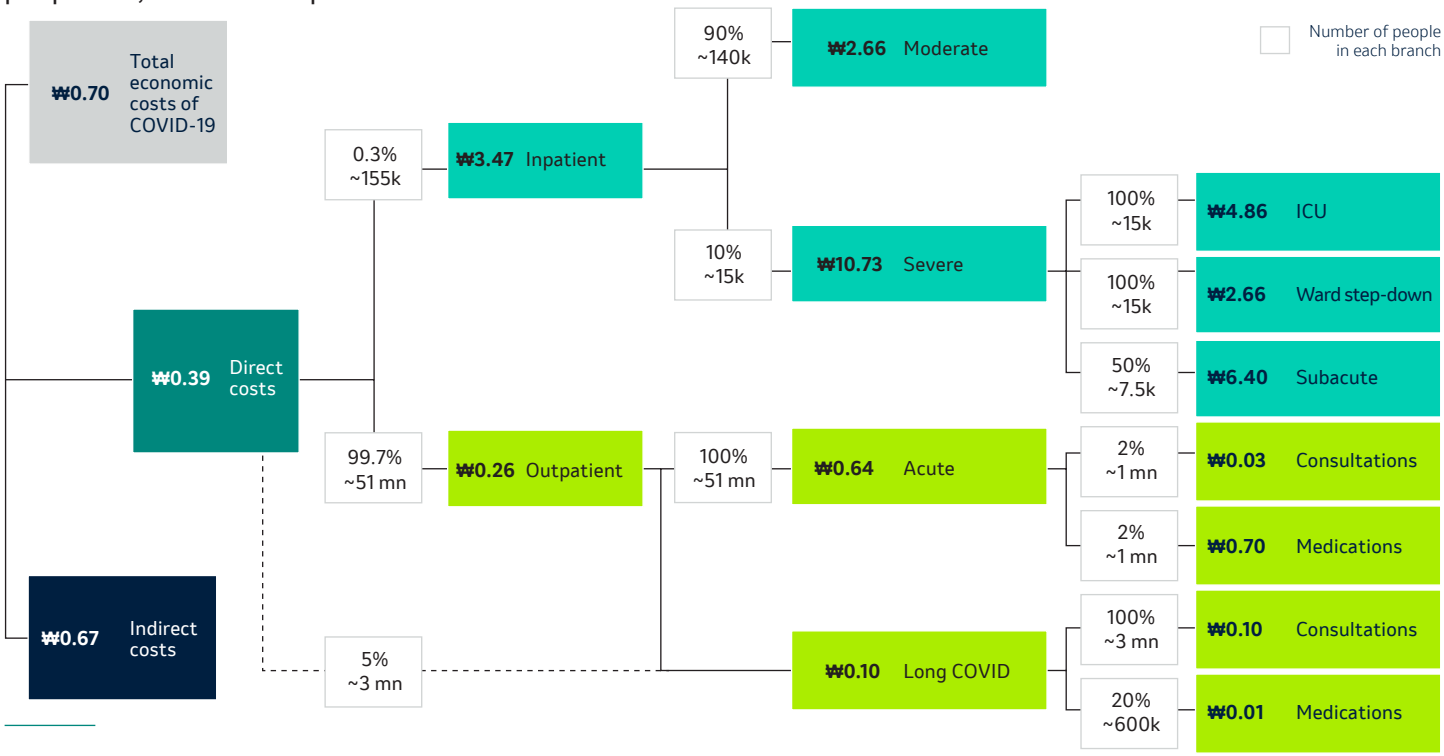
'Moderate illness' requires ward-based inpatient care, and 'Severe illness' requires ICU-level care; 'Acute illness' refers to all infections not included in inpatient care; Long COVID refers to a small subset (~5%) of total infections and represents infections with symptoms lasting 12 weeks or more.

With ~155,000 hospital admissions (including ~15,000 ICU admissions) and ~2.6 million cases of long COVID in the base case scenario, a number of variables could have a significant cumulative impact in reducing the direct costs imposed by COVID-19 on the health system, namely limiting hospital admissions and reducing lengths of stay, as well as differences in recovery times and/or the incidence of long COVID. Given that ~40% of admissions and ~60% of inpatient costs are borne by patients >60 years of age[127] preventing moderate to severe illness in this cohort would have a particularly impactful role in mitigating costs. More broadly, the magnitude of COVID-19's ongoing impact on the health system underscores the importance of continuing to test for and treat the disease, despite potentially changing societal attitudes towards the pandemic.

In this scenario, as displayed in Exhibit 21, COVID-19 could cost the South Korean health system KRW ~1.5 trillion p.a. This is a significant expense, equating to ~0.1% of South Korea's GDP. Despite the magnitude of this figure, direct costs are still a minority of the total economic costs of COVID-19 in South Korea, accounting for only ~4% of the overall total. Indirect costs, comprising productivity losses due to missed work, account for the remainder and could add up to KRW ~35 trillion p.a. (~1.5% of GDP). These are discussed further in Section (5.3.2). While together these amount to a significant expense, they still do not put an accurate value on the damage to health caused by COVID-19, nor the secondary effects to critical industries and vulnerable populations such as the health workforce.

127. HIRA and NHIS [Internet]. 2021 National Health Insurance Statistical Yearbook. 2021 Dec 17. Available from: https://www.hira.or.kr/bbsDummy.do?pgmid=HIRAJ030000007001&brdScnBltNo=4&brdBltNo=3

Exhibit 22: Direct economic costs from COVID-19, per person, KRW million p.a.



Costs per person for each segment are calculated by dividing the total cost of that segment by the number of individuals in that segment that utilize a health service; 'Moderate illness' requires ward-based inpatient care, and 'Severe illness' requires ICU-level care; 'Acute illness' refers to all infections not included in inpatient care; Long COVID refers to a small subset (~5%) of total infections and represents infections with symptoms lasting 12 weeks or more.

Despite the relatively minor weighting of direct costs within the wider economic impact of COVID-19, they remain significant on a per-infection basis. As illustrated in Exhibit 22, each infection that uses some form of health service could impose an average cost of KRW ~390,000. This is concentrated in the costs of inpatient care, where a single ward admission could cost up to KRW ~2.7 million and a single ICU admission (with subsequent ward and rehabilitation stays) could cost as much as KRW ~10.7 million.

As indicated in Exhibits 21 and 22, direct costs are incurred in two major settings:

- Inpatient (hospital-based) care (KRW ~540 billion p.a.; 35%; KRW ~3.47 million per person)
- Outpatient (primarily clinic-based) care (KRW ~970 billion p.a.; 65%; KRW ~260,000 per person)

The profile of inpatient care costs suggests that ameliorating the severity of illness acquired could have a significant impact on cost. Particularly in a reopened economy, where individuals at risk of severe disease are less protected from infection by community measures, the extent of ongoing costs to the health system underscores the importance of continuing to test for and treat the disease.

Costs in this category comprise those arising from moderate infections requiring ward-based care (KRW ~370 billion p.a.; KRW ~2.7 million per person) and severe infections requiring ICU (KRW ~170 billion p.a.; KRW ~10.7 million per person). The more costly care for moderate infections is driven largely by length of stay on the ward (~10 days on average), while the cost of care for severe infections is driven mostly by higher bed day costs (KRW ~650,000 per day in ICU), followed by substantial periods of inpatient rehabilitation (a median stay of 20 days).

The profile of outpatient care costs indicates that limiting the incidence, duration, and/or severity of long COVID would have a substantial impact on this portion of the cost burden. Outpatient care for COVID-19 infections adds KRW ~970 billion p.a. to the total economic costs incurred due to COVID-19. While seemingly less resource-intensive,

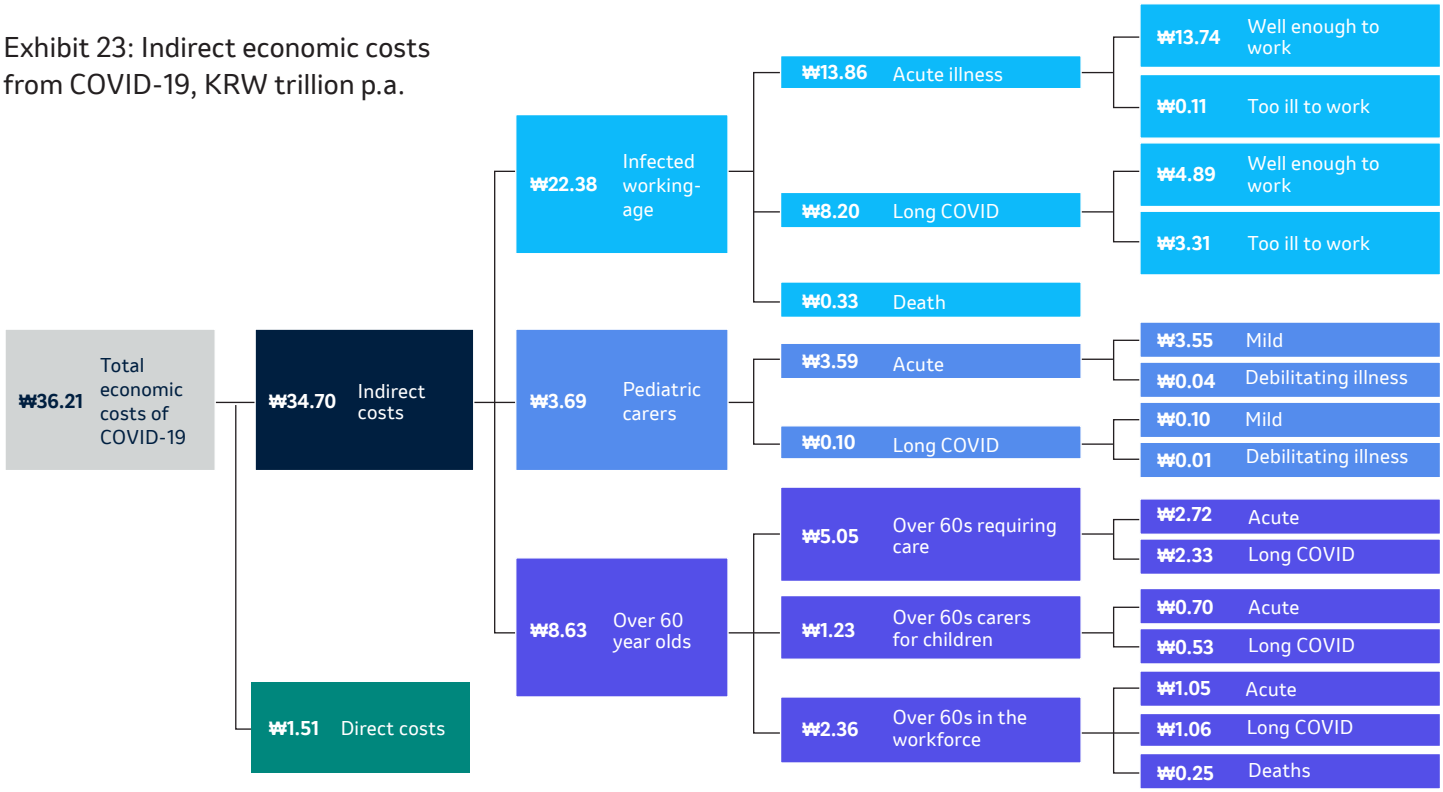
outpatient infections are not inexpensive on a per-person basis, each costing KRW ~260,000. Outpatient costs can be separated into acute outpatient care (consultations and medications; KRW ~700 billion p.a.) and chronic outpatient or long COVID care (consultations and medication; KRW ~270 billion p.a.; see also Section 5.4.6).

The figures for acute outpatient care are driven largely by the cost of medication (such as oral antivirals, KRW ~670 billion p.a.[128]), which equates to ~2% of total economic costs, representing a small investment toward partially reducing a much larger burden of direct and indirect costs (KRW ~36 trillion p.a.). Additionally, it is important to recognize the healthcare labor costs associated with prescribing medications. For example, a complex treatment regimen that requires comprehensive checks or reviews would incur an additional cost of KRW~ 2,000 for every extra 10-minute period of healthcare worker labor is worth,[129] without accounting for the opportunity cost of servicing other patients, which is imposed by this burden. Aggregate consultation costs in this cohort are lower because there are fewer of them – it is estimated that 2% of all infections visit a clinic[130] (~1 million visits p.a.).

Together, direct costs from the inpatient and outpatient cohorts amount to KRW ~1.5 trillion p.a. or 0.1% of South Korea's GDP. While significant on their own, these costs are in addition to the indirect costs to South Korea's economy (discussed below in Section 5.3.2), the value of lost health they represent, and the secondary effects on the health system (such as its workforce) and other critical industries (discussed below in Section 5.4).

128. '일동제약 코로나19 치료제 허가 가시권, 윤웅섭 화이자 MSD와 승부 앞둬'. Business Post [Internet]. 2022 Nov. Available from: https://www.businesspost.co.kr/BP?command=article_view&num=299133.
129. Based on a median weekly earnings figure of ₩693,000. Statista [Internet]. Average monthly salary of employees in South Korea from 2010 to 2021. 2022 Jun 29. Available from: https://www.statista.com/statistics/689751/south-korea-average-wage/
130. Goldstein EV, Seiber EE et al. Journal of Primary Care & Community Health [Internet]. Early Data on Predictors of COVID-19 Treatment Frequency at Community Health Centers. 2021 Dec 23. Available from: https://journals.sagepub.com/doi/full/10.1177/21501319211069473

Exhibit 23: Indirect economic costs from COVID-19, KRW trillion p.a.



Indirect costs arise from productivity losses incurred due to infection with COVID-19; 'Well enough to work' refers to those who can continue working while infected, albeit with reduced productivity; 'Too ill to work'' refers to those who cannot work, at least for a portion of the time, while infected; 'Acute illness' refers to all infections not included in inpatient care; Long COVID refers to a small subset (~5%) of total infections and represents infections with symptoms lasting 12 weeks or more.

5.3.2 Indirect costs to the economy

Reducing the sheer volume of COVID-19 infections and the duration of illness and/or recovery time for working-age adults, children, and the older population would have a significant impact on the economic and societal costs of COVID-19 in South Korea.

In the base case scenario, and as Exhibit 23 illustrates, COVID-19 could cost the South Korean economy KRW ~35 trillion p.a. (~1.5% of GDP) in productivity losses if current epidemiological conditions and response settings continue.[131,132] As with direct costs to the health system, this is a significant expense, equating to ~1.5% of GDP. When discounting for productivity losses due to potential changes in isolation mandates (which may be reduced in the future), indirect costs would remain significant at KRW ~31 trillion p.a.[133] While these costs are significant, as with direct costs, they still do not put an accurate value on the damage to health due to COVID-19, nor on the secondary effects to critical industries and vulnerable populations, such as the health workforce.

As illustrated in Exhibit 23, indirect costs result from productivity losses borne by three major groups:

- **Infections in working-age adults (19 to 59 years old) – KRW ~22.4 trillion p.a.** (~62%; KRW ~750,000 per person)
- **Infections in the older population (60 years old and above) – KRW ~8.6 trillion p.a.** (~24%; KRW ~860,000 per person)
- **Infections in children and adolescents (18 years old and under) – KRW ~3.7 trillion p.a.** (~10%; KRW ~370,000 per person)

Infections in working-age adults impose a significant economic burden on South Korea, with productivity losses valued at KRW ~22.4 trillion p.a. (~1.0% of GDP). This burden highlights the broader economic impact that can be inflicted by an illness that, although mild for most, can be significant enough to last ~12 days and impair productivity by ~35% on days worked while unwell (an average of ~10).

Productivity losses incurred by the working-age group can be considered in two ways:

- Acute illness (KRW ~13.9 trillion p.a.), chronic illness or long COVID (KRW ~8.2 trillion p.a.), and deaths (KRW ~330 billion p.a.);
- Infected adults still well enough to work, but with reduced capacity (KRW ~18.6 trillion p.a.), and infected adults who are too ill to work (KRW ~3.4 trillion p.a.).

Taking these together, acute illness in those who can still work but at reduced capacity accounts for ~60% of productivity losses incurred by working-age adults. The magnitude of this cost illustrates that, despite the mildness of the illness for most, when modest reductions in working capacity are multiplied across a multi-day illness affecting ~33 million people in South Korea, the result is a substantial cost impact for the whole market.

Infections in the older population impose KRW ~8.6 trillion p.a. (~0.4% of GDP) in costs on the South Korean economy from productivity losses, adding to the burden from working-age adults. This highlights that productivity losses are not limited to those borne by the working-age population alone and that adjacent cohorts are of proportional importance.

Older people that incur productivity losses due to COVID-19 fall into three categories:

- **Older people with COVID-19 who require care from a working-age person** – 9 million working-age adults incurring a KRW ~560,000 productivity loss – resulting in a total impact of KRW ~5.1 trillion p.a.
- **Older people who directly participate in South Korea's labor force** – ~19% of those over 60.[134] Infections in this group result in KRW ~2.4 trillion p.a. of productivity losses.

131. Based on a median weekly earnings figure of ₩693,000. Based on a median weekly earnings figure of ₩693,000. Statista [Internet]. Average monthly salary of employees in South Korea from 2010 to 2021. Available from: https://www.statista.com/statistics/689751/south-korea-average-wage/
132. As of December 2022, the isolation mandate for an individual who becomes infected with COVID-19 is 7 days.
133. Assumes that individuals infected by COVID-19 do not isolate unless they voluntarily take sick absence from work.
134. Wise Person [Internet]. 65세 이상 취업자 345만명, 45%는 근로소득 100만원 미만. 2022 Sep 20. Available from: http://www.wiseperson.co.kr/news/articleView.html?idxno=2039

- **Older people (e.g., grandparents) who care for children to enable parents to work** – one survey found that ~30% of grandparents (including in multi- and single-generation households) provided care for grandchildren.[135] When this work-enabling care is disrupted, the productivity loss amounts to KRW ~1.2 trillion p.a.

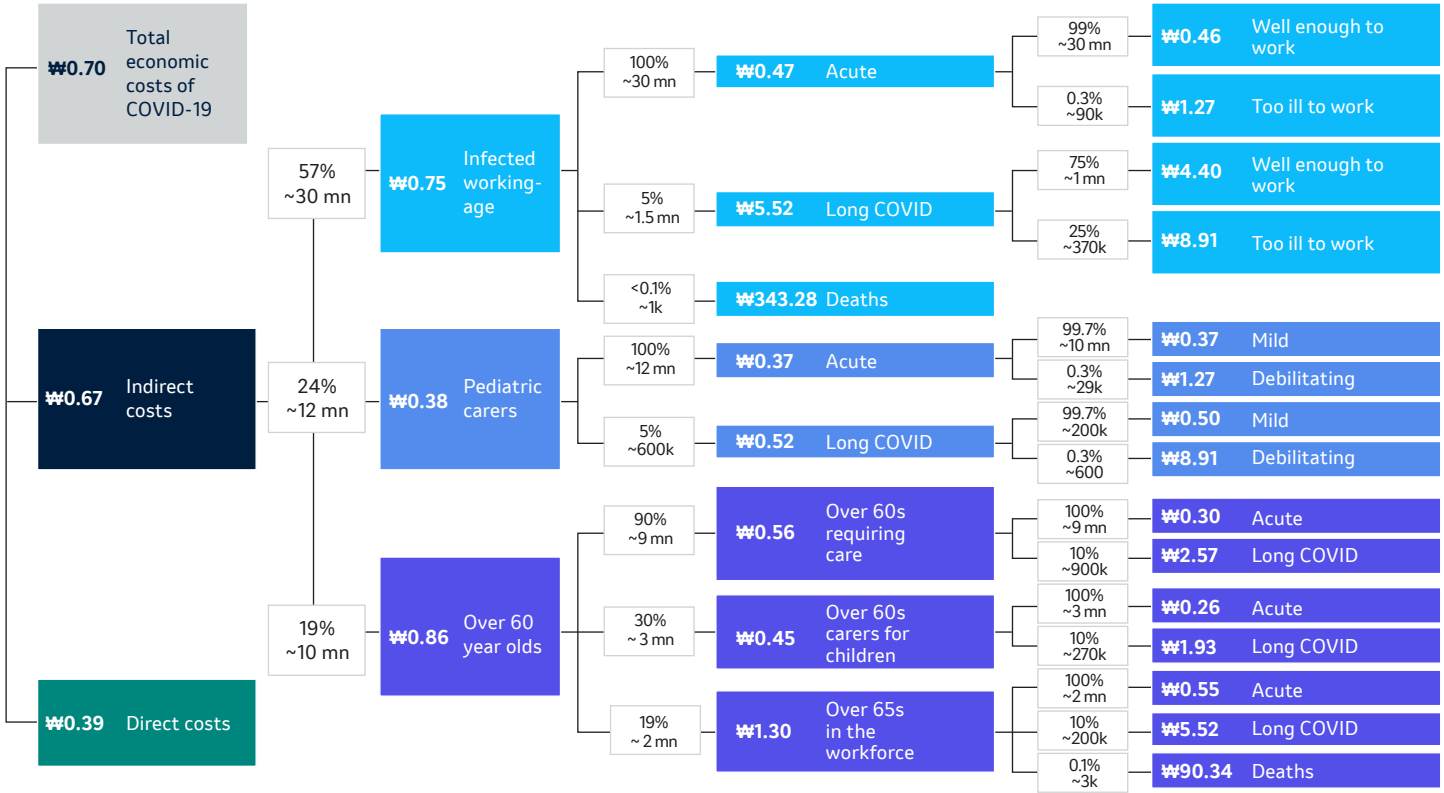
Infections in the older population account for KRW ~9.0 trillion p.a., or ~25% of all direct and indirect costs combined, serving as a stark reminder of the need to address costly infections in cohorts adjacent to working-age adults.

Finally, infections in children impose an additional economic cost of KRW ~3.7 trillion p.a. (~0.2% of GDP), owing to productivity losses borne by adults who are absent from or less productive at work while caring for children. Along with those from the older population, productivity losses arising from infections in children can be difficult to recognize in advance, but are significant when they emerge.

Productivity losses arising from infections in children are predominantly driven by adults caring for children with acute, mild illness. The cohort of infected children, which constitutes the majority (~99%) of productivity losses in adults caring for children with acute illness, is worth KRW ~3.55 trillion p.a. This cost is driven by care for ~6.9 million mild infections in children, who despite having a mild illness require one parent to

135. Stuck AE, Tuckett AG. International Journal of Environmental Research and Public Health [Internet]. Longitudinal Patterns of Grandchild Care in South Korea. 2022 Jan 20. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8834307/

Exhibit 24: Indirect economic costs from COVID-19, per person, KRW million p.a.



Costs per person for each segment are calculated by dividing the total cost of that segment by the number of individuals in that segment; Indirect costs arise from productivity losses incurred due to infection with COVID-19; 'Well enough to work' refers to those who can continue working while infected, albeit with reduced productivity; 'Too ill to work'' refers to those who cannot work, at least for a portion of the time, while infected; 'Acute illness' refers to all infections not included in inpatient care; Long COVID refers to a small subset (~5%) of total infections and represents infections with symptoms lasting 12 weeks or more.

care for them at home. The remaining ~1% is driven by productivity losses from caring for children with debilitating infections. For parents who can work from home (~32%), productivity is estimated to halve, while all productivity is foregone by parents who cannot (~68%).[136] This is a substantial cost driven more by lost work than the illness itself, reiterating that significant costs imposed by productivity losses are not limited to infections in working-age adults.

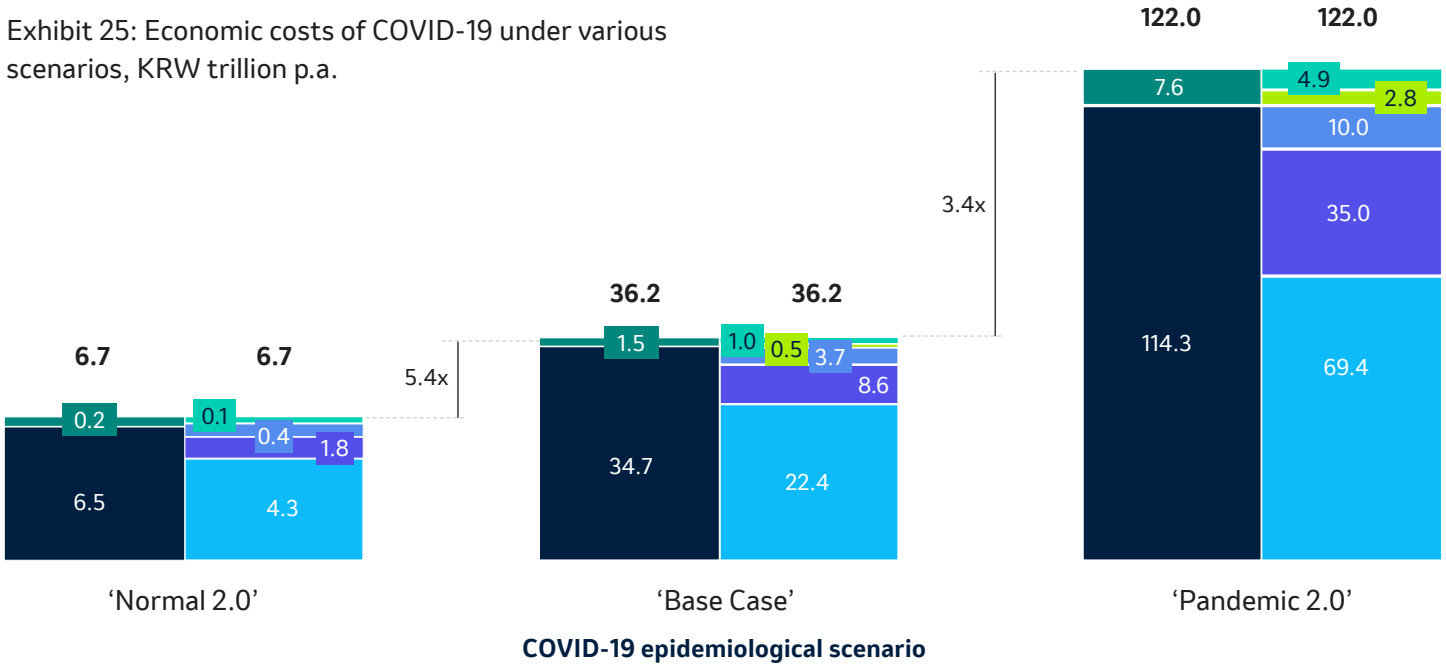
Despite the apparent reduction in resource intensiveness compared to direct healthcare costs, the magnitude of productivity losses imposed by COVID-19 means indirect costs are actually more expensive on a per-person basis (as indicated in Exhibit 24), with each infection costing KRW ~670,000 (versus KRW ~390,000 for direct costs) on average. This is concentrated in productivity losses resulting from infections in working-age (KRW ~750,000 per person) and older populations (KRW ~860,000 per person).

Together, economic costs arising from productivity losses in these groups amount to KRW ~34.7 trillion p.a. or ~1.5% of South Korea's GDP and are in addition to the value of lost health and direct costs to South Korea's health system. Although already substantial, these costs are likely to underestimate the entirety of the burden imposed on society by COVID-19, including second-order impacts on health system capacity and knock-on effects on the health workforce, supply chains, and other aspects of critical industry; all of these factors contribute to directly measurable economic impacts.

The entirety of the economic burden imposed by COVID-19 needs also to be understood in the context of the prevailing epidemiological scenario, as the impacts and costs described can significantly increase under plausible scenarios where novel variants emerge. Such scenario variations are described below.

136. Statista [Internet]. Remote work in South Korea. Available: https://www.statista.com/study/105361/remote-work-in-south-korea/

Exhibit 25: Economic costs of COVID-19 under various scenarios, KRW trillion p.a.



Normal 2.0 refers to a scenario featuring ~230,000 infections per million population and ~23,000 hospitalizations. Pandemic 2.0 refers to a scenario featuring ~2 million infections per million population (i.e., 2 infections per person per year) and ~1,000,000 hospitalizations, reflecting conditions observed in March and August of 2022, annualized.

5.3.3 Alternative scenarios: costs of Pandemic 2.0 and Normal 2.0

In addition to the base case, two further scenarios are considered, as illustrated in Exhibit 25.

In a Pandemic 2.0 scenario, total economic costs could reach KRW ~122 trillion p.a. (~5.5% of GDP). Conversely, in the Normal 2.0 scenario, economic costs could be reduced to KRW ~7 trillion p.a. (~0.3% of GDP).

The two example scenarios represent divergent epidemiological outcomes, both of which are plausible as the pandemic evolves. Each theoretical scenario is constructed with two key features:

- Infection volume (driven by contagiousness, measured by cases per million population per year);
- Case severity (driven by a prevailing strain's virulence factors, measured by the resulting hospitalization rate)

A Pandemic 2.0 scenario would feature a case volume of ~2 million cases per million population per year (i.e., the entire population is infected twice, on average) and a case severity that drives a hospitalization rate of ~1% of all infections. This is in comparison to the base case scenario, where a case volume of ~1 million infections per million population and a hospitalization rate of 0.3% is assumed.[137]

In this scenario, economic impacts from COVID-19 could increase to KRW ~122 trillion p.a., equating to ~5.5% of GDP and KRW ~1.3 million per person. In this scenario, direct costs could be KRW ~7.6 trillion p.a. (i.e., KRW ~6 trillion p.a. higher than the base case, or a five-fold increase), while indirect costs could reach KRW ~114 trillion p.a. (i.e., KRW ~80 trillion p.a. higher than the base case, or a more than three-fold increase). These increases would be driven by an uptick in hospitalization rates and longer periods of stay, as well as augmented productivity losses, caused by a more prevalent incidence of debilitating illness and longer periods of missed work.

The magnitude of cost increases that could result from a plausible epidemiological scenario such as this demonstrates the need for a range of preparedness settings, which include options to limit impacts at all junctures.

By contrast, a Normal 2.0 scenario would feature a case volume of ~320,000 cases per million population per year and a hospitalization rate of 0.2%. These thresholds represent the lowest recorded levels for each measure observed in South Korea during the pandemic. Under a Normal 2.0 scenario, economic impacts from COVID-19 could reduce to KRW ~6.7 trillion p.a. (~0.3% of GDP) and KRW ~577,000 per person. Direct costs could decrease to KRW ~200 billion p.a. and indirect costs to KRW ~6.5 trillion p.a. Decreases in costs would be driven by lower hospitalization rates and diminished productivity losses owing to reduced periods of missed work.

While these different scenarios help us to consider potential trajectories that the COVID-19 pandemic may take in the future, their scope is largely restricted to the consideration of quantifiable economic costs. Equally worthy of consideration are the second-order impacts that COVID-19 could exert on health system capacity and the knock-on effects that this would have on vulnerable populations and critical industries. This aptly demonstrates the broad economic and societal impacts of the pandemic.

137. Infection numbers and hospitalization rates are sourced from modeling of COVID-19 infections in South Korea by the Institute of Health Metrics and Evaluation (IHME; used with permission). Available from: https://www.healthdata.org/covid/data-downloads

5.4 Considerations For Critical Cohorts And Industries

The economic costs of COVID-19 described will impact different populations and industries disproportionately. This includes cohorts that play a critical economic or societal role (e.g., logistics workers, health care workers), those that are particularly vulnerable to severe disease (e.g., people with comorbidities), and those that go on to develop long COVID. These groups may be worthy of additional focus when considering countermeasure approaches to mitigate the impacts of COVID-19.

Specifically, interventions that protect health and productivity losses in these critical industries and populations may yield corresponding, disproportionate economic returns.

5.4.1 Critical workers and industries

As outlined above, some critical industries experience disproportionate indirect costs (i.e., productivity losses) that generate significant public concern. Here, the focus is on three industries in particular – healthcare, logistics, and travel and tourism.

The economic costs of COVID-19 borne by critical industries and their stakeholders may increase under a Pandemic 2.0 scenario. In this scenario, workforces that are largely unable to work from home may be required to isolate while they recover. The resulting loss of productive time can be 50% greater (up to the equivalent of ~3 workdays) than that of individuals in desk-based jobs who are able to perform work tasks in their home environment.

5.4.2 Healthcare

South Korea's health system serves as the market's first and last line of defense against COVID-19 and other health threats. Medical services are a KRW ~127 trillion industry, employing ~780,000 healthcare practitioners.[138]

At a potential minimum cost of KRW ~1 trillion p.a. (~3% of combined total cost), [139] healthcare workers who become infected with COVID-19 represent a disproportionate slice of the impact that this disease exerts on the economy. However, this is likely to significantly underestimate the total cost to the South Korean economy and citizens' welfare, as it would also translate into secondary impacts on patient outcomes.

Health service employers typically experience higher rates of absenteeism due to COVID-19 compared with other industries. A root cause of these inflated figures is the heightened risk of severe COVID-19 that healthcare workers are exposed to, due to their frequent contact with infectious patients.[140] Productivity losses are not only incurred by sick workers but also by the remaining workers who are required to take up additional responsibilities. This extra workload reduces their capacity for completing non-patient care tasks and contributes to exhaustion, diminished empathy, and an increased risk of mistakes.[141]

138. Korean Health Industry Development Institute [Internet]. 2021 Market Overview. Available from: https://www.khidi.or.kr/board?menuId=MENU00793&siteId=SITE00012
139. Based on the proportion (3%) of the workforce represented by healthcare workers. This figure is an underestimate as healthcare workers are likely to represent a disproportionate number of infections due to increased exposure.
140. Kim S, Kang H, Jeong H, Jang S, Lee J, Kim D et al. Journal of Korean Medical Science [Internet]. Vaccination in Healthcare Workers: 3-Dose Versus 2-Dose Vaccination. 2022 Sep 5. Available from: https://jkms.org/pdf/10.3346/jkms.2022.37.e267
141. Docdocdoc [Internet]. "국립대병원 의료인력 부족으로 의료 붕괴 위기 직면" ("Facing the crisis of medical collapse due to lack of medical personnel at national university hospitals"). 2022 Mar 28. Available from: http://www.docdocdoc.co.kr/news/articleView.html?idxno=2021244

The second-order economic impacts of COVID-19-related absenteeism among healthcare workers are significant. COVID-19 has exacerbated pre-existing workforce shortages, resulting in poorer quality and safety of healthcare provision. Shortages have the potential to exacerbate ambulance wait times, for example, which have reached up to six hours in some hospitals.[142] Such reductions in the availability and timeliness of medical care may subsequently lead to prolonged illness or recovery times for patients, who in turn accumulate their own additional productivity losses.

Additionally, during the COVID-19 pandemic, unprecedented levels of workforce burnout and attrition have been seen.[143] Although the initial response to the COVID-19 pandemic has subsided, global talent shortages and mobility challenges are an ongoing concern.

A countermeasure approach that targets healthcare workers could have a significant effect in mitigating overall economic costs, as well as the impacts of COVID-19 on public health. This is demonstrated by the disproportionate costs of COVID-19 infections among healthcare workers, against the backdrop of an increasingly constrained talent market.

5.4.3 Logistics

COVID-19 has caused unprecedented disruption to South Korea's logistics sector, which delivers vital goods and services across the nation. It is a KRW ~114 trillion industry, with a workforce of ~750,000 people.[144] During the pandemic, the sector experienced a disproportionate impact of productivity loss from workers, which has snowballed to disrupt local and global supply chain networks.

South Korea has experienced significant workforce shortages in the logistics sector due to the COVID-19 pandemic.[145] Among this workforce are warehouse staff, forklift drivers, unloading crews, and technicians, who are unable to complete their tasks at home while ill, isolating, or caring for others who have been infected with COVID-19. Taking on the workload of sick colleagues adds to high levels of pressure on the logistics workforce, which has led to collective strikes.[146]

Workforce shortages have downstream consequences for end-point retailers, users, and customers too. Disruptions have the dual effect of driving inflation in the costs of goods and services while impeding the ability of businesses, and their workers, to deliver them. Among these, there are necessities of particular public concern – life-changing medicines, gas, and oil.[147]

The impact of workforce shortages may point to an incremental opportunity for targeted COVID-19 countermeasures to support South Korea's logistics industry workforce as it grapples with the multitude of challenges (including geopolitical tensions) at the heart of today's "supply chain crisis".

142. "Docdocdoc [Internet]. "응급환자 이송 지연 해결하려면 '수용 거부' 제재해야" ("In order to solve the delay in transporting emergency patients, 'acceptance refusal' should be sanctioned). 2021 Aug 19. Available from: http://www.docdocdoc.co.kr/news/articleView.html?idxno=2013637

    Medical Times [Internet]. Infinite waiting at ambulance due to lack of corona confirmed paediatric and maternal wards. 2022 Aug 27. Available from: https://www.medicaltimes.com/Main/News/NewsView.html?ID=1149116

143. Keimyung University Sleep Centre [Internet].코로나19 대응 의료진 정신건강 '적신호' (Mental health red glad for medical staff responding to COVID-19) 2021 Apr 12. Available from: http://www.docdocdoc.co.kr/news/articleView.html?idxno=2009575. IHME [Internet]. Worldwide shortage of health workers threatens effective health coverage IHME. 2022 May 23. Available from: https://www.healthdata.org/news-release/worldwide-shortage-health-workers-threatens-effective-health-coverage

    Seoul Economic Daily [Internet]. 코로나 2년 사투에 '번아웃'…의료진이 떠난다 ('Burnout' in the 2-year struggle with Corona… medical staff leave). 2021 Dec 14. Available from: https://www.sedaily.com/NewsView/22VAGVCHRT

144. Statistics Korea [Internet]. Transport Survey. Available from: https://kostat.go.kr/anse/?bmode=read&aSeq=417098&pageNo=&rowNum=10&amSeq=&sTarget=&sTxt=

145. Shin J. The Korea Herald [Internet]. Korea struggles to respond to labor shortage amid pandemic. 2021 Mar 28. Available from: https://www.koreaherald.com/view.php?ud=20210328000132

146. Crossing [Internet]. 韓國物流業大罷工——快速便利的電商文化背後，是過勞的惡性循環 ('Strike in South Korea's logistics industry—Behind the fast and convenient e-commerce culture is a vicious cycle of overwork'). 2021 Jul 9. Available from: https://crossing.cw.com.tw/article/15025

147. Lee Y, Cha S. Bloomberg [Internet]. South Korea Plans to Order Fuel, Steel Truckers Back to Work. 2022 Dec 4. Available from: https://www.bloomberg.com/news/articles/2022-12-04/south-korea-to-order-fuel-steel-truckers-to-return-to-work?leadSource=uverify%20wall

5.4.4 Travel and tourism

Despite a strong recovery since the re-opening of borders in October last year, South Korea's travel and tourism sector continues to face headwinds due to workforce shortages. Representing a major portion of the South Korean economy, the sector's contribution to GDP had been projected to reach KRW ~73 trillion and support ~1.3 million jobs in 2022.[148] Prior to last year, the impact of the pandemic could be observed through the steep decline in visitor volumes and spending, due to border restrictions, isolation orders, and general hesitancy among travelers.

COVID-19-related absenteeism has wreaked havoc across airports and accommodation services. Staff shortages (coupled with demand surges as travel restrictions ease) have forced flight cancellations with passengers waiting 2 to 7 days, rather than 24 hours, for the next available option.[149] Flight disruptions can impede the productive work time of corporate travelers and impact the consumer spending of holidaymakers. On the flights themselves, as few as six flight attendants are being assigned, compared to the usual nine crew members, leading to concerns around safety and workforce fatigue.[150]

Countermeasures that are targeted specifically at South Korea's travel and tourism workforce may help the sector fully overcome any remaining hurdles in its recovery from the COVID-19 pandemic.

5.4.5 Vulnerable populations

COVID-19 illness in South Korea's vulnerable populations – those over 60, or over 18 with a comorbidity – represents a minimum impact of KRW ~18 trillion p.a. (~0.8% of GDP) to South Korea's economy. These populations are at greater risk of severe COVID-19 disease and are more heavily reliant on the healthcare system than others. Vulnerable populations that have received particular attention throughout the pandemic include those over 60 years old and those with comorbidities. Almost all (KRW ~17.4 trillion p.a.; ~48% of total economic costs and ~0.8% of GDP) of the costs in this category result from infections that are eligible for oral antivirals.[151,152]

COVID-19 illness in South Korea's older population (60 years and over) could have an economic impact of KRW ~9.0 trillion p.a. (~25% of annual economic costs). This is significant on a per-person basis too, at KRW ~896,000. Despite representing just ~12% of confirmed cases, the older population accounts for a higher proportion of COVID-19 hospitalizations, at ~40%.[153] This is unsurprising when one considers that the prevalence of comorbidities (predominantly high blood pressure, cancer, and diabetes) is particularly high in this age group, reaching ~71% for those over 65 years old.[154]

148. World Travel and Tourism Council [Internet]. South Korea's tourism to create nearly half a million jobs. 2022 Jul 7. Available from: https://insights.ehotelier.com/global-news/2022/07/07/south-koreas-tourism-to-create-nearly-half-a-million-jobs/
149. Yoo H. The Korea Herald [Internet]. Damage claims surge over frequent flight cancellations. 2022 Jul 18. Available from: https://www.koreaherald.com/view.php?ud=20220718000652
150. Park T. Hankyoreh [Internet]. 코로나19 끝나니 '일터 지옥'…"항공사들이 노동력 쥐어짜" ('Corona 19 is over, 'workplace hell'… Airlines squeeze the labour force'). 2022 Aug 23. Available from: https://www.hani.co.kr/arti/society/labor/1055895.htmlAssumes ~19.5% infections are >60 and eligible; assumes ~57.4% infections are aged 19-60 years, of which ~36.5% have a comorbidity and are eligible.
151. Assumes ~19.5% infections are >60 and eligible; assumes ~57.4% infections are aged 19-60 years, of which ~36.5% have a comorbidity and are eligible.
152. Eul, H. Journal of Health Informatics [Internet]. Analysis of multiple chronic disease characteristics in South Koreans by age groups using association rules analysis. 2022 Jan 17. Available from: https://journals.sagepub.com/doi/full/10.1177/14604582211070208#bibr5-14604582211070208
153. Calculated based on age distribution of inpatients. Specific data related to COVID-19 or similar respiratory illnesses was unavailable. HIRA and NHIS [Internet]. National Health Insurance Statistical Yearbook, 2021. Available from: https://www.hira.or.kr/bbsDummy.do?pgmid=HIRAJ030000007001&brdScnBltNo=4&brdBltNo=3
154. Eul, H. Journal of Health Informatics [Internet]. Analysis of multiple chronic disease characteristics in South Koreans by age groups using association rules analysis. 2022 Jan 17. Available from: https://journals.sagepub.com/doi/full/10.1177/14604582211070208#bibr5-14604582211070208

Comorbidities in the younger, working-age (19-59 years) population could also have a disproportionate impact of KRW ~8.7 trillion p.a.[155] one comorbidity doubles the risk of severe COVID-19,[156] subsequently increasing the likelihood of hospitalization and prolonging recovery time away from work. This could be a reality for ~39% of adults in South Korea.[157]

With vulnerable populations bearing ~50% of combined direct and indirect costs, countermeasures that reduce their duration of illness and/or recovery time could significantly mitigate the costly impacts of COVID-19. Countermeasures may include ongoing vaccination,[158] community interventions, or the use of oral antivirals.[159] Oral antivirals were introduced in South Korea in the second quarter of 2022 to provide an additional option for protection against COVID-19.

5.4.6 Long COVID

Long COVID[160] has a potential minimum impact of KRW ~12.5 trillion p.a. (~0.6% of GDP and KRW ~4.8 million per person p.a.) on South Korea's economy. Individuals who develop this condition experience prolonged productivity losses (increasing indirect costs) and reliance on health services (increasing direct costs).

Direct costs due to long COVID collectively amount to at least KRW ~268 billion (KRW ~103,00 per person), largely driven by the need for ongoing medical consultations. This higher figure results from the incidence and the relative complexity and duration (90 days) of long COVID illness. When case complexity and duration are factored in, this could mean ~15 million healthcare consultations are required for this cohort alone.[161,162] Long COVID, therefore, represents a substantial burden on the health system, both in terms of capacity requirement and economic cost.

Indirect costs/productivity losses arising from long COVID could amount to at least KRW ~12.2 trillion p.a. (KRW ~4.7 million per person p.a. and ~33% of all indirect costs). By a significant margin, the largest contributors are productivity losses arising from long COVID in the working-age population (KRW ~8.2 trillion p.a. or ~67%). To illustrate this case, an adult with long COVID could still lose an aggregate of 44 workdays over a three-month period, despite being well enough to work.[163]

Given the large share (~32%) of total economic costs that long COVID imposes on the South Korean economy, any countermeasure that is able to reduce the incidence and/or duration of this condition would contribute a great deal to mitigating economic costs associated with the pandemic. Current conservative estimates suggest that the incidence and course of long COVID are at 5% and 90 days respectively; however, the evidence is still nascent, and these impacts may yet be shown to be underestimates.

155. Calculated based on age distribution of inpatients. Specific data related to COVID-19 or similar respiratory illnesses was unavailable. HIRA and NHIS [Internet]. National Health Insurance Statistical Yearbook, 2021. Available from: https://www.hira.or.kr/bbsDummy.do?pgmid=HIRAJ030000007001&brdScnBltNo=4&brdBltNo=3
156. Liu B, Spokes P, He W, Kaldor J. BMC Infectious Diseases [Internet]. High risk groups for severe COVID-19 in a whole of population cohort in Australia. 2021 Jul 16. 685(2021). Available from: https://bmcinfectdis.biomedcentral.com/articles/10.1186/s12879-021-06378-z
157. Proportion of total population with chronic diseases, including hypertension, diabetes, heart disease, and cerebrovascular disease. Age distribution was unavailable. HIRA and NHIS [Internet]. Available from: https://www.hira.or.kr/bbsDummy.do?pgmid=HIRAJ030000007001&brdScnBltNo=4&brdBltNo=3
158. KDCA [Internet]. 누가 먼저 코로나19 예방접종을 하나요? (Who gets vaccinated against COVID-19 first?). Available from: https://ncv.kdca.go.kr/menu.es?mid=a10117010000
159. Oral antivirals are indicated for over 18-year-olds with COVID-19 confirmed with severe risk factors within 5 days of onset. Risk factors include being over 65 years of age or having cardiovascular disease, high blood pressure, or chronic lung disease. KDCA [Internet]. 코로나19 치료제 및 치료제 지침 (COVID-19 Treatment and Treatment Guidance). Available from: https://ncv.kdca.go.kr/hcp/page.do?mid=030301
160. Also commonly described as 'post-COVID 19 syndrome', long COVID describes the prolonged duration of COVID-19 symptoms beyond twelve weeks after the initial infection.
161. Kim, Y., Bitna-Ha, Kim, SW. et al. BMC Infectious Diseases [Internet]. Post-acute COVID-19 syndrome in patients after 12 months from COVID-19 infection in Korea. 2022 Jan 27. 93(2022). Available from: https://bmcinfectdis.biomedcentral.com/articles/10.1186/s12879-022-07062-6
162. Each case could require 6 consultations on average over the 90-day period of long COVID illness.
163. Based on an average of 6 days of sick leave and reported reductions in working hours due to long COVID.

6. Economic Cost of COVID-19 in Singapore

In Singapore, the future economic cost of COVID-19 could range from SGD ~1.1 billion p.a. (~0.2% of GDP) to SGD ~16.0 billion p.a. (~2.8% of GDP), depending on the scenario that evolves. This represents a greater cost to society than is commonly recognized. COVID-19 not only inflicts health losses through illness and death but also imposes substantial economic costs, including a direct strain on the healthcare system and productivity losses from missed work.

As a society, Singapore has largely accepted the reality of living with ongoing transmission of the virus and the disease burden this incurs. However, there is an opportunity for better leveraging the tools available to reduce this burden. To better inform the ongoing discussion on COVID-19's impacts and the benefits of addressing them, it would be fruitful to understand the full range of economic costs imposed by COVID-19.

There is a variety of potential epidemiological scenarios for how the COVID-19 pandemic may evolve. This is reflected in the wide range of existing estimates for the economic costs resulting from COVID-19.[164] Possible epidemiological scenarios include a base case, where current conditions prevail, and alternative scenarios that differ in the rate of infections and their severity (driven, for example, by the interplay between variants and the level of immunity maintained in the population).

In the base case scenario, total economic costs could be SGD ~3.6 billion p.a. (equivalent to ~0.6% of GDP), assuming a transmission rate that results in ~3.3 million infections p.a. and ~8,200 hospitalizations p.a., with:

- The majority of costs (SGD ~3.4 billion p.a., ~96%) due to productivity losses (indirect costs) through missed work by both working-age adults and elderly in the workforce, either during their own illness or while caring for dependents (children and over 65-year-olds) affected by COVID-19;
- A further cost (SGD ~142 million p.a., ~4%) borne by the health system (direct costs), in both the inpatient (SGD ~68 million p.a.) and outpatient (SGD ~74 million p.a.) settings.

164. Please see Section 1 for more details.

- Local currencies have been used in this Section, reflecting the use and findings of local data sources. The below exchange rates were used in all local currency conversions to USD in this report. USD currency exchange rate conversions via Google Finance as of 28 February 2023 (USD1 = AUD 1.4861 = HKD 7.8493 = KRW 1,322 = SGD 1.3484 = TWD 30.6608): https://www.google.com/finance/markets/currencies?hl=en

In a Pandemic 2.0 scenario, economic costs could reach as high as SGD ~16.0 billion p.a. (~2.8% of GDP). This assumes transmission rates that result in ~11.3 million infections per year (instead of ~3.3 million as in the base case) and a severity that results in ~57,000 hospitalizations (compared with ~8,200 as in the base case). In contrast, at the lower end of the spectrum, a Normal 2.0 scenario could feature ~1.1 million infections over the course of a year with only ~2,000 hospitalizations, which would translate into direct and indirect costs of SGD ~1.1 billion p.a.

These economic costs fall unevenly. The health and logistics workforces, those affected by long COVID, and vulnerable populations are likely to be disproportionately impacted. For example, COVID-19 illness in vulnerable populations (see Section 6.4.7) contributes a loss of SGD ~1.7 billion p.a. in the base case scenario, while SGD ~1.9 billion p.a. in cost (~52% of total economic costs) results from infections in people eligible for oral antivirals, who tend to be older and/or affected by some comorbidity. Separately, the health workforce is impacted by high levels of absenteeism and a high risk of infection, with consequences for health system capacity and quality of care. Economic costs arising from these disruptions to the health workforce total ~SGD 101 million p.a. in the base case scenario. Those affected by long COVID (see Section 6.4.8) are impacted most significantly, with the value of lost work and health system utilization totaling ~SGD 1.3 billion p.a. or ~37% of all economic costs.

Fortunately, a range of countermeasures remains available that may mitigate the economic costs of COVID-19 (see Section 8), including vaccination, therapeutics, and community measures (i.e., non-pharmaceutical interventions). Strengthening these countermeasures may allow Singapore to mitigate the potentially high economic costs of the continuing pandemic.

6.1 Context: The Situation In Singapore

Today, Singapore is relatively free of restrictive measures. Most of the community measures employed earlier in the pandemic, such as lockdowns and mandatory isolation, have been pared back. In their place, Singapore now has wide vaccine availability and uptake, while there is some usage of therapeutics such as antivirals which are available to a subset of the Singaporean population based on pandemic special authorization. As of February 13, 2023, Singapore has stepped down its remaining COVID-19 restrictions as it establishes an endemic new norm. Following on from that, since April 1, 2023, the authorities have scaled back pandemic subsidies, vowing to redirect financing schemes for COVID-19 testing and treatment to help address other acute illnesses.

Over the three months to and including January 2023, Singapore experienced a stable period of infections and hospitalizations. With ~5,200 new infections per day and an effective transmission number[165] of ~0.93, infection volumes were likely declining. By contrast, in January 2022 there were ~26,000 infections per day, with an effective transmission number of ~1.7, indicating the early stages of the first Omicron wave. Since then, however, most countermeasures have been pared back. The change in Singapore's pandemic response is both a reaction to the volume of infections, as well as a driver of subsequent infections.

165. The number of people a single case will infect, on average.

Singapore's initial measures were effective at containment and then suppression of the virus, while also imposing significant economic costs. By international standards, the countermeasures employed during the first phase (2020 to 2021) were largely successful. The number of reported cases (~280,000) and deaths (~830) were among the lowest in the OECD.[166] However, border closures, lockdowns, social-distancing requirements (including capacity limits on indoor spaces), and mask-wearing imposed significant hardships on the community. The successful rollout of vaccines[167] afforded an easing of many restrictions, although the immunity conferred was found to wane over time. This temporary and diminishing character of immunity necessitated third (and ultimately fourth) doses, while novel variants capable of immune escape, such as Omicron, also emerged.

Oral antivirals have been added to Singapore's response toolkit and will continue to remain fully subsidized for clinically eligible patients in outpatient (including primary care), ambulatory settings of public hospitals and nursing homes from 1 April 2023 until further notice. The necessarily short-term nature of restrictive community measures and the remaining health threat posed by COVID-19 led Singapore to broaden its approach to include oral antivirals, which had become available in Singapore between January and April 2022.[168] They are available to the over-60 age group, and to people above the age of 18 who exhibit additional risk factors; together, these could be termed as vulnerable populations. See Section 6.4.7 for further detail.

Nevertheless, the health and economic outcomes of the reopening phase have been mixed. The vast majority (~93%) of Singapore's infections to date occurred in 2022.[169] While the severity of infections remained relatively mild compared to early in the pandemic, the high volume of infections nevertheless made 2022 the busiest year for the hospital system during the pandemic, with ~52 admissions per day on average, compared to ~14 in 2021 and ~22 in 2020.[170] This also translated into the number of deaths increasing, to 861 in 2022, compared with 817 in 2021 and just 29 in 2020. It is worth noting that COVID-19 has potentially contributed to excess mortality (additional deaths relative to pre-pandemic mortality) both due to deaths caused by COVID-19 itself and deaths that may have arisen as a second-order impact of COVID-19 on health system capacity.

The high volume of infections has also wrought an economic impact, both in terms of costs borne directly by the health system in addressing COVID-19, and the economic losses borne indirectly by society in the form of absenteeism and productivity declines. These will be explored in detail in Sections 6.3.1 and 6.3.2. Singapore's reopening experience has illustrated that the costs of COVID-19 borne by Singaporean society extend beyond the value of health losses calculated merely by traditional health technology assessments. Indeed, productivity losses driven by infections across all age groups constitute a major economic cost.

Singapore has kept vaccination as its primary defense and updated its vaccination guidelines, as reflected in its National Vaccination Programme. While oral antivirals continue to remain fully subsidized for clinically eligible patients in outpatient, ambulatory settings of public hospitals and nursing homes, they too continue to play a role in treating those who are vulnerable and suffer from severe illness if they are found to be infected with COVID-19. **A better understanding of the economic costs of the pandemic may allow for a more accurate assessment of the costs and benefits of various measures to address the virus, as Singapore transitions to "living with COVID-19".**

166. Our World in Data [Internet]. Cumulative reported cases and deaths for Singapore from 2020 to 2021. Available from: https://ourworldindata.org/explorers/coronavirus-data-explorer?time=earliest..2021-12-30&facet=none&Interval=Cumulative&Relative+to+Population=false&Color+by+test+positivity=false&country=~AUS&Metric=Confirmed+cases
167. As in many international jurisdictions, a vaccine rollout strategy was adopted during 2021 as a conduit to an easing of various restrictions. As of January 2023, 92% of people aged 16 and over had received at least one dose of a COVID-19 vaccine while 83% had received 3 doses. Singapore Ministry of Health [Internet]. Vaccination Statistics. Available from: https://www.health.gov.au/our-work/covid-19-vaccines/vaccination-numbers-and-statistics
168. They are currently available for all COVID-19 positive patients over the age of 18 and with one additional risk factor, or those over the age of 60 regardless of risk factors. Risk factors include active cancer, chronic kidney disease and diabetes, among others.
169. There have been ~8.3 million infections in Singapore this year, compared to ~360,000 in 2021 and ~297,000 in 2020.
170. Institute of Health Metrics and Evaluation, used with permission. Available from: https://www.healthdata.org/covid/data-downloads

6.2 Key Assumptions In The Singaporean Context

A range of informed assumptions is used to derive the estimates of economic costs in Singapore as a result of COVID. Exhibit 26 illustrates how these assumptions are used and provides a list of key assumptions used, while a full list of assumptions is given in the Appendix section.

Exhibit 26: Use of assumptions in the Singaporean context

A | Epidemiological scenarios

Scenario	Infections (mn) p.a.	Hosp. rate (%)
Normal 2.0	~1.14	0.20
Base	~3.27	0.25
Pandemic 2.0	~11.34	0.50

→

B | Direct costs: borne by the health system

Key Base Case Assumptions	
# Ward admissions p.a.	~7,400
# ICU admissions p.a.	~820
% Infections that visit a GP	1.8%
% Infections prescribed OAVs	0.3%
# Long COVID cases p.a.	~164,000

+

C | Indirect costs: economic productivity losses borne by society

Key Base Case Assumptions	
Working-age infections as proportion of total	64%
Proportion of working-age infections that can work	99.7%
Proportion of working-age infections that can work from home	80%
Average number of working days lost due to acute illness in working-age population	~6
Average daily salary	SGD 166

=

D | Total economic cost to society

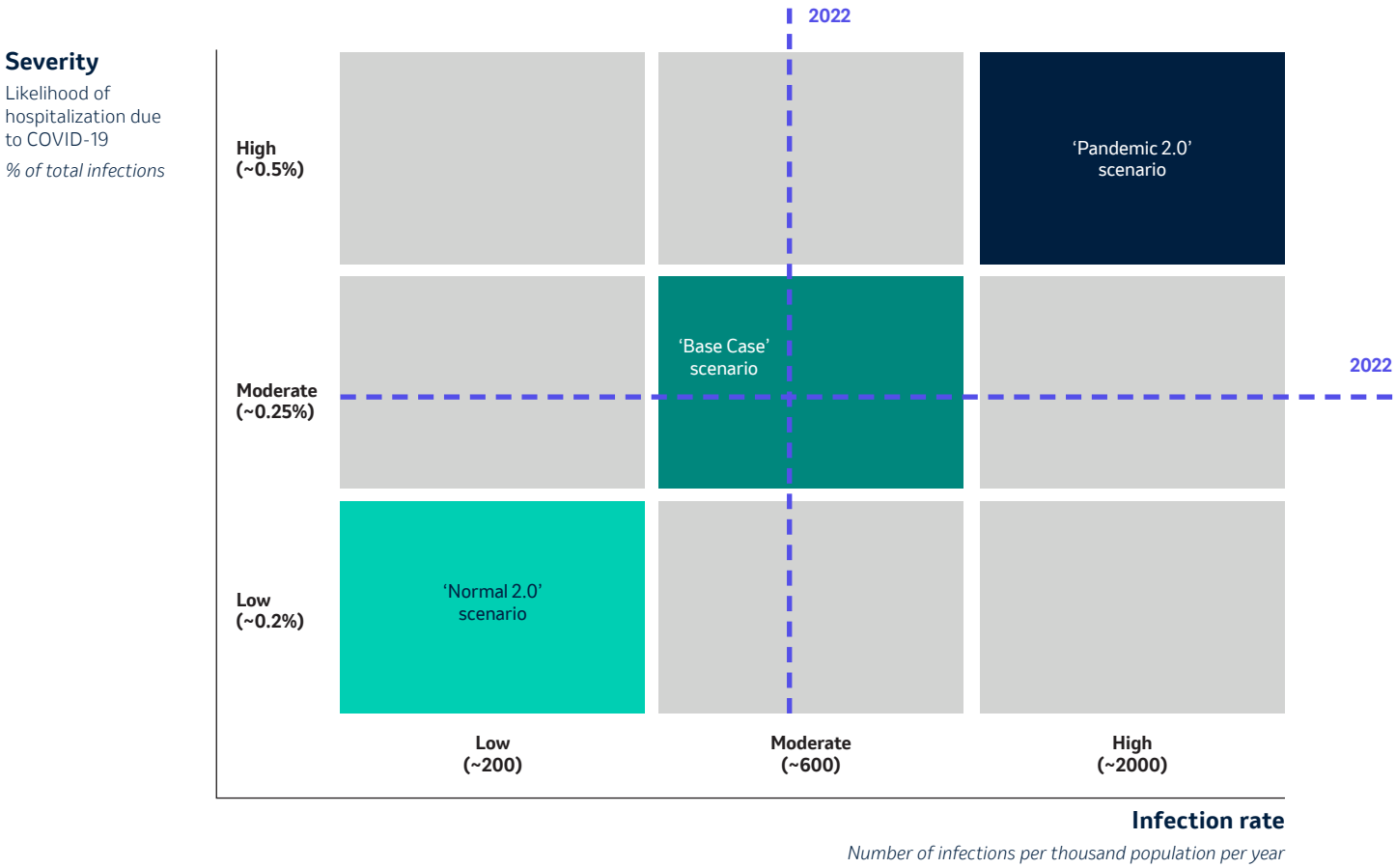
- **Total direct and indirect costs,** broken down by patient/demographic group
- **Costs per person** in each patient/ demographic group

  - E.g., if total inpatient costs are $68m, and 8,200 patients are admitted, the cost per person is ~ $8,300

A full list of assumptions is given in the appendix.

6.3 Future:
Scenario-Based Estimates Of The Economic Costs Of COVID-19 In Singapore

Exhibit 27: Potential epidemiological scenarios



Scenarios are indicative only and based on the observed epidemiology of COVID-19 in Singapore in 2022.

Scenarios help us to consider and envisage the potential courses that the COVID-19 pandemic may take in the future. One way to express scenarios is in the form of low (Normal 2.0), base case, and high (Pandemic 2.0) epidemiological trajectories.

As Exhibit 27 illustrates, in the Singaporean context this could mean:

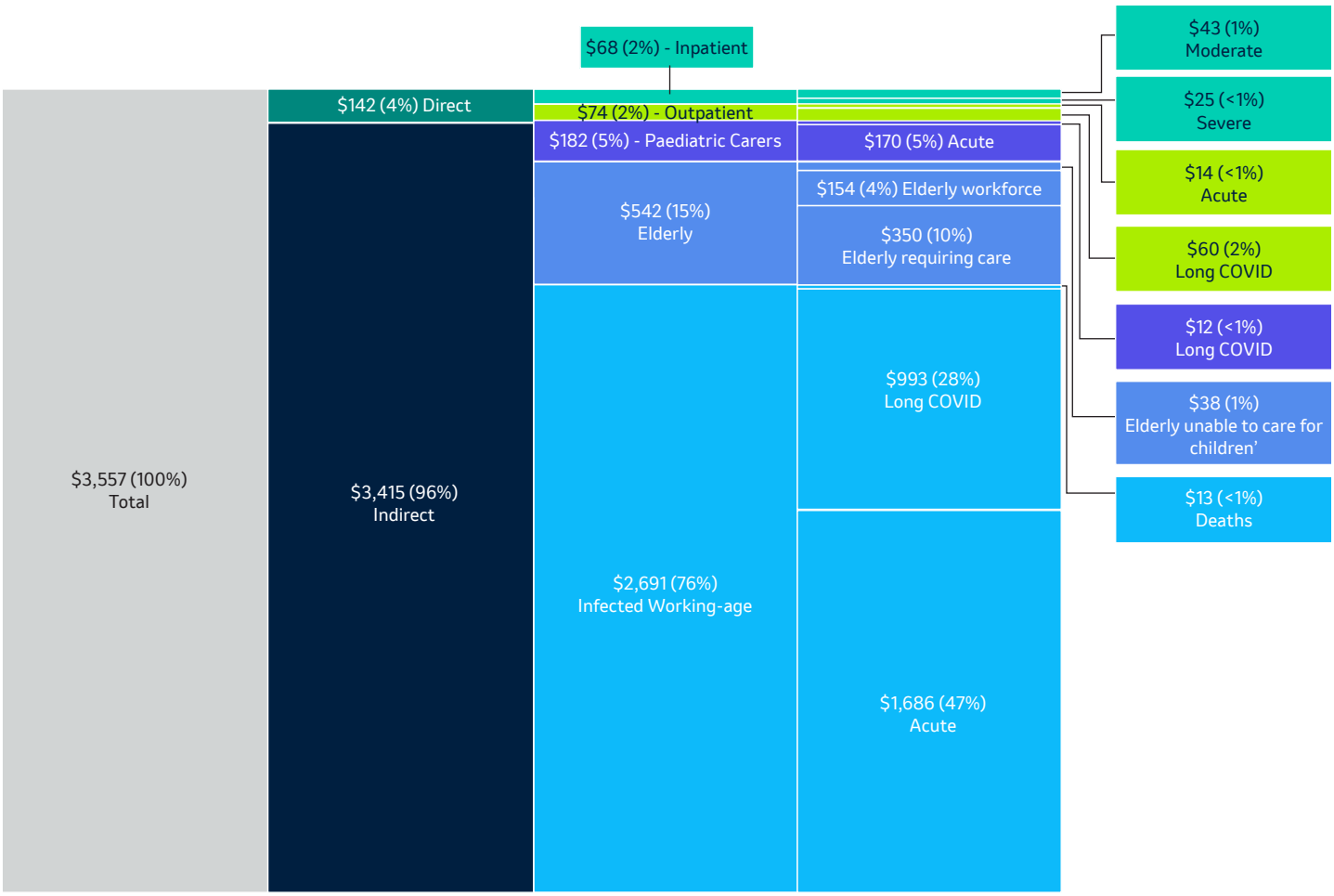
- A base case, with an economic cost of SGD ~3.6 billion p.a. (~0.6% of GDP, in addition to the value of lost health, such as that already considered in HTAs), which assumes a rate of infection and a viral severity similar to that seen in late 2022, i.e., the costs Sections below.

171. Infection numbers and hospitalization rates are sourced from modelling of COVID-19 infections in Singapore by the Institute of Health Metrics and Evaluation (IHME; used with permission). Available from: https://www.healthdata.org/covid/data-downloads

- **A high or Pandemic 2.0 case, with an economic cost of SGD ~16.0 billion p.a. (~2.8% of GDP),** which assumes a higher rate of infection and a higher viral severity, similar to that seen in the first half of 2022, i.e., 2 million infections per million population per year, driving ~57,000 hospitalizations annually.
- **A low or Normal 2.0 case, with an economic cost of SGD ~1.1 billion p.a. (~0.2% of GDP),** which assumes a lower rate of infection and lower viral severity, similar to that seen in mid-late 2021, prior to the Omicron wave, i.e., ~200,000 infections per million population per year, driving ~2,000 hospitalizations.

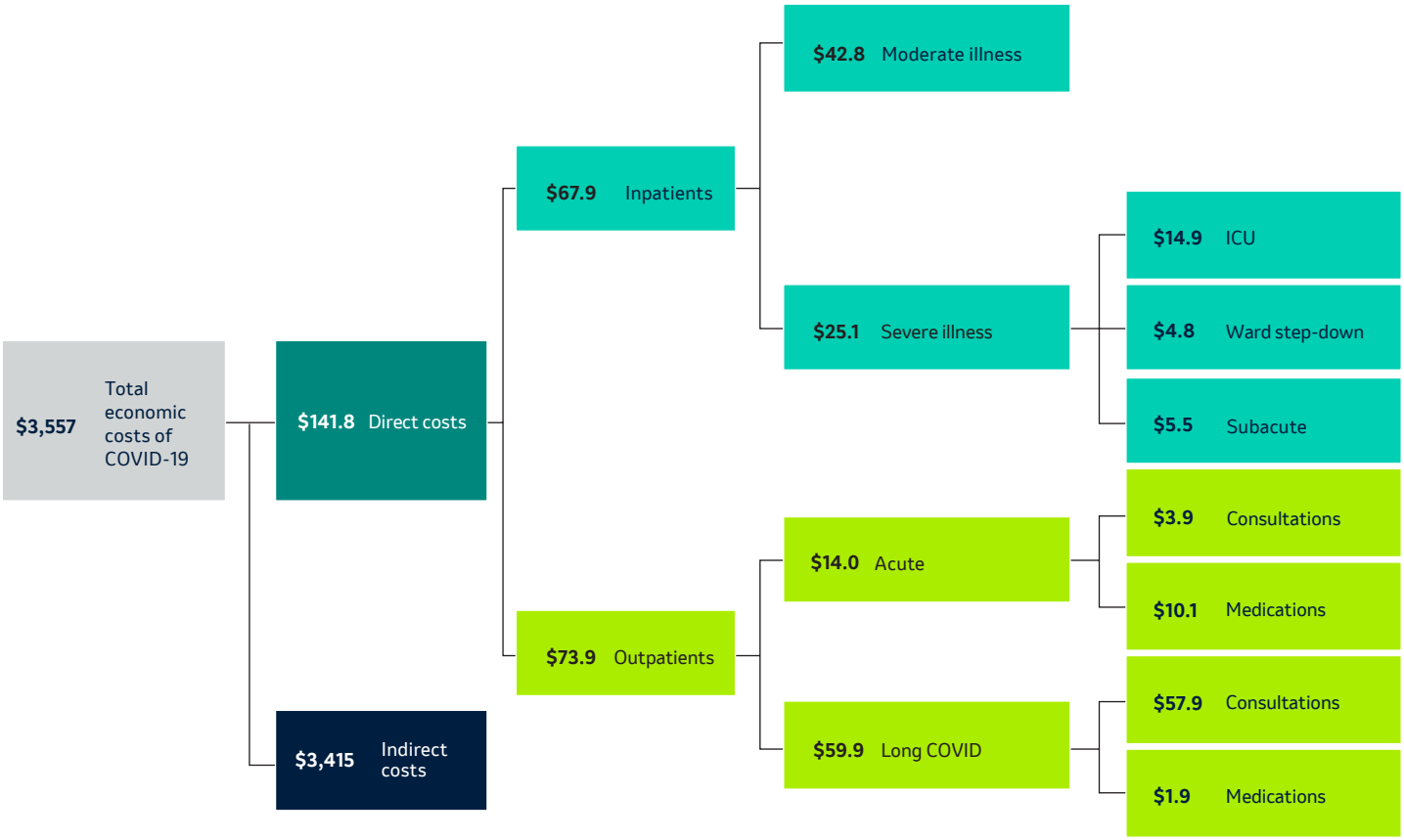
As Exhibit 28 illustrates, the base case scenario is designed to reflect a continuation of recent conditions. To do this, infection volumes and the prevailing hospitalization rate from Q4 2022 have been drawn from the Institute of Health Metrics and Evaluation (IHME; used with permission) model of COVID-19 and annualized.

Exhibit 28: Direct and indirect costs of COVID-19 to Singapore's economy in a base case scenario, SGD million p.a.



Costs are indicative only and based on the distribution of COVID-19 infections between cohorts in Singapore in 2022.

Exhibit 29: Direct economic costs from COVID-19, base case, SGD million p.a.



'Moderate illness' requires ward-based inpatient care and 'Severe illness' requires ICU-level care; 'Acute illness' refers to all infections not included in inpatient care; Long COVID refers to a small subset (~5%) of total infections and represents infections with symptoms lasting 12 weeks or more.

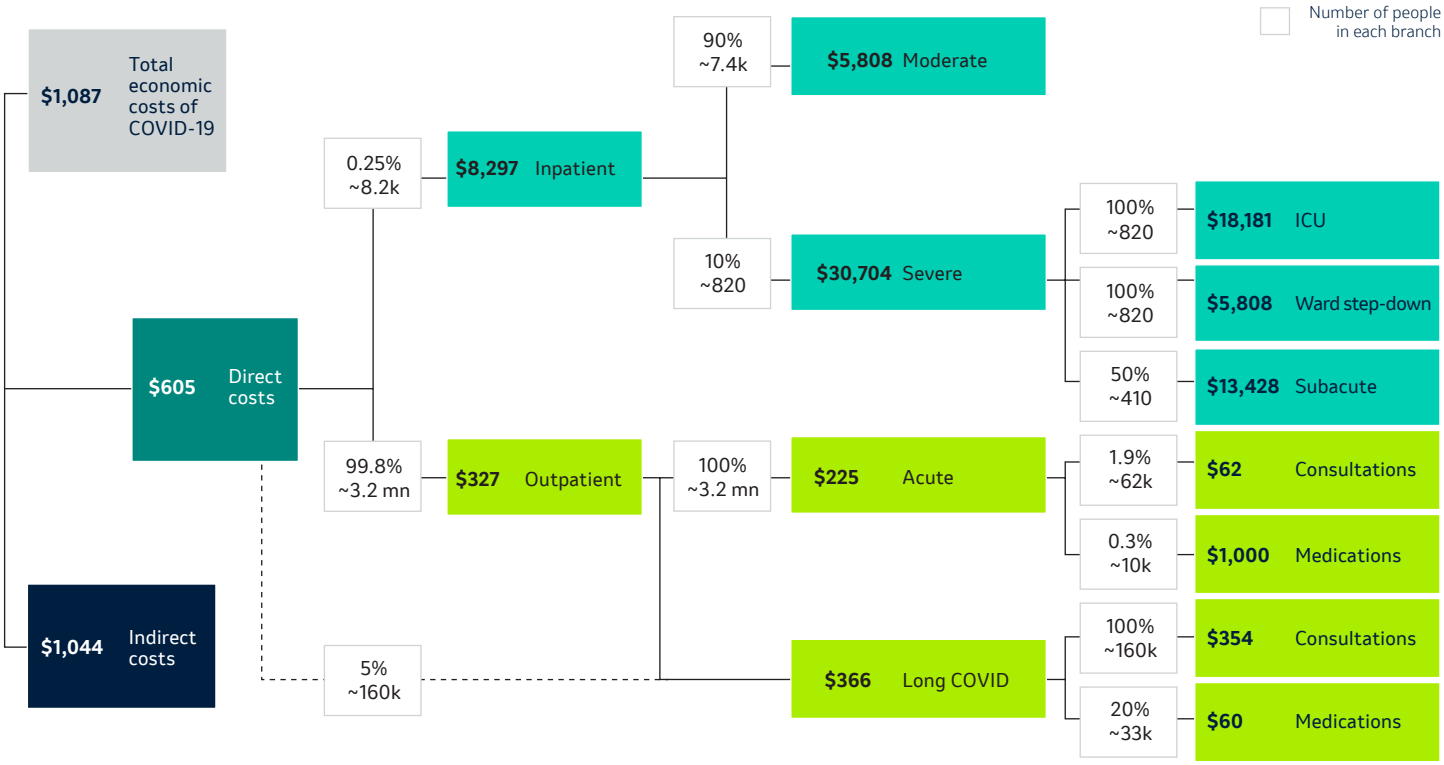
6.3.1 Direct costs to the health system

With ~8,200 hospital admissions (including ~820 to the ICU) and ~164,000 cases of long COVID in the base case scenario, a number of variables could have a significant cumulative impact in reducing the direct costs imposed by COVID-19 on the health system, namely limiting hospital admissions and reducing lengths of stay, as well as differences in recovery times and/or the incidence of long COVID. Given that those over 65 are over-represented in the COVID-19 inpatient population, preventing severe illness in this cohort would likely be particularly impactful in reducing direct costs.

In this scenario, as displayed in Exhibit 29, COVID-19 could result in direct costs of SGD ~142 million p.a. for the Singaporean health system. Despite the magnitude of this figure, direct costs are still a minority of the total economic costs of COVID-19 in Singapore, accounting for ~4% of the overall total. Indirect costs, comprising productivity losses due to missed work, account for the remainder and could add up to SGD ~3.4 billion p.a. These are discussed further in Section (6.3.2).

Despite the relatively minor weighting of direct costs within the wider economic impact of COVID-19, they remain significant on a per-infection basis. As illustrated in Exhibit 30, each infection that uses some form of health service could impose an average cost of SGD

Exhibit 30: Direct economic costs from COVID-19, per person, base case, SGD p.a.



Costs per person for each segment are calculated by dividing the total cost of that segment by the number of individuals in that segment that utilize a health service; 'Moderate illness' requires ward-based inpatient care and 'Severe illness' requires ICU-level care; 'Acute illness' refers to all infections not included in inpatient care, where ~2% visit a GP and 0.3% are prescribed medication; Long COVID refers to a small subset (~5%) of total infections and represents infections with symptoms lasting 12 weeks or more.

~605. This is most concentrated in the costs of inpatient care, where a single ward admission could cost SGD ~5,808 and a single ICU admission (with subsequent ward and rehabilitation stays) could cost SGD ~30,704.

As indicated in Exhibit 29, direct costs are incurred in two major settings:

- Inpatient (hospital-based) care (SGD ~67.9 million p.a.; 48%; SGD ~8,297 per person)
- Outpatient (primarily GP-based) care (SGD ~73.9 million p.a.; 52%; SGD ~327 per person)

The profile of inpatient care costs suggests that ameliorating the severity of illness acquired could have a significant impact on cost. Particularly in a reopened economy, where individuals at risk of severe disease are less protected from infection by community health measures, the extent of ongoing costs to the health system underscores the importance of continuing to prevent, test for, and treat the disease.

Costs in this category comprise those arising from moderate infections requiring ward-based care (SGD ~42.8 million p.a.; SGD ~5,808 per person) and severe infections requiring ICU (SGD ~25.1 million p.a.; SGD ~30,704 per person). The more costly care for moderate infections is driven mostly by the large volume of patients exhibiting moderate infections (~7,400, compared to ~820 patients with severe infections), while the cost of care for severe infections is driven largely by high bed day costs (SGD ~2,300 per day in ICU), followed by substantial periods of inpatient rehabilitation.

The profile of outpatient care costs indicates that limiting the incidence, duration, and/or severity of long COVID would have a substantial impact on this portion of the cost burden. Outpatient care for COVID-19 infections adds SGD ~73.9 million p.a. to the total economic costs incurred due to COVID-19. While seemingly less resource-intensive, outpatient infections that use health services are also expensive on a per-person basis, each costing SGD ~327.

Outpatient costs can be separated into acute outpatient care (consultations and medications; SGD ~14 million p.a.) and chronic outpatient or Long COVID care (consultations and medications; SGD ~60 million p.a.; see Section 6.4.8).

While the cost of acute outpatient care is driven largely by the cost of medications (such as oral antivirals, SGD ~10.1 million), this equates to just ~7% of all direct costs, representing a small investment towards partially reducing the much larger economic burden associated with COVID-19 (SGD ~3.6 billion p.a.), which could be larger still in the absence of such treatments. Visits to GPs account for the remainder of outpatient costs, which could total more than 60,000 consultations per year if ~2% of those infected seek the care of their GP. While the cost of these services is lower compared to inpatient costs (SGD 67.9 million p.a.), it is not insignificant and the patient volume represents a substantial additional burden on the primary care system.

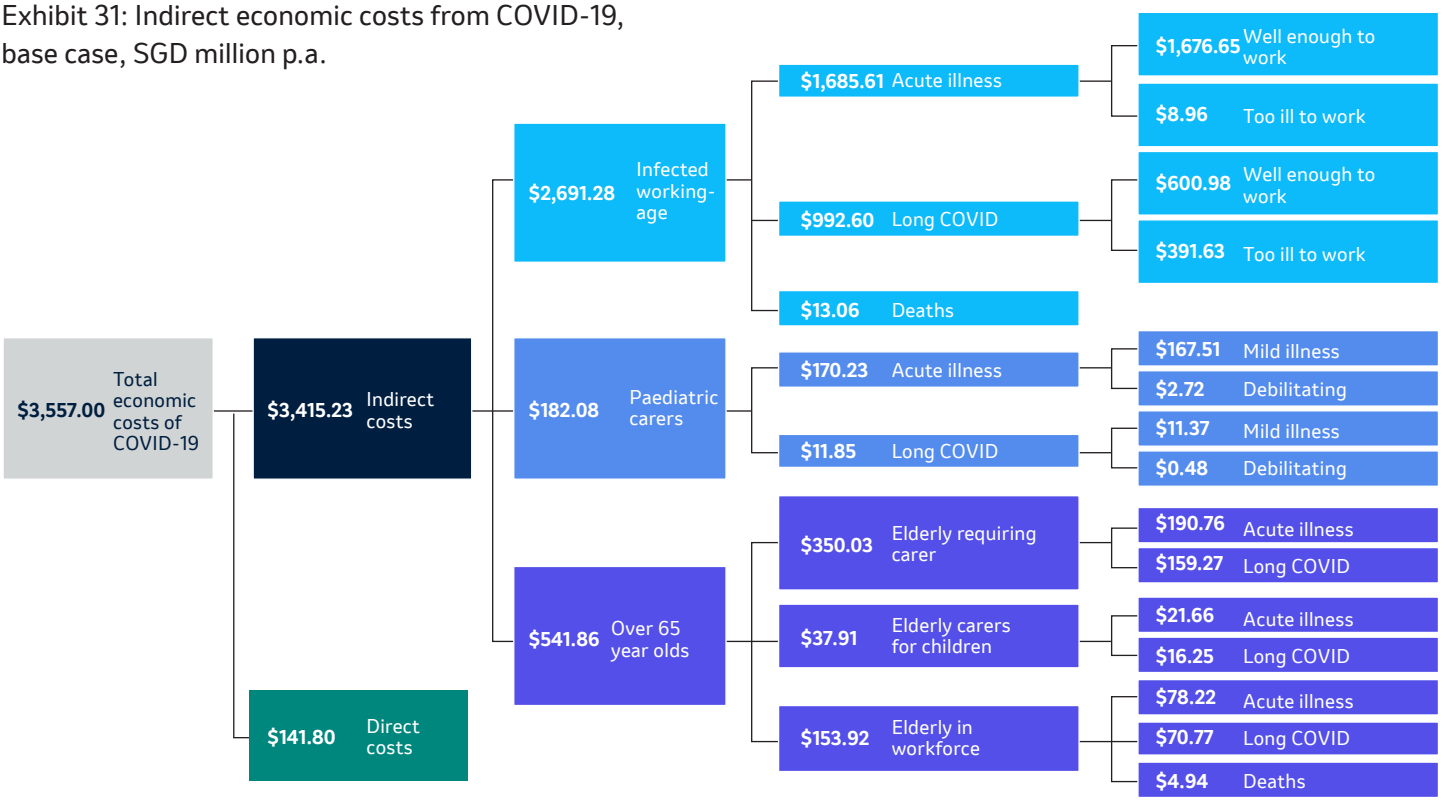
Together, direct costs from the inpatient and outpatient cohorts amount to SGD ~141.8 million p.a. While significant on their own, these costs are in addition to the indirect costs to Singapore's economy (discussed below), the value of lost health they represent, and the secondary effects on the health system (such as its workforce) and other critical industries.

6.3.2 Indirect costs to the economy

Reducing the sheer volume of COVID-19 infections and the duration of illness and/or recovery time for working-age adults, children, and the older population would have a significant impact on the economic and societal costs of COVID-19.

In the base case scenario, and as Exhibit 31 illustrates, COVID-19 could cost the Singaporean economy SGD ~3.4 billion p.a. in productivity losses if current epidemiological conditions and response settings

Exhibit 31: Indirect economic costs from COVID-19, base case, SGD million p.a.



Note: Totals may not sum precisely due to rounding to 2 decimal places

Indirect costs arise from productivity losses incurred due to infection with COVID-19; 'Well enough to work' refers to those who can continue working while infected, albeit with reduced productivity; 'Too ill to work'' refers to those who cannot work, at least for a portion of the time, while infected; 'Acute illness' refers to all infections not included in inpatient care; Long COVID refers to a small subset (~5%) of total infections and represents infections with symptoms lasting 12 weeks or more.

continue.[172] This estimate could be larger if stricter isolation protocols were to return. As with direct costs to the health system, this is a significant expense, equating to ~0.6% of GDP. While these costs are significant, as with direct costs, they still do not put an accurate value on the damage to health due to COVID-19, nor on the secondary impacts to critical industries and vulnerable populations, such as the health workforce.

As illustrated in Exhibits 31 and 32, indirect costs result from productivity losses borne by three major groups:

- **Infections in working-age adults (20-64 years old) – ~SGD 2.7 billion p.a.** (~79%; SGD ~1,285 per person)
- **Infections in the older population (65 years old and above) – ~SGD 542 million p.a.** (~16%; SGD ~998 per person)
- **Infections in children and adolescents (19 years old and under) – ~SGD 182 million p.a.** (~5%; SGD ~287 per person)

Infections in working-age adults impose a significant economic burden on Singapore, through productivity losses valued at ~SGD 2.7 billion p.a., a significant figure that equates to ~0.5% of Singapore's GDP. This burden highlights the broader economic impact that can be inflicted by an illness that, although mild for most, can be significant enough to last ~12 days and impair productivity by ~35% for three-quarters of them.[173]

Productivity loss incurred by the working-age group can be considered in two ways:

- Acute illness (SGD ~1.7 billion p.a.), chronic illness or long COVID (SGD ~993 million p.a.), and deaths (SGD ~13 million p.a.);
- Infected adults with mild illness who are still well enough to work but with reduced capacity (SGD ~2.3 billion p.a.), and infected adults who are too ill to work (i.e., are hospitalized) (SGD ~400 million p.a.).

Taking these together, acute illness in those who can still work but at reduced capacity accounts for ~63% of productivity losses incurred by working-age adults. The magnitude of this cost illustrates that, despite the mildness of the illness for most, when modest reductions in working capacity are multiplied across a multi-day illness affecting ~3.3 million Singaporeans, the result is a substantial cost impact for the whole market.

Infections in the older population impose SGD ~542 million p.a. in costs from productivity losses on the Singaporean economy, adding to the burden from working-age adults. This highlights that productivity losses are not limited to those borne by the working-age population alone and that adjacent cohorts are of proportional importance.

Older people that incur productivity losses due to COVID-19 fall into three categories:

- **Older people with COVID-19 who require care from a working-age person** – ~380,000 working-age adults, incurring an SGD ~921 productivity loss – resulting in a total impact of SGD ~350 million p.a.
- **Older people who directly participate in Singapore's labor force** – estimated to be 33% of over-65s, 66% of whom work full-time. Infections in this group result in SGD ~154 million in productivity losses.
- **Older people (e.g., grandparents) who care for children to enable parents to work** – one in four households rely on grandparents as the main caregiver. When this work-enabling care is disrupted, productivity loss amounts to SGD ~38 million.

Infections in the older population account for SGD ~565 million p.a., or ~16% of all direct and indirect costs combined, serving as a stark reminder of the need to address costly infections in cohorts adjacent to working-age adults.

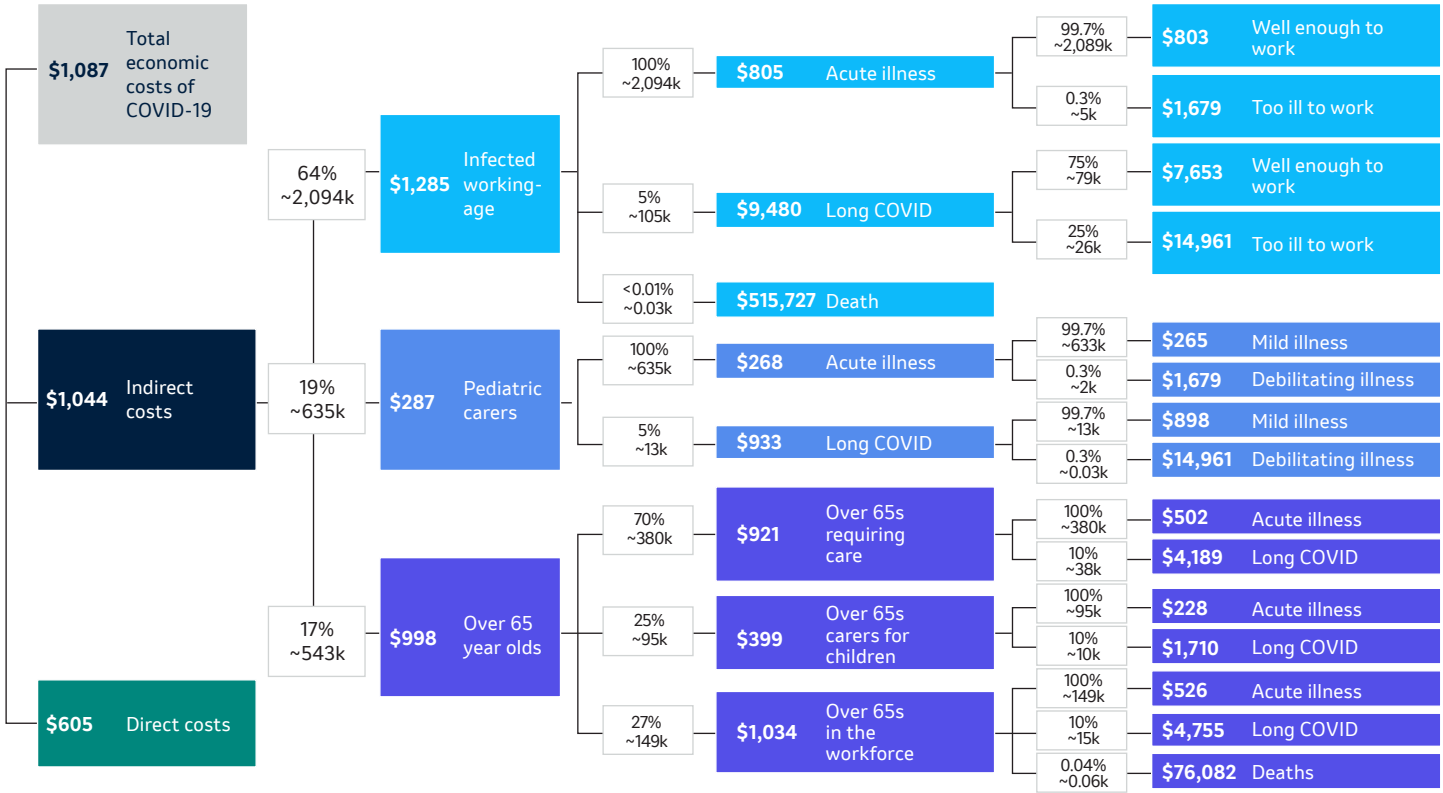
172. Based on a median monthly earnings figure of $5,070. Singapore Ministry of Manpower [Internet]. Income Summary Table. Available from: https://stats.mom.gov.sg/Pages/Income-Summary-Table.aspx
173. Johnsen et al. European Respiratory Journal [Internet]. Descriptive analysis of long COVID sequelae identified in a multidisciplinary clinic serving hospitalised and non-hospitalised patients. Available from: https://openres.ersjournals.com/content/erjor/7/3/00205-2021.full.pdf

Finally, infections in children impose an additional economic cost of SGD ~182 million p.a. owing to productivity losses borne by adults who are absent from or less productive at work while caring for children. Along with those from the older population, productivity losses arising from infections in children can be difficult to recognize in advance but are significant when they emerge.

Productivity losses arising from infections in children are predominantly driven by adults caring for children with acute, mild illness. The cohort of infected children, which constitutes the majority (~98%) of productivity losses in adults caring for children with acute illness, is worth SGD ~168 million p.a. This cost is driven by care for ~486,000 mild infections in children, who despite having a mild illness require one parent to care for them at home. The remaining ~2% is driven by productivity losses from caring for children with debilitating infections. For parents who can work from home (~80%), productivity is estimated to halve, while all productivity is foregone by parents who cannot (~20%). This is a substantial cost driven more by lost work than the illness itself, reiterating that significant costs imposed by productivity losses are not limited to infections in working-age adults.

Despite the apparent reduction in resource intensiveness compared to direct healthcare costs, the magnitude of productivity losses imposed by COVID-19 means indirect costs are nearly as expensive on a per-person basis (as indicated in Exhibit 32), with each infection costing SGD ~1,044 on average. This is concentrated in productivity losses resulting from infections in the working-age (SGD ~1,285 per person) and older populations (SGD ~998 per person).

Exhibit 32: Indirect economic costs from COVID-19, per person, base case, SGD p.a.



Costs per person for each segment are calculated by dividing the total cost of that segment by the number of individuals in that segment; Indirect costs arise from productivity losses incurred due to infection with COVID-19; 'Well enough to work' refers to those who can continue working while infected, albeit with reduced productivity; 'Too ill to work' refers to those who cannot work, at least for a portion of the time, while infected; 'Acute illness' refers to all infections not included in inpatient care; Long COVID refers to a small subset (~5%) of total infections and represents infections with symptoms lasting 12 weeks or more.

Together, economic costs arising from productivity losses in these cohorts amount to SGD ~3.4 billion p.a. or ~0.6% of Singapore's GDP and are in addition to the value of lost health and direct costs to Singapore's health system. Although already substantial, these costs are likely to underestimate the entirety of the burden imposed on society by COVID-19, including second-order impacts on health system capacity and knock-on effects on the health workforce, supply chains, and other aspects of critical industry; all of these factors contribute to directly measurable economic impacts.

The entirety of the economic burden imposed by COVID-19 needs also to be understood in the context of the prevailing epidemiological scenario, as the impacts and costs described can significantly increase under plausible scenarios where novel variants emerge. Such scenario variations are described below.

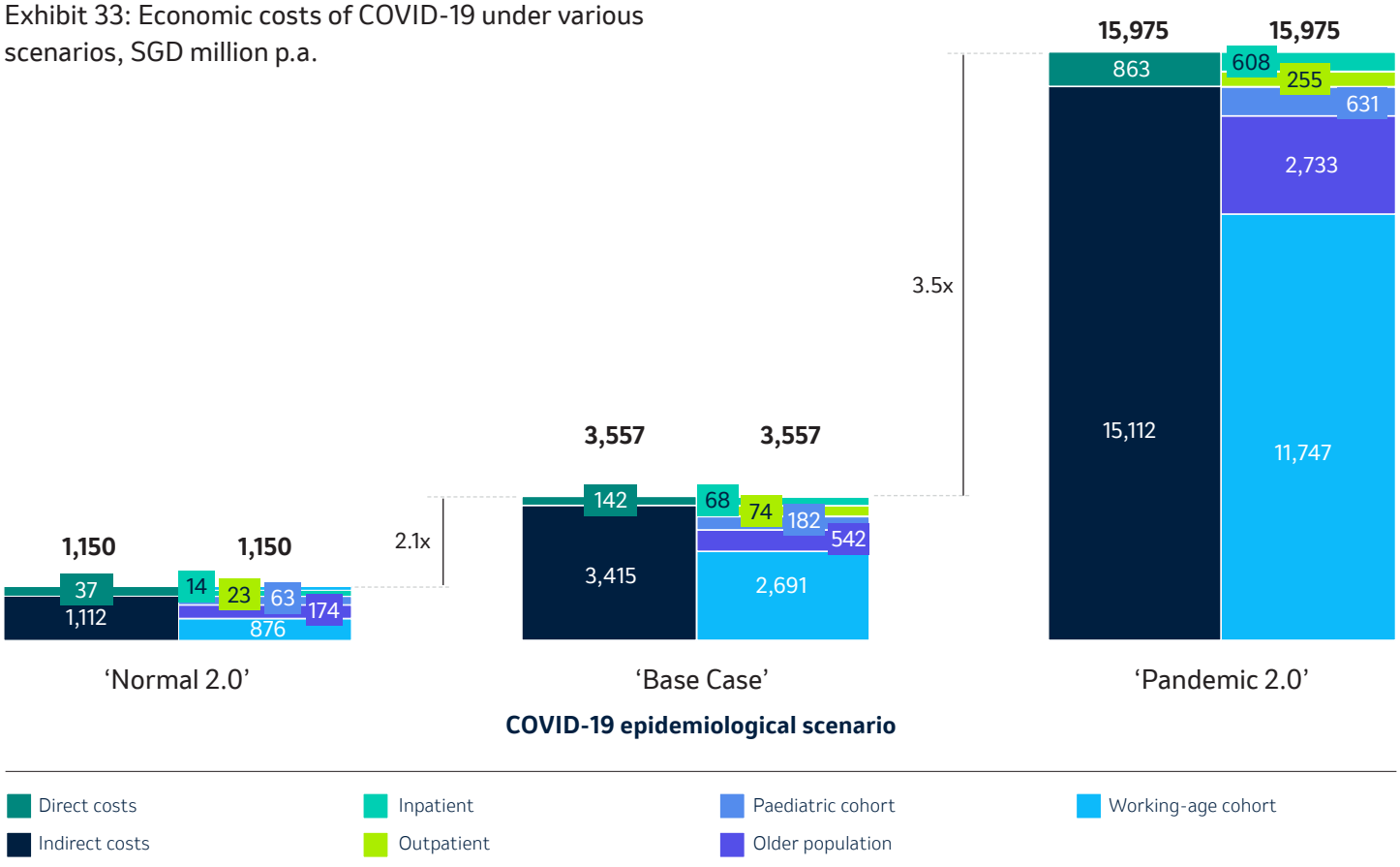
6.3.3 Alternative scenarios: costs of Pandemic 2.0 and Normal 2.0

In addition to the base case, two further scenarios have been considered, as illustrated in Exhibit 33.

In a Pandemic 2.0 scenario, total economic costs could reach SGD ~16 billion p.a. Conversely, in the Normal 2.0 scenario, economic costs could be reduced to SGD ~1.1 billion p.a.

The two example scenarios represent divergent epidemiological outcomes, both of which are plausible as the pandemic evolves. Each theoretical scenario is constructed with two key features:

Exhibit 33: Economic costs of COVID-19 under various scenarios, SGD million p.a.



Normal 2.0 refers to a scenario featuring ~200,000 infections per million population and ~2,000 hospitalizations, reflecting conditions observed in mid-late 2021; Pandemic 2.0 refers to a scenario featuring ~2 million infections per million population and ~57,000 hospitalizations, reflecting conditions observed in the first half of 2022.

- Infection volume (driven by contagiousness; measured by cases per million population per year);
- Case severity (driven by a prevailing strain's virulence factors; measured by resulting hospitalization rate).

A Pandemic 2.0 scenario would feature a case volume of ~2 million cases per million population per year (i.e., the entire population is infected twice, on average) and a case severity that drives a hospitalization rate of 0.5% of all infections. This is in comparison to the base case scenario, where a case volume of ~580,000 infections per million population and a hospitalization rate of 0.25% is assumed.

In the Pandemic 2.0 scenario, economic impacts from COVID-19 could increase to SGD ~16 billion p.a., equating to ~2.8% of GDP and SGD ~1,476 per person. In this scenario, direct costs could be SGD ~863 million p.a. (i.e., SGD ~721 million p.a. higher than the base case, or a 6.1X increase), while indirect costs could reach SGD ~15.1 billion p.a. (i.e., SGD ~11.7 billion p.a. higher than the base case, or a 4.4X increase). These increases would be driven by the higher case volumes, resulting in an uptick in hospitalization rates and longer periods of stay, as well as augmented productivity losses, caused by a more prevalent incidence of debilitating illness and longer periods of missed work.

The magnitude of the cost increases that could result from a plausible epidemiological scenario such as this demonstrates the need for a range of preparedness settings, which include options to limit impacts at all junctures.

A Normal 2.0 scenario would feature a case volume of ~200,000 cases per million population per year and a hospitalization rate of 0.2%. Under a Normal 2.0 scenario, economic impacts from COVID-19 could reduce to SGD ~1.1 billion p.a., equating to ~0.2% of GDP and SGD ~1,005 per person. Direct costs could decrease to SGD ~37 million p.a. and indirect costs to SGD ~1.1 billion p.a. Decreases in costs would be driven by a fall in case volume, lower hospitalization rates, and diminished productivity losses, owing to reduced periods of missed work.

While these different scenarios help us to consider potential trajectories that the COVID-19 pandemic may take in the future, their scope is largely restricted to the consideration of quantifiable economic costs. Equally worthy of consideration are the 'second order' impacts that COVID-19 could exert on health system capacity and the knock-on effects that this would have on vulnerable populations and critical industries. This aptly demonstrates the broad economic and societal impacts of the pandemic.

6.4 Considerations For Particular Cohorts And Industries

The economic costs of COVID-19 described will impact different populations and industries disproportionately. This includes those that play a critical economic/social role (e.g., health care workers), those that are particularly vulnerable to severe disease (e.g., people with comorbidities), and those that go on to develop long COVID.

Interventions that protect health and productivity losses in these critical industries and populations may yield corresponding, disproportionate economic returns. Disruptions to these groups also cause significant economic and societal concern and may be worthy of additional focus when considering countermeasure approaches to mitigate the impacts of COVID-19.

6.4.1 Critical workers and industries

As outlined above, some critical industries experience disproportionate workforce productivity losses that generate significant public concern. Here, the focus is on five industries in particular – healthcare, logistics, travel and tourism, food and beverage, and education.

The economic costs of COVID-19 borne by critical industries and their stakeholders may increase under a Pandemic 2.0 scenario. In this scenario, workforces that are largely unable to work from home may be required to isolate while they recover. The resulting loss of productive time can be 30% greater (the equivalent of 1-2 workdays) than individuals in desk-based jobs.

6.4.2 Healthcare

Singapore's health system serves as the market's first and last line of defense against COVID-19 and other health threats. Healthcare expenditure is expected to reach SGD ~56 billion by 2030[174] and ~153,000 residents are currently employed in the Health and Social Services sector in Singapore.[175]

At a potential minimum cost of SGD ~101 million p.a. (~2.8% of combined total cost),[176] healthcare workers who become infected with COVID-19 represent a disproportionate slice of the impact that this disease exerts on the economy. However, this is likely to significantly underestimate the total costs to the Singaporean economy and citizens' welfare, as it would also translate into secondary impacts on patient outcomes.

Health service employers experience higher rates of absenteeism due to COVID-19 compared with other industries. Employees in the Health and Social Services industry were more likely to take outpatient sick leave and hospitalization leave in the first half of 2020 compared to other industries, with 55% taking outpatient sick leave and 14% taking hospitalization leave.[177] A root cause of these inflated figures is the heightened risk of COVID-19 infection that healthcare workers are exposed to in the workplace.[178] Productivity losses are not only incurred by sick workers but also by remaining workers who are required to take up additional responsibilities.

The second-order economic impacts of COVID-19-related absenteeism among healthcare workers are significant, as COVID-19 exacerbates pre-existing workforce shortages. Even recently, some emergency departments have experienced admission wait times of up to 50 hours, with hospitals also deferring non-urgent elective surgery and admissions to preserve beds and staff.[179] Such reductions in the availability and timeliness of medical care may subsequently lead to prolonged illness or recovery times for patients, who in turn accumulate their own, additional productivity losses.

Additionally, during the COVID-19 pandemic, unprecedented levels of workforce burnout and attrition have been seen.[180,181] Although the initial response to the COVID-19 pandemic has subsided, global talent shortages and mobility challenges are an ongoing concern.

A countermeasure approach that targets healthcare workers could have a significant effect in mitigating overall economic costs, as well as the impacts of COVID-19 on public health. This is demonstrated by the disproportionate costs of COVID-19 infections among healthcare workers, against the backdrop of an increasingly constrained talent market.

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174. International Trade Administration, Singapore [Internet]. Country Commercial Guide. 2022 Aug. Available from: https://www.trade.gov/singapore-country-commercial-guide
175. Department of Statistics Singapore [Internet]. Employed Residents Aged 15 Years And Over By Industry And Occupation. 2022 Oct. Available from: https://www.singstat.gov.sg/find-data/search-by-theme/economy/labour-employment-wages-and-productivity/latest-data
176. Based on a median monthly earnings figure of $4,680. Ministry of Manpower, Manpower Research and Statistics Department [Internet]. Statistical Table: Income. 2023 Jan 31. Available from: https://stats.mom.gov.sg/Pages/IncomeTimeSeries.aspx
177. Ng BS. Ministry of Manpower, Manpower Research and Statistics Department [Internet]. Conditions of Employment 2020. 2021 Mar. Available from: https://stats.mom.gov.sg/iMAS_PdfLibrary/msd-coe-2020.pdf
178. Lai YW, Yee SL et al. NIH National Library of Medicine [Internet]. Healthcare workers in Singapore infected with COVID-19: 23 January-17 April 2020. 2020 Sep 13. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7902262/#irv12803-bib-0007
179. Lim J. The Straits Times [Internet]. Public hospitals working with MOH to ease patient loads at emergency depts amid latest Covid-19 wave. 2022 Oct 21. Available from: https://www.straitstimes.com/singapore/health/healthcare-authorities-working-to-ease-patient-loads-in-emergency-departments-amid-covid-19-surge
180. Yong N. Yahoo News Singapore [Internet]. Leave policy for hospital workers may change if COVID cases keep rising: MOH official. 2022 Jan 21. Available from: https://sg.news.yahoo.com/leave-policy-hospital-workers-change-covid-cases-moh-official-103707412.html?guccounter=2
181. Nanda A. The Straits Times [Internet]. More doctors in Singapore face burnout, anxiety amid the pandemic. 2021 Aug 03. Available from: https://www.straitstimes.com/life/more-doctors-in-singapore-face-burnout-anxiety-amid-the-pandemic

6.4.3 Logistics

COVID-19 has caused unprecedented disruption to Singapore's transport and logistics sector, which delivers vital goods and services across the nation. It is an SGD ~255.5 billion industry, with a growing workforce of over 200,000 people.[182,183] During the pandemic, the sector experienced a disproportionate impact of productivity loss from workers, which has snowballed to disrupt local and global supply chain networks.

Singapore's transport operators and distribution centers have experienced significant workforce shortages due to COVID-19 illness. Among this workforce are warehouse staff, forklift drivers, unloading crews, and technicians, who are unable to complete their tasks at home while ill, isolating, or caring for others who have been infected with COVID-19. Consequently, these businesses struggle to retain other employees, who find themselves having to work longer hours to accommodate these gaps in capacity, leading to overwork and stress.

Workforce shortages have downstream consequences for end-point retailers, users, and customers too. In 2021, 32% of Singaporean organizations reported that their operations were significantly impacted by COVID-19, with the most impacted area being operation and supply chain.[184] Disruptions have the dual effect of driving inflation in the costs of goods and services while impeding the ability of businesses, and their workers, to deliver them. Among these, there are necessities of particular public concern – food, life-changing medicines, oil, and gas.

The impact of workforce shortages may point to an incremental opportunity for targeted COVID-19 countermeasures to support Singapore's logistics industry, as it grapples with the multitude of challenges (including geopolitical tensions) at the heart of today's "supply chain crisis".

6.4.4 Travel and tourism

Despite a strong economic recovery, Singapore's travel and tourism sector continues to face headwinds due to workforce shortages. One of the highest-yielding destinations in the world prior to the COVID-19 pandemic, by 2022 spending from tourists in Singapore had only returned to approximately 50% of 2019 levels.[185] The impact of the pandemic could be observed through the steep declines in visitor volumes and spending, due to border closures, stay-at-home restrictions, and hesitancy among travelers.

However, the return of visitors to Singapore in large numbers may also entail risks of 'importing' COVID-19 infections and the economic impacts these carry. By 2024, Singapore is expecting tourism arrivals and activity to recover to pre-pandemic levels.[186] To that end, in 2023, Singapore will host 19 MICE events[187] and the Singapore Grand Prix (among other major events). In 2022, the Grand Prix attracted a record crowd of 302,000 – many of whom were overseas visitors.[188] While these events bring positive economic returns, the potential inherent risk of imported COVID-19 infections should also be acknowledged – particularly given the recent removal of all COVID-19-related requirements for travelers entering Singapore.[189] This is of particular note given the impact that the pandemic and its various outbreaks have had on the airport and accommodation workforces.

182. Department of Statistics Singapore [Internet].Transport and Storage Industry. 2021. Available from: https://www.singstat.gov.sg/-/media/files/visualising_data/infographics/industry/transportation-and-storage.ashx
183. Department of Statistics Singapore [Internet]. Employed Residents Aged 15 Years And Over By Industry And Occupation. 2022 Oct. Available from: https://www.singstat.gov.sg/find-data/search-by-theme/economy/labour-employment-wages-and-productivity/latest-data
184. PwC [Internet]. Global Crisis Survey 2021 Singapore. 2021 May. Available from: https://www.pwc.com/sg/en/publications/global-crisis-survey-2021.html
185. Chew HM. Channel News Asia [Internet]. Visitor arrivals in Singapore creep back to pre-pandemic levels as tourism sector rebounds. 2023 Jan 17. Available from: https://www.channelnewsasia.com/singapore/tourism-visitor-arrivals-receipts-2022-singapore-tourists-3209721
186. Singapore Tourism Board [Internet]. Singapore's tourism sector recovers strongly in 2022, visitor numbers expected to double in 2023. 2023 Jan 17. Available from: https://www.stb.gov.sg/content/stb/en/media-centre/media-releases/Singapore-tourism-sector-recovers-strongly-in-2022-visitor-numbers-expected-to-double-in-2023.html
187. As of February 2023, Singapore has announced 19 MICE events to take place between February and October 2023; Visit Singapore [Internet]. Event Listing. Available from: https://www.visitsingapore.com/mice/en/event-listing/
188. Singapore Grand Prix [Internet]. Available from: https://singaporegp.sg/en/news
189. Immigration and Checkpoints Authority [Internet]. Entering Singapore. Available from: https://www.ica.gov.sg/enter-transit-depart/entering-singapore

COVID-19-related absenteeism has wreaked havoc across airports and accommodation services: ~30% of the workforce in the aviation sector was lost during the pandemic, which by late 2022 had only been restored to ~80% of the pre-COVID-19 levels.[190] This is contributing to delays at airports, with cargo processing times taking up to two weeks instead of the usual few days.[191]

Countermeasures that are targeted at Singapore's travel and tourism workforce may help the sector fully overcome the remaining hurdles in its recovery from the COVID-19 pandemic.

6.4.5 Food and beverage

COVID-19 has significantly impacted Singapore's food and beverage industry, in particular through restrictions on dining in at restaurants and reductions in catering orders due to a lack of group gatherings. Food and beverage sales in Singapore declined by 26% year-on-year in 2020, with a year-on-year decline of 51% specifically during the Circuit Breaker period from April to May 2020.[192] With COVID-19 compounding existing pressures in labor and rental costs, ~1,200 outlets in Singapore permanently shut between January and July 2020.[193]

Frontline workers in this sector have faced disruption to their jobs, with most unable to work from home and some let go due to revenue declines. 15,400 employees left the food and beverages sector in 2020, with low productivity in the sector further affecting job quality and wages for those that remain.[194] Operational changes have also occurred in the food and beverage sector aimed at reducing reliance on labor (e.g., installation of self-service kiosks); these developments continue to threaten the jobs of employees who earn, on average, below the 20th percentile income level of all full-time employed residents.[195]

Given the importance of the food and beverage industry for Singapore's economy and as a source of income for Singaporeans, countermeasures that facilitate recovery in its workforce could assist with improving overall productivity.

6.4.6 Education

Although Singapore adapted rapidly to home-based learning, the full consequences of online teaching for Singaporean students, as a result of COVID-19, are yet to be seen. During the circuit breaker period from April to May 2020, Singapore shifted toward fully home-based learning, with a pause also in preschool and student care center services.[196] The effects of this are mixed, with increased flexibility being counteracted by several disruptions, including the loss of peer-to-peer interaction, a lack of direct access to the teacher, and potentially unstable internet connection disadvantaging some students.[197]

190. Ministry of Trade and Industry, Economic Survey of Singapore Second Quarter 2022 [Internet]. Recovery of Air Travel and Tourism in Singapore. 2022 Aug. Available from: https://www.mti.gov.sg/-/media/MTI/Resources/Economic-Survey-of-Singapore/2022/Economic-Survey-of-Singapore-Second-Quarter-2022/BA_2Q22.pdf
191. Yong C. The Straits Times [Internet]. Covid-19 cases among staff, CNY holiday lead to cargo being stuck at Changi Airport. 2022 Feb 09. Available from: https://www.straitstimes.com/singapore/cargo-stuck-at-changi-airport-as-covid-19-causes-shortage-of-manpower
192. Qua K, Yeo M, Lee J, Chua K. Singapore Department of Statistics, Statistics Singapore Newsletter [Internet]. Impact of COVID-19 on the Retail and Food & Beverage Services Sectors. 2021 Mar. Available from: https://www.singstat.gov.sg/-/media/files/publications/industry/ssn121-pg1-5.ashx
193. Paulo DA, Klimowicz G. Channel News Asia [Internet]. For F&B outlets, COVID-19 is a wake-up call. Here are seven changes they can make. 2020 Oct 25. Available from: https://www.channelnewsasia.com/cnainsider/food-f-b-outlets-restaurants-covid-19-wake-up-call-seven-changes-980351
194. Low Y. Channel News Asia [Internet]. The Big Read: F&B manpower woes — whither the big productivity push? Or are there just too many eateries in Singapore? 2022 Apr 18. Available from: https://www.channelnewsasia.com/singapore/big-read-food-beverage-manpower-woes-eateries-robots-covid-19-2630486
195. As above
196. Ministry of Health, Singapore [Internet]. Circuit Breaker to Minimise Further Spread of COVID-19. 2020 Apr 03. Available from: https://www.moh.gov.sg/news-highlights/details/circuit-breaker-to-minimise-further-spread-of-covid-19
197. Jürgen R. Educational Research for Policy and Practice [Internet]. Perceived quality of online learning during COVID-19 in higher education in Singapore: perspectives from students, lecturers, and academic leaders. 2022 Nov 17. Available from: https://link.springer.com/article/10.1007/s10671-022-09325-0

The education sector was further impacted by teacher absenteeism due to COVID-19. Globally, countries faced an increase in teacher absences during the COVID-19 pandemic, with 40% of OECD countries needing to recruit temporary staff in order to fill absences and allow classes to continue with minimal disruption.[198] Furthermore, educators experienced increased burnout and stress as a result of the additional workload of teaching remotely, compounded by the effects of isolation during COVID-19 lockdowns.[199]

Countermeasures that help reduce significant periods of illness and absenteeism in teachers and students could help maintain Singapore's high level of education in the future.

6.4.7 Vulnerable populations

COVID-19 illness in Singapore's vulnerable populations represents a minimum impact of SGD ~1.7 billion p.a. to Singapore's economy. These populations are at greater risk of severe COVID-19 disease and are more heavily reliant on the healthcare system than others. Populations that have received particular attention throughout the pandemic include those over 65 years old and those with comorbidities.

COVID-19 illness in Singapore's older population (65 years and over) could have an economic impact of SGD ~565 million p.a. (~16% of the combined annual impact). This is significant on a per-person basis too, at SGD ~1,041. Despite accounting for just ~17% of confirmed cases, the older population represents a significantly higher proportion of deaths, with ~95% of deaths from COVID-19 occurring in those aged over 60.[200] This is unsurprising when one considers that the prevalence of comorbidities is particularly high in this age group. 37% of Singaporeans over 60 years old have three or more chronic health conditions.[201]

Comorbidities in the younger, working-age population could also have a disproportionate impact of ~SGD 1.1 billion p.a. Just one comorbidity doubles the risk of severe COVID-19,[202] subsequently increasing the likelihood of hospitalization and prolonging recovery time away from work. This could be a reality for ~40% of Singaporeans.[203]

Given that ~47% of combined direct and indirect costs are borne by these vulnerable populations, countermeasures that reduce the duration of illness and/or recovery time for this group alone could significantly mitigate the costly impacts of COVID-19. Countermeasures may include ongoing vaccination, community measures, or the use of oral antivirals. Indeed, infections in individuals eligible for oral antivirals account for SGD~ 1.9 billion p.a. in economic costs or ~52% of the total economic costs to Singapore.

198. Charbonnier E, Doumet MH et al. OECD [Internet]. The State of Global Education 18 Months into the Pandemic. 2021 Sep. Available from: https://www.oecd-ilibrary.org/docserver/1a23bb23-en.
199. Jürgen R. Educational Research for Policy and Practice [Internet]. Perceived quality of online learning during COVID-19 in higher education in Singapore: perspectives from students, lecturers, and academic leaders. 2022 Nov 17. Available from: https://link.springer.com/article/10.1007/s10671-022-09325-0
200. Reuters [Internet]. Singapore may see 2,000 COVID-19 deaths each year - minister. 2021 Nov 1. Available from: https://www.reuters.com/world/asia-pacific/singapore-may-see-2000-covid-19-deaths-annually-minister-2021-11-01/
201. Choo F. Tomorrow's Medicine, The Straits Times [Internet]. Proportion of older adults with multiple chronic diseases surges. 2019 May 8. Available from: https://www.sgh.com.sg/news/tomorrows-medicine/proportion-of-older-adults-with-multiple-chronic-diseases-surges
202. Liu B, Spokes P, He W, Kaldor J. BMC Infectious Diseases [Internet]. High risk groups for severe COVID-19 in a whole of population cohort in Australia. 2021 Jul 16. Available from: https://bmcinfectdis.biomedcentral.com/articles/10.1186/s12879-021-06378-z
203. Shu YT, Kaiwei JL, Ying X et al. The Annals, Academy of Medicine, Singapore [Internet]. Healthcare cost of patients with multiple chronic diseases in Singapore public primary care setting. 2021 Nov 29. Available from: https://annals.edu.sg/healthcare-cost-of-patients-with-multiple-chronic-diseases-in-singapore-public-primary-care-setting/

6.4.8 Long COVID

Long COVID[204] has a potential minimum impact of SGD ~1.31 billion p.a. on Singapore's economy. Individuals who develop this condition experience prolonged productivity losses (increasing 'indirect costs') and reliance on health services (increasing 'direct costs').

Direct costs due to long COVID collectively amount to at least SGD ~60 million (SGD ~366 per person), largely driven by the need for ongoing medical consultations. This higher figure results from the incidence and the relative complexity and duration (90 days) of long COVID illness. When case complexity and duration are factored in, this could mean ~982,000 healthcare consultations are required for this cohort alone.[205] Therefore, long COVID represents a substantial burden on the health system, both in terms of capacity requirement and economic costs.

Productivity losses from long COVID could amount to SGD ~1.25 billion p.a. (SGD ~7,645 per person and ~37% of all indirect costs). By a significant margin, the largest contributor is productivity loss arising from long COVID in the working-age population (SGD ~0.99 billion p.a. or ~79% of indirect costs from long COVID).

To illustrate this further, an adult with long COVID could still lose the equivalent of 46 work days over a three-month period of illness, because of impairments to productivity, despite being well enough to work.[206]

Given the large share (~37%) of total economic costs that long COVID imposes on the Singaporean economy, any countermeasure able to reduce the incidence and/or duration of this condition would contribute a great deal to mitigating economic costs associated with the pandemic. Current conservative estimates suggest that the incidence and course of long COVID are at 5% and 90 days respectively; however, the evidence is still nascent, and these impacts may yet be shown to be underestimates.

204. Also commonly described as 'post-COVID 19 syndrome', long COVID describes the prolonged duration of COVID-19 symptoms beyond twelve weeks after the initial infection.
205. Estimating ~164,000 long COVID cases, where each case could require 6 consultations on average over the 90-day period of long COVID illness.
206. Based on an average of 9 days of sick leave and reported reductions in productivity while working, due to long COVID.

7. Economic Cost of COVID-19 in Hong Kong

In Hong Kong, the future economic cost of COVID-19 could range from HKD ~4.0 billion p.a. (~0.1% of GDP) to HKD ~108.7 billion p.a. (~3.8% of GDP), depending on the scenario that evolves. This represents a far greater cost to society than is commonly recognized. COVID-19 not only inflicts health losses through illness and death but also imposes substantial economic costs, including direct costs on the healthcare system and productivity losses from missed work.

Hong Kong society has now generally accepted the reality of living with ongoing transmission of the virus and the burden this incurs. However, there is an opportunity to better leverage the tools available to reduce this burden. To better inform the ongoing discussion on COVID-19's impacts and the benefits of addressing them, it is helpful to first understand the full range of economic costs imposed by COVID-19.

There is a variety of potential epidemiological scenarios for how the COVID-19 pandemic may evolve. This is reflected in the wide range of existing estimates for the economic costs due to COVID-19 (which also vary due to different interventions explored and the scope of costs included).[207] Our epidemiological scenarios include a base case, where current conditions prevail, as well as more and less severe scenarios with differing rates of infections (as affected by, for example, different variants and levels of population immunity).

In our base case scenario, total economic costs could be HKD ~41.6 billion p.a. (equivalent to ~1.4% of GDP), assuming a transmission rate that results in ~8.7 million infections p.a. and ~36,000 hospitalizations p.a., with:

- The majority of costs (HKD ~36.6 billion p.a., 88%) due to productivity losses (indirect costs) through missed work by both working-age adults and elderly people in the workforce, either during their own illness or while caring for dependents (children and over 60 year-olds) affected by COVID-19, and
- A further cost (HKD ~5.1 billion p.a., 12%) borne by the health system (direct costs), in both inpatient (HKD ~1.7 billion p.a.) and outpatient (HKD ~3.3 billion p.a.) settings.

207. See Section 1 for further details.

- Local currencies have been used in this Section, reflecting the use and findings of local data sources. The below exchange rates were used in all local currency conversions to USD in this report. USD currency exchange rate conversions via Google Finance as of 28 February 2023 (USD1 = AUD 1.4861 = HKD 7.8493 = KRW 1,322 = SGD 1.3484 = TWD 30.6608): https://www.google.com/finance/markets/currencies?hl=en

In a higher Pandemic 2.0 scenario, economic costs could reach as high as HKD ~108.7 billion p.a. (~3.8% of GDP). This assumes transmission rates that result in ~15.5 million infections per year (instead of ~8.7 million in the base case) and a severity that results in ~108,000 hospitalizations (compared with ~36,000 in the base case).

At the lower end of the spectrum, a Normal 2.0 scenario might feature ~928,000 infections over the course of a year with only ~2,500 hospitalizations, which would translate to direct and indirect costs of HKD ~4.0 billion p.a.

These economic costs fall unevenly. The health and logistics workforces, those affected by long COVID, and vulnerable populations are likely to be disproportionately impacted. For example, COVID-19 illness in vulnerable populations (see Section 7.4.3) contributes HKD ~16.1 billion p.a. in the base case scenario (~39% of total economic costs); these costs result from infections in people eligible for oral antivirals, who tend to be older and/or affected by comorbidity. Meanwhile, the health workforce is impacted by high levels of absenteeism and a high risk of infection, with consequences for health system capacity and quality of care. Economic costs arising from these disruptions to the health workforce total HKD ~793 million p.a. in the base case scenario. Those affected by long COVID (see Section 7.4.4) are impacted most significantly, with the value of lost work and use of health system resources totaling HKD ~15.9 billion p.a. or ~38% of all economic costs.

Fortunately, a range of countermeasures remains available that could mitigate the economic costs of COVID-19 (see Section 8), including vaccination, therapeutics, and community measures (i.e., non-pharmaceutical interventions). Strengthening these countermeasures may allow Hong Kong to mitigate the potentially high economic costs of the continuing pandemic.

7.1 Context: The Situation In Hong Kong

Today, Hong Kong is relatively free of restrictive measures. Most of the community measures employed earlier in the pandemic, such as lockdowns, mandatory isolation, and mandated mask-wearing have been pared back or discontinued. In their place, Hong Kong has wide availability and uptake of vaccines, and there is some usage of therapeutics such as antivirals – which have been made available to a subset of the Hong Kong population after conditional approval.

Over the three months up to January 2023, Hong Kong was experiencing one of several waves of infections and hospitalizations following the city's progressive reopening in late 2022. With ~15,700 new infections per day (accounting for under-detection) and an effective transmission number[208] of ~1.01, infection volumes were stabilizing. By contrast, in the first quarter of 2022 – the peak of the first Omicron wave – there were ~42,100 infections per day, with an effective transmission number of ~1.7. The change in Hong Kong's pandemic response posture since then is both a reaction to the lower volume of infections and a driver of subsequent infections.

208. The number of people a single case will infect, on average.

Hong Kong's initial set of pandemic response measures was very effective at containing the virus, while also imposing significant economic costs. By international standards, the countermeasures employed during the first phase (2020 to 2021) were very successful. The numbers of reported cases (~12,650) and deaths (~213) were among the lowest in the developed world. However, border closures, lockdowns, social-distancing requirements (including capacity limits on indoor spaces), and mask-wearing mandates imposed significant hardships on the community. The successful rollout of vaccines[209] conferred widespread population immunity, but this was found to wane over time. Waning immunity necessitated third doses, while novel variants emerged, such as Omicron, which were capable of immune escape.

Oral antivirals have been added to Hong Kong's response toolkit. These became available in Hong Kong in February 2022 to help address a significant outbreak at the time.[210] Antivirals remain a part of the SAR's response toolkit following the general reopening of its borders and economy in early 2023.

The health and economic outcomes of the reopening phase have been mixed. The vast majority (~99%) of Hong Kong's infections to date occurred in 2022.[211] While the severity of infections remained relatively mild compared to that seen early in the pandemic, the high volume of infections nevertheless gave the hospital system its busiest year of the pandemic so far, with ~82 admissions per day on average, compared to ~3 in 2021 and 2020.[212] This also meant that the number of deaths increased enormously, to ~10,000 in 2022 compared with 65 in 2021 and 148 in 2020.[213] It is worth noting that COVID-19 has potentially contributed to excess mortality (that is, additional deaths relative to pre-pandemic mortality), both due to deaths caused by COVID-19 and deaths that may have arisen as a second-order impact of COVID-19 on health system capacity.

The high volume of infections has also wrought an economic impact, both in costs borne directly by the health system in addressing COVID-19, and the economic losses borne indirectly by society in the form of absenteeism and productivity losses. These will be explored in detail in Sections 7.3.1 and 7.3.2. Hong Kong's reopening experience has illustrated that the costs of COVID-19 borne by Hong Kong society extend beyond the value of health losses captured traditionally by health technology assessments. Indeed, productivity losses driven by infections across all age groups constitute a major economic cost.

A better understanding of the economic costs of COVID-19 could inform the assessment of the costs and benefits of various measures to address COVID-19. Indeed, despite the ongoing burden of COVID-19 on society, vaccination coverage remains incomplete. As of February 2023, 94.6% of Hong Kong residents have received at least one dose of a COVID-19 vaccine and 83% have received three doses.[214] Hong Kong's three-dose coverage is higher than South Korea's (~80%) for example but less than Japan's (100%). And while the use of antivirals has tracked infection waves, their use remains relatively uncommon, at a prescription rate of ~3% of all infections.[215]

209. As of February 2023, ~94.6% of the population had received at least one dose of a COVID-19 vaccine, while ~93.1% had received two doses and 83.7% had received three doses. Coronavirus website of the Hong Kong authorities [Internet]. Local situation dashboard. Available from: https://chp-dashboard.geodata.gov.hk/covid-19/en.html
210. They are currently available for all COVID-19 positive patients over the age of 18 and with one additional risk factor, or for those over the age of 60 regardless of risk factors. Risk factors include a range of chronic illnesses.
211. There were ~7.3 million infections in Hong Kong in 2022, compared to ~44,000 in 2021 and ~37,000 in 2020.
212. Institute of Health Metrics and Evaluation, used with permission. Available from: https://www.healthdata.org/covid/data-downloads#
213. Institute of Health Metrics and Evaluation, used with permission. Available from: https://www.healthdata.org/covid/data-downloads#
214. Coronavirus website of the Hong Kong authorities [Internet]. Local situation dashboard. Available from: https://chp-dashboard.geodata.gov.hk/covid-19/en.html
215. Legislative Council of the Hong Kong SAR [Internet]. Official record of proceedings of 2023 January 11. Available from: https://www.legco.gov.hk/yr2023/chinese/counmtg/floor/cm20230111-confirm-ec.pdf#nameddest=app_01_07

7.2 Key Assumptions In The Hong Kong Context

A range of informed assumptions is used to derive the estimates of economic costs in Hong Kong as a result of COVID-19. Exhibit 34 illustrates how these assumptions are used and provides a list of the key assumptions used, while a full list of assumptions is given in the Appendix section.

Exhibit 34: Use of assumptions in the Hong Kong context

A | Epidemiological scenarios

Scenario	Infections (mn) p.a.	Hosp. rate (%)
Normal 2.0	~0.9	0.3
Base	~8.6	0.4
Pandemic 2.0	~15.5	0.7

→

B | Direct costs: borne by the health system

Key Base Case Assumptions	
# Ward admissions p.a.	~33,000
# ICU admissions p.a.	~3,200
% Infections that visit a GP	8-12%
% Infections prescribed OAVs	3.4%
# Long COVID cases p.a.	~434,000

+

C | Indirect costs: economic productivity losses borne by society

Key Base Case Assumptions	
Working-age infections as proportion of total	61%
Proportion of working-age infections that can work	99.6%
Proportion of working-age infections that can work from home	45%
Average number of working days lost due to acute illness in working-age population	~6
Average daily salary	HKD 18,700

=

D | Total economic cost to society

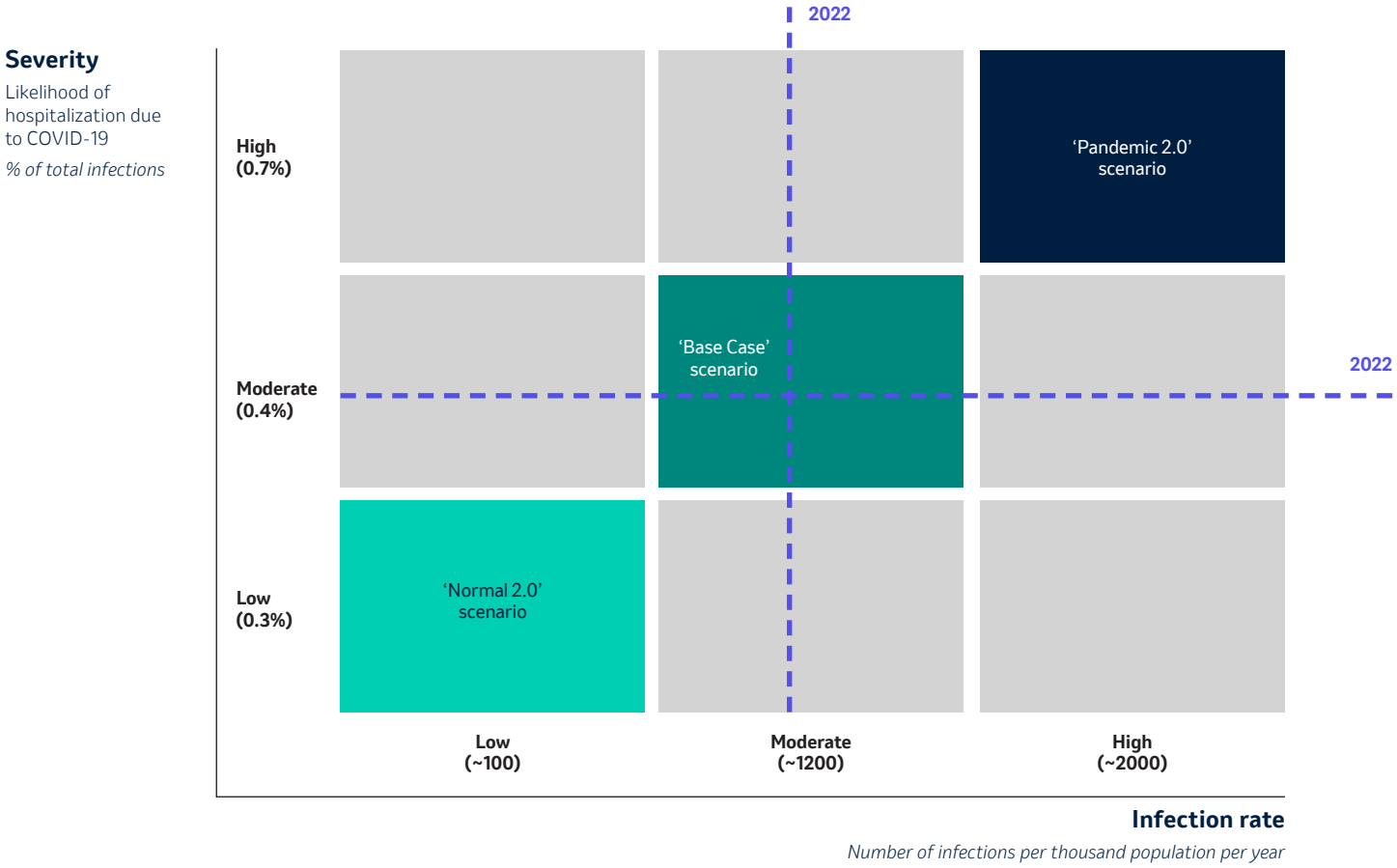
- **Total direct and indirect costs,** broken down by patient/demographic group
- **Costs per person** in each patient/ demographic group

  - E.g., if total inpatient costs are $1.7b, and 36,000 patients are admitted, the cost per person is ~ $48,000

A full list of assumptions is given in the appendix.

7.3 Future:
Scenario-Based Estimates Of The Economic Costs Of COVID-19 In Hong Kong

Exhibit 35: Potential epidemiological scenarios



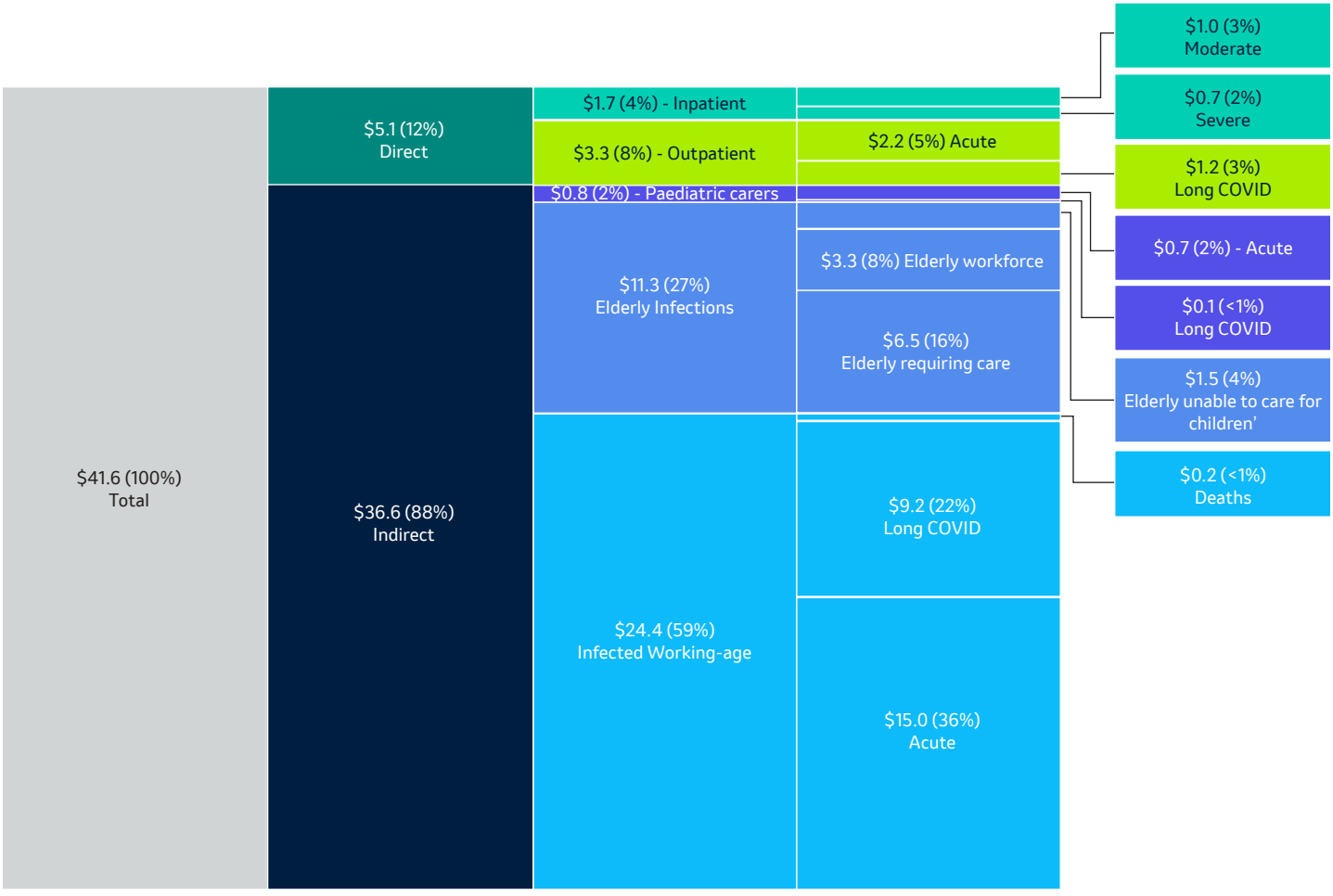
Scenarios are indicative only and based on the observed epidemiology of COVID-19 in Hong Kong in 2022.

As Exhibit 35 illustrates, Hong Kong could experience a range of cost scenarios:

- A base case, with an economic cost of HKD ~41.6 billion p.a. (~1.4% of GDP, in addition to the value of lost health such as that already considered in HTAs), which assumes a rate of infection (e.g., ~1.2 million infections per million population annually) and a viral severity driving ~36,000 hospital admissions annually, similar to that seen in late 2022. This is the scenario shown in Exhibit 36 below and described in the direct (7.3.1) and indirect (7.3.2) costs Sections below.
- A high or Pandemic 2.0 case, with an economic cost of HKD ~108.7 billion p.a. (~3.8% of GDP), which assumes a higher rate of infection (e.g., ~2.1 million infections per million population per year) and a higher viral severity driving ~108,000 hospitalizations annually, similar to that seen in the early part of 2022. A scenario of this type could result from a variety of circumstances, such as the emergence of a novel, more infectious variant, and could be exacerbated by the return of mass movement to and from Hong Kong, including the reopening of domestic and international borders.

- **A low or Normal 2.0 case, with an economic cost of HKD ~4.0 billion p.a. (~0.1% of GDP),** which assumes a lower rate of infection (e.g., ~120,000 infections per million population per year) and a viral severity driving ~2,500 hospitalizations, similar to that seen in mid-2022.

Exhibit 36: Direct and indirect costs of COVID-19 to Hong Kong's economy in a base case scenario, HKD billion p.a.

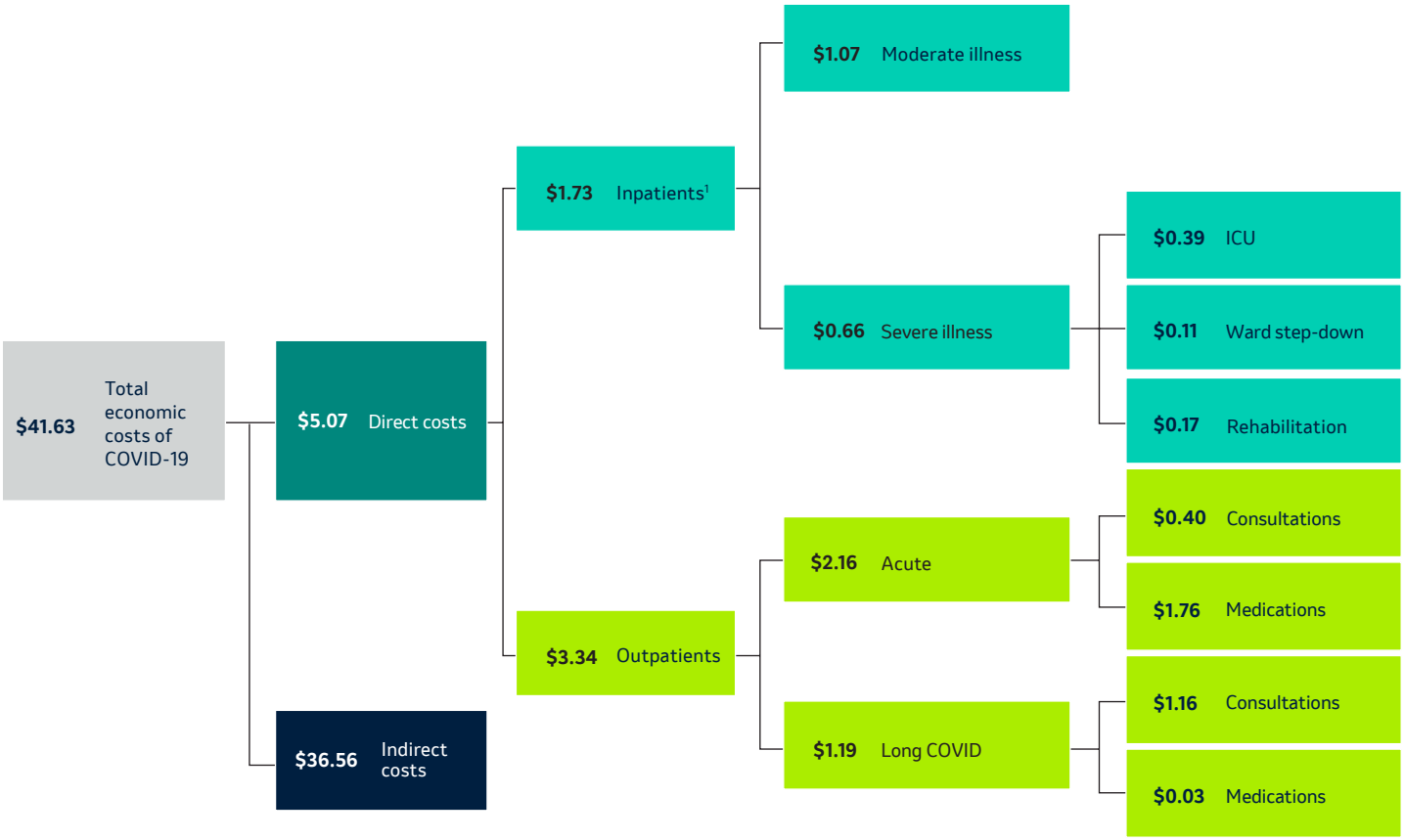


Proportion of costs borne by infected cohorts, HKD billion (% of total)"

Costs are indicative only and based on the distribution of COVID-19 infections between cohorts in Hong Kong in 2022.

Exhibit 36 maps out our base case scenario, which is designed to reflect a continuation of recent conditions. To create this scenario, infection volumes and the prevailing hospitalization rate from Q4 2022 have been drawn from the Institute of Health Metrics and Evaluation (IHME) model of COVID-19 (figures used with permission) and annualized.

Exhibit 37: Direct economic costs from COVID-19, base case, HKD billion p.a.



1. Cost is 'all inclusive' (i.e., includes accommodation, all aspects related to medical care, and medications)
Note: Totals may not sum precisely due to rounding to 2 decimal places.

'Moderate illness' requires ward-based inpatient care and 'Severe illness' requires ICU-level care; 'Acute illness' refers to all infections not included in inpatient care; Long COVID refers to a small subset (~5%) of total infections and represents infections with symptoms lasting 12 weeks or more.

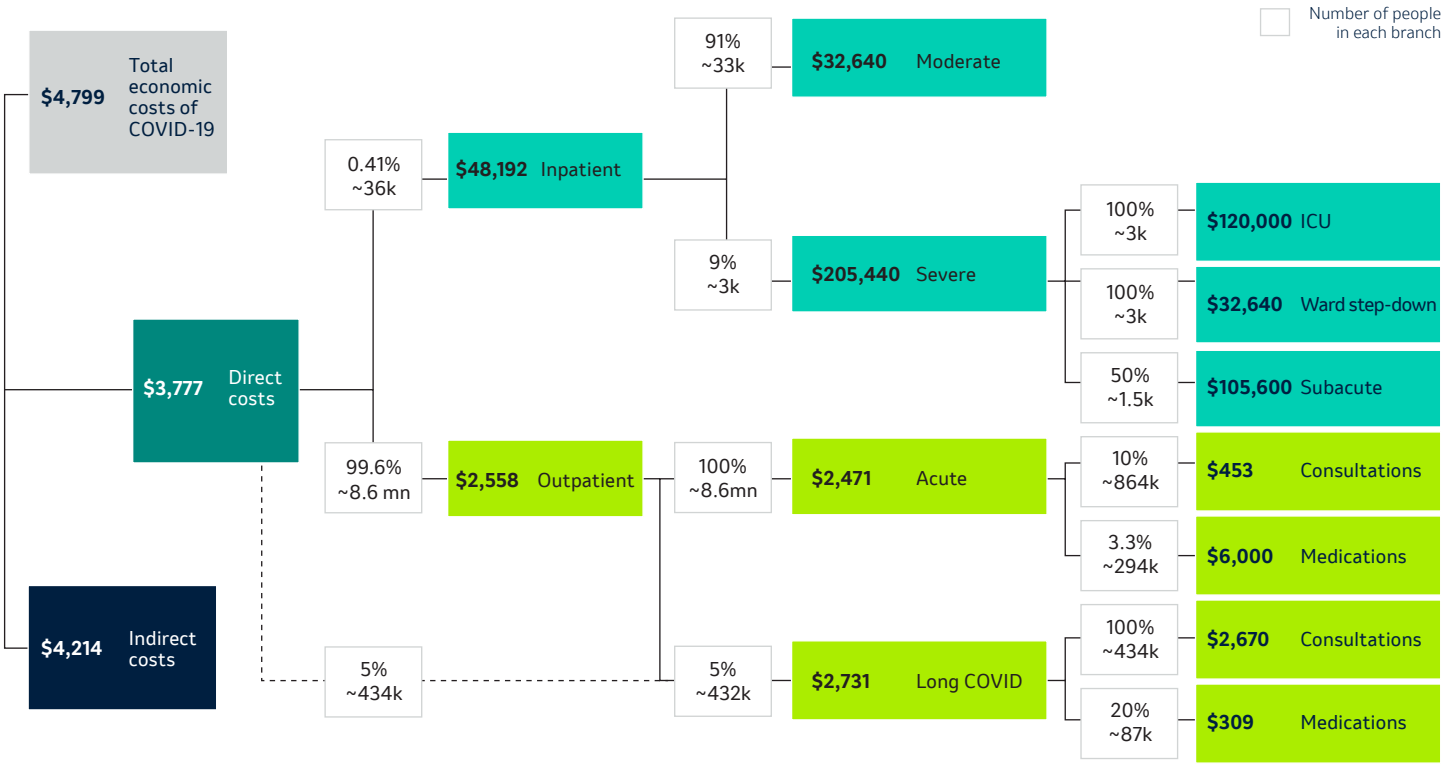
7.3.1 Direct costs to the health system

With ~36,000 hospital admissions (including ~3,000 to the ICU) and ~434,000 cases of long COVID in our base case scenario, preventing admissions (including to ICU), reducing lengths of stay, time to recovery, and/or the incidence of long COVID could significantly lower the direct costs imposed by COVID-19 on our health system. Given that those over 60 are over-represented in the COVID-19 inpatient population, preventing severe illness in this age group would likely be particularly impactful in reducing direct costs.

In the base case scenario (see Exhibit 37), COVID-19 could cost the Hong Kong health system HKD ~5.1 billion p.a. Despite the magnitude of this figure, direct costs in fact account for a minority of the total economic costs of COVID-19 in Hong Kong, at just ~12% of the total. The indirect cost of productivity losses due to missed work accounts for the remainder and could be HKD ~36.6 billion p.a. These indirect costs are discussed further in Section 7.3.2.

Despite the relatively minor scale of direct costs in the wider scheme of COVID-19's economic impact, they remain significant on a per-infection basis. As illustrated in Exhibit 38, each infection that necessitates some form of health service could impose an average cost of

Exhibit 38: Direct economic costs from COVID-19, per person, base case, HKD p.a.



Costs per person for each segment are calculated by dividing the total cost of that segment by the number of individuals in that segment that use a health service; 'Moderate illness' requires ward-based inpatient care and 'Severe illness' requires ICU-level care; 'Acute illness' refers to all infections not included in inpatient care, where ~10% visit a GP and 3.4% are prescribed medication; Long COVID refers to a small subset (~5%) of total infections and represents infections with symptoms lasting 12 weeks or more.

HKD ~3,777. The bulk of this cost is from inpatient care, where a single ward admission could cost HKD ~32,640 and a single ICU admission (with subsequent ward and rehabilitation stays) could cost HKD ~205,440.

As indicated in Exhibits 37 and 38, direct costs are incurred in two major settings:

- Inpatient (hospital-based) care (HKD ~1.7 billion p.a.; 34%; HKD ~48,192 per person)
- Outpatient (primarily GP-based) care (HKD ~3.3 billion p.a.; 66%; HKD ~2,558 per person)

The profile of inpatient care costs suggests that ameliorating the severity of illness acquired could have a significant impact on cost. Particularly in a reopened economy, where individuals at risk of severe disease are less protected from infection by community health measures, the extent of ongoing costs to the health system underscores the importance of continuing to prevent, test for, and treat the disease.

Costs in this category comprise those arising from moderate infections requiring ward-based care (HKD ~1.1 billion p.a.; HKD ~32,640 per person) and severe infections requiring ICU treatment (HKD ~660 million p.a.; HKD ~205,440 per person). The higher overall cost of care for moderate infections is due to the greater volume of patients with moderate infections (33,000, compared to 3,000 patients with severe infections), while the cost of care for severe infections is principally due to high bed day costs (HKD ~24,000 per day in ICU), followed by substantial periods of inpatient rehabilitation.

Analysis of outpatient care costs indicates that limiting the incidence, duration, and/or severity of long COVID would have a substantial impact on

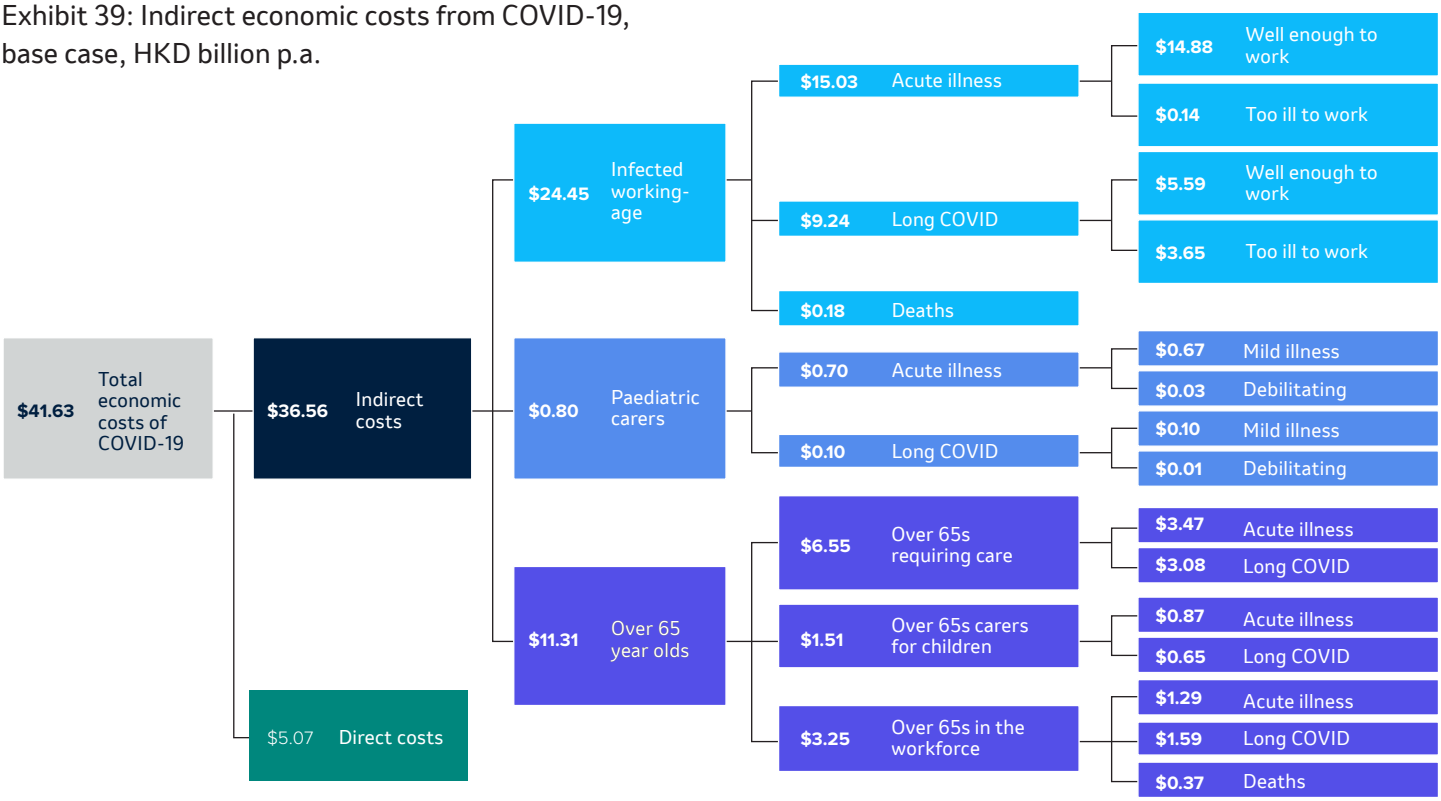
this portion of the cost burden. Outpatient care for COVID-19 infections adds HKD ~3.3 billion p.a. to the total economic costs incurred due to COVID-19. While seemingly less resource-intensive, outpatient infections that call for health services are also expensive on a per-person basis, costing HKD ~2,558 each.

Outpatient costs can be separated into acute outpatient care (consultations and medications: HKD ~2.2 billion p.a.) and chronic outpatient or Long COVID care (consultations and medications: HKD ~1.2 billion p.a.; see 7.4.4).

While the cost of acute outpatient care is largely due to the cost of medications (such as oral antivirals, HKD ~1.8 billion), it is only around 4% of the total economic cost. This seems a small investment for treatment that partially reduces the total economic costs associated with COVID-19 (HKD ~41.6 billion p.a.) and helps prevent them from spiraling. The remaining outpatient costs are from GP visits, which could exceed 3.5 million consultations per year assuming ~10% of those acutely infected seek care from their GP and ~5% develop long COVID (all of whom would have to seek primary care). The cost of these services is higher than inpatient costs (HKD ~1.7 billion p.a.) and represents a substantial added burden on the primary care system.

Together, direct costs from inpatients and outpatients amount to HKD ~5.1 billion p.a. While significant on their own, these costs should be seen together with the indirect costs to Hong Kong's economy (discussed below), the value of lost health, and ripple effects on the health system (such as its workforce) and other critical industries.

Exhibit 39: Indirect economic costs from COVID-19, base case, HKD billion p.a.



Note: Totals may not sum precisely due to rounding to 2 decimal places

Indirect costs arise from productivity losses incurred due to infection with COVID-19; 'Well enough to work' refers to those who can continue working while infected, albeit with reduced productivity; 'Too ill to work'' refers to those who cannot work, at least for a portion of the time, while infected; 'Acute illness' refers to all infections not included in inpatient care; Long COVID refers to a small subset (~5%) of total infections where symptoms last 12 weeks or more.

7.3.2 Indirect costs to the economy

Reducing the sheer volume of COVID-19 infections and the duration of illness and/or time to recovery for working-age adults, children, and the older population would have a significant impact on reducing the economic and societal costs of COVID-19.

In the base case scenario, and as Exhibit 39 illustrates, COVID-19 could cost the Hong Kong economy HKD ~36.6 billion p.a. in productivity losses if current epidemiological conditions and responses continue.[216] The impact could be larger if the city were to see a return to stricter isolation protocols. As with direct costs to the health system, this is a significant expense, equating to ~1.2% of GDP. While these costs are significant, as with direct costs, they still do not account for the value of health lost due to COVID-19, nor the ripple effects on critical industries and vulnerable populations such as the health workforce.

As illustrated in Exhibit 39, indirect costs result from productivity losses borne by three separable age groups:

- **Infections in working-age adults (20-59 year-olds) – HKD ~24.4 billion p.a.** (~67%; HKD ~4,626 per person)
- **Infections in the older population (60 year-olds and above) – HKD ~11.3 billion p.a.** (~31%; HKD ~5,147 per person)
- **Infections in children and adolescents (19 years old and below) – HKD ~800 million p.a.** (~2%; HKD ~698 per person)

Infections in working-age adults impose a significant economic burden on Hong Kong, through productivity losses valued at HKD ~24.4 billion p.a., which equates to ~0.8% of Hong Kong's GDP. An illness that is mild for most people but significant enough to last ~12 days and impairs productivity by ~35% for three-quarters of us has a major impact on the broader economy.[217]

Productivity loss according to working-age groups can be separated into two categories:

- Acute illness (HKD ~15.0 billion p.a.), chronic illness, or long COVID (HKD ~9.2 billion p.a.), and deaths (HKD ~0.2 billion p.a.)
- Infected adults with mild illness who are still well enough to work but with reduced capacity (HKD ~20.5 billion p.a.), and infected adults who are too ill to work (i.e., are hospitalized) (HKD ~3.8 billion p.a.)

Looking at these together, acute illness in those who can still work but at reduced capacity accounts for ~61% of productivity losses incurred by working-age adults. Even modest reductions in working capacity at the individual level have a substantial cost when the illness lasts several days and affects ~8.7 million infections in Hong Kong per year.

Infections in the older population impose an overall cost of HKD ~11.3 billion p.a. in productivity losses for the Hong Kong economy on top of the burden of infections in working-age adults. This underlines the fact that productivity losses are not limited to those borne by working-age adults, and that infections in younger and older people also bring an economic cost.

COVID-19 infections in older people can lead to loss of productivity in three main ways:

- **Older people with COVID-19 who require care from a working-age person** – ~1.9 million working-age carers, each incurring an HKD ~3,512 productivity loss – resulting in a total impact of HKD ~6.5 billion p.a.
- **Older people who directly participate in Hong Kong's labor force** – estimated to be 23% of those over 60. Infections in this group result in HKD ~3.3 billion in productivity losses.
- **Older people (e.g., grandparents) who care for children to enable parents to work** – one in three parents in Hong Kong report that their parents (i.e., the child's grandparents) have helped them raise their children. When this work-enabling care is disrupted, the productivity loss amounts to HKD ~1.5 billion.

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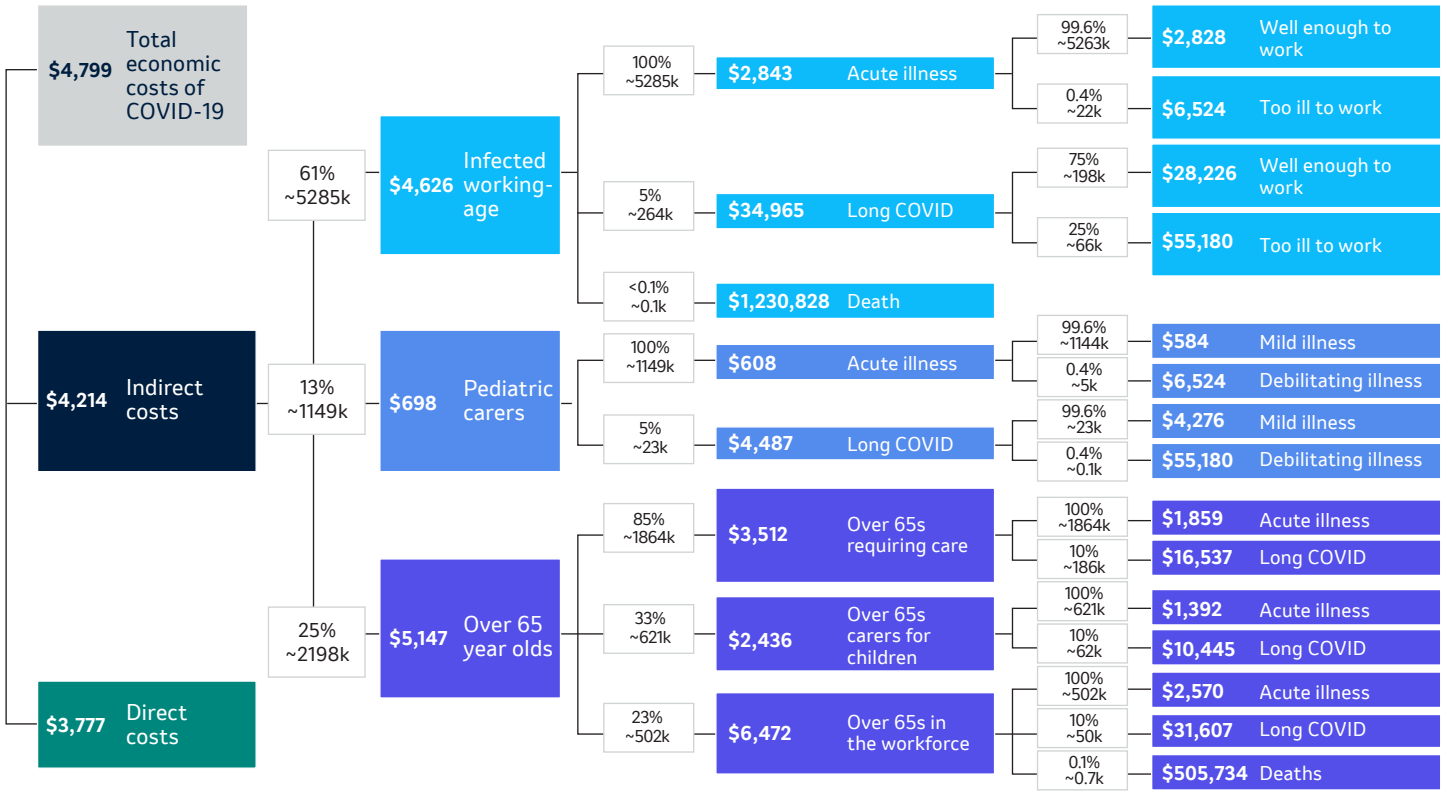
216. Based on a median monthly earnings figure of $18,700 as at 2021 May-Jun. Hong Kong SAR government press release [Internet]. Survey results of 2021 Annual Earnings and Hours Survey. Available from: https://www.info.gov.hk/gia/general/202203/21/P2022032000685.htm
217. Johnsen S. et al. ERJ Open Research [Internet]. Descriptive analysis of long COVID sequelae identified in a multidisciplinary clinic serving hospitalised and non-hospitalised patients.2021 Aug 2; 7: 00205-2021. Available from: https://openres.ersjournals.com/content/erjor/7/3/00205-2021.full.pdf

Infections in the older population account for HKD ~12.6 billion p.a., or ~30% of all direct and indirect costs combined, serving as a stark reminder of the need to address the cost of infections in the older population.

Finally, infections in children impose an additional economic cost of HKD ~802 million p.a. owing to productivity losses borne by adults who are absent from or less productive at work while caring for children. As with productivity losses from the older population, losses arising from infections in children can be difficult to recognize in advance but are significant when they emerge.

Productivity losses arising from infections in children are predominantly driven by adults caring for children with acute, mild illness. The cohort of infected children, which constitutes the majority (~96%) of productivity losses in adults caring for children with acute illness, is worth HKD ~670 million p.a. This cost is driven by care for ~234,000 mild but symptomatic infections in children, who despite having a mild illness require one parent to care for them at home. The remaining ~4% is driven by productivity losses from caring for children with debilitating infections. For parents who can work from home (~45%), productivity is estimated to halve, while parents who cannot (~55%) lose all productivity. This is a substantial cost driven more by lost work than the illness itself, another demonstration that the substantial cost of productivity losses is not limited to infections in working-age adults.

Exhibit 40: Indirect economic costs from COVID-19, per person, base case, HKD p.a.



Costs per person for each segment are calculated by dividing the total cost of that segment by the number of individuals in that segment; Indirect costs arise from productivity losses incurred due to infection with COVID-19; 'Well enough to work' refers to those who can continue working while infected, albeit with reduced productivity; 'Too ill to work' refers to those who cannot work, at least for a portion of the time, while infected; 'Acute illness' refers to all infections not included in inpatient care; Long COVID refers to a small subset (~5%) of total infections and represents infections with symptoms lasting 12 weeks or more.

Despite their seemingly lower resource intensiveness compared to direct healthcare costs, indirect costs from COVID-19 are nearly as expensive on a per-person basis (as indicated in Exhibit 40) due to the massive loss of productivity – with each infection costing HKD ~4,214 on average. This is concentrated in productivity losses resulting from infections in the working-age (HKD ~4,626 per person) and older population (HKD ~5,147 per person).

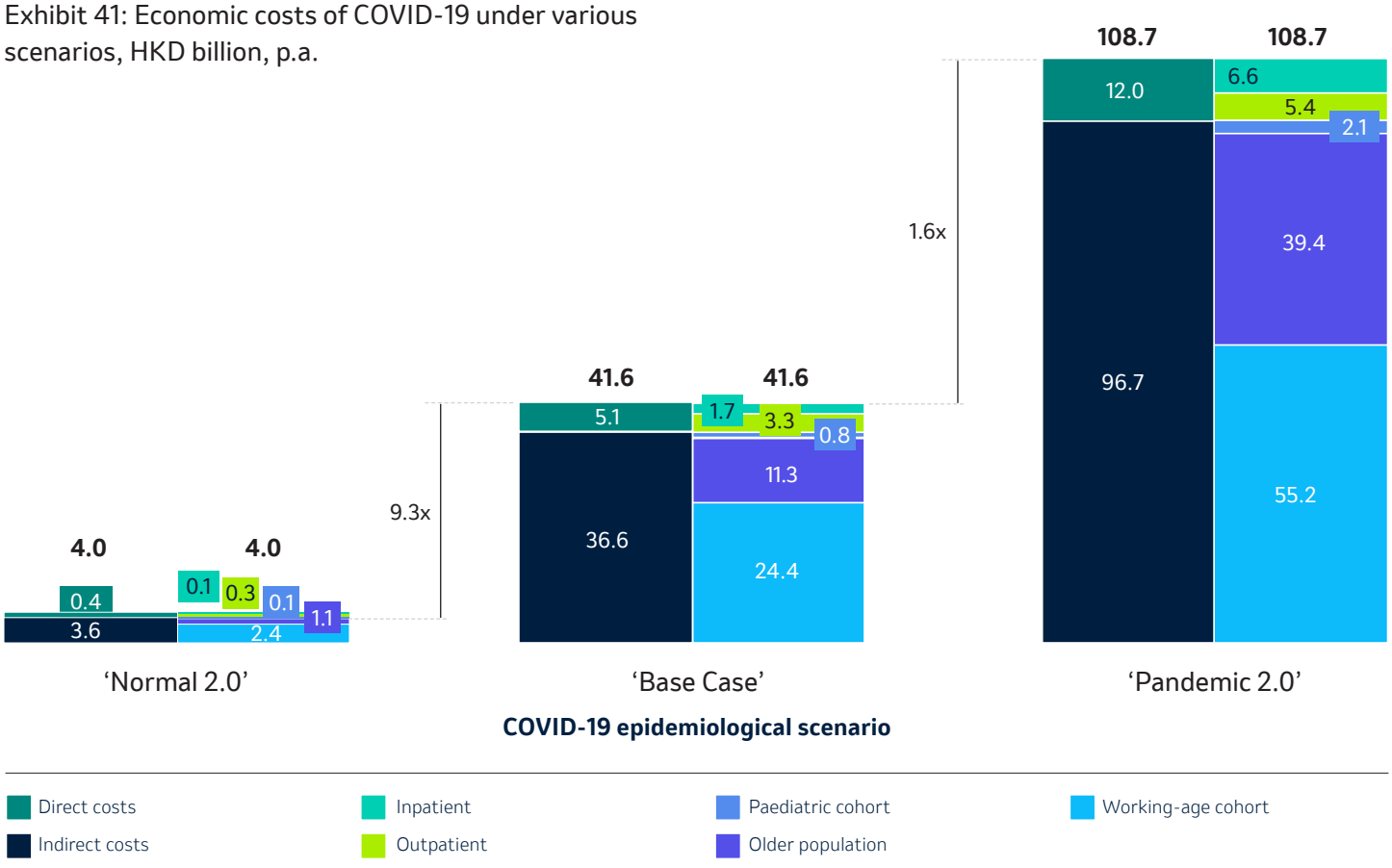
Together, economic costs arising from productivity losses in these age groups amount to HKD ~36.6 billion p.a. or ~1.2% of Hong Kong's GDP, which is in addition to the value of lost health and direct costs to Hong Kong's health system. Although already substantial, these costs likely underestimate the entirety of the burden imposed on society by COVID-19, including second-order impacts on health system capacity and ripple effects on the health workforce, supply chains, and other aspects of critical industry that all add measurable economic impacts.

In fact, the whole economic burden imposed by COVID-19 needs to be understood in the context of the prevailing epidemiological scenario, as the impacts and costs described can significantly increase in plausible scenarios where novel variants emerge. These scenarios are described below.

7.3.3 Alternative scenarios: costs of Pandemic 2.0 and Normal 2.0

In addition to the base case, two further scenarios have been considered, as illustrated in Exhibit 41.

Exhibit 41: Economic costs of COVID-19 under various scenarios, HKD billion, p.a.



Normal 2.0 refers to a scenario featuring ~120,000 infections per million population and ~2,500 hospitalizations, reflecting conditions observed in mid-2022; Pandemic 2.0 refers to a scenario featuring ~2.1 million infections per million population and ~108,000 hospitalizations, reflecting conditions observed in early 2022.

In a Pandemic 2.0 scenario, total economic costs could reach HKD ~108.7 billion p.a. Conversely, in the Normal 2.0 scenario, economic costs could drop to HKD ~4.0 billion p.a.

These scenarios represent two divergent but plausible epidemiological outcomes amid the evolving pandemic. Each scenario is theorized using two key features:

- Infection volume (driven by contagiousness; measured by cases per million people per year), and
- Case severity (driven by a prevailing strain's virulence factors; measured by the resulting hospitalization rate)

A Pandemic 2.0 scenario would feature a case volume of ~2.1 million cases per million population per year (i.e., the entire population is infected twice on average) and a case severity where ~0.7% of all infected people are hospitalized. By comparison, the base case scenario assumes a case volume of ~1.2 million infections per million people and a hospitalization rate of 0.4%.

In the Pandemic 2.0 scenario, economic impacts from COVID-19 could increase to HKD ~108.7 billion p.a., equating to ~3.8% of GDP and HKD ~7,034 per person. Direct costs could be HKD ~12.0 billion p.a. (a 2.4X increase of HKD ~6.9 billion p.a.) and indirect costs could reach HKD ~96.7 billion p.a. (a 2.6 times increase of HKD ~60.1 billion p.a.). These increases would be driven by the higher case volume, increased hospitalization rates, longer lengths of stay, and exacerbated productivity losses due to an increased incidence of debilitating illness and longer periods of missed work.

The sharp rise in costs that could result from a plausible epidemiological scenario like this demonstrates the need for a range of preparedness settings, including options to limit impacts at every stage.

A Normal 2.0 scenario would feature a case volume of ~120,000 cases per million population per year and a hospitalization rate of 0.3%. Under a Normal 2.0 scenario, economic impacts from COVID-19 could diminish to HKD ~4.0 billion p.a., equating to ~0.1% of GDP and HKD ~4,323 per person. Direct costs could decrease to HKD ~400 million p.a. and indirect costs to HKD ~3.6 billion p.a. Decreases in costs would be driven by the lower case volume, lower hospitalization rates, and diminished productivity losses owing to reduced periods of missed work.

While scenarios help us to consider potential courses that the COVID-19 pandemic may take in the future, their scope is largely restricted to quantifiable economic costs. Equally important to consider are the broader 'second order' impacts that COVID-19 could have on health system capacity and ripple effects on vulnerable populations and critical industries.

7.4 Considerations For Particular Cohorts And Industries

The economic costs of COVID-19 will impact people in different populations and industries disproportionately. This includes those who play critical economic/social roles (e.g., health care workers), those who are particularly vulnerable to severe disease (e.g., people with comorbidities), and those who go on to develop long COVID.

Interventions that protect health and avoid productivity losses in these critical industries and populations may yield similarly significant economic returns. Disruptions to these groups also cause significant economic and societal concern and may be worthy of closer focus when considering countermeasures to mitigate the impacts of COVID-19.

7.4.1 Critical workers and industries

As outlined above, some critical industries experience disproportionate workforce productivity losses that generate significant public concern. Here, the focus is on one industry in particular: healthcare.

The economic costs of COVID-19 borne by critical industries and their stakeholders may increase in a Pandemic 2.0 scenario. Critical workers who are largely unable to work from home may be required to isolate while they recover. The resulting loss of productive time can be 30% greater (the equivalent of 1-2 workdays) than for individuals in desk jobs.

7.4.2 Healthcare

Hong Kong's health system serves as our first and last line of defense against COVID-19 and other health threats. Healthcare expenditure totaled HKD ~190 million in 2019/20[218] and ~117,000 healthcare professionals are currently employed in Hong Kong.[219]

At a potential minimum cost of HKD ~793 million p.a. (~1.9% of the combined total cost),[220] healthcare workers who catch COVID-19 represent a disproportionate slice of the impact on the economy. However, this is likely a significant underestimation of the total impact on the Hong Kong economy and citizens' welfare due to ripple effects on patient outcomes.

Frontline healthcare workers are at high risk of contracting COVID-19 due to their high exposure risk. At the Queen Mary Hospital during the fifth COVID-19 wave, 25% of healthcare workers tested positive, a significantly higher infection rate than the general population (16%).[221] Of those healthcare workers infected, 79% were symptomatic.[222] Productivity losses are not only incurred by sick workers but also by the remaining workers who are required to take up additional responsibilities.

The economic ripple effects of COVID-19 among healthcare workers are significant, as COVID-19 exacerbates (pre-existing) workforce shortages. In March 2022, waiting times for an ambulance rose to 39 hours, with only 30% of emergency calls being responded to within the target time of 12 minutes.[223] During December 2022, Hong Kong residents faced emergency department wait times of at least 8 hours and up to 20 hours.[224] Such reductions in the availability and timeliness of medical care may subsequently lead to prolonged illness or recovery times for patients, many of whom lose productivity in the process.

Additionally, during the COVID-19 pandemic, high levels of workforce anxiety and burnout have been seen.[225] Although the initial response to the COVID-19 pandemic has subsided, global talent shortages and mobility challenges are ongoing challenges.

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218. Hong Kong Health Bureau [Internet]. Domestic Health Accounts, June 2021. Available from: https://www.healthbureau.gov.hk/statistics/en/dha/dha_summary_report.htm
219. Department of Health [Internet]. Health Facts of Hong Kong, 2022 edition. Available from: https://www.dh.gov.hk/english/statistics/statistics_hs/files/2022.pdf
220. Based on a median monthly earnings figure of $19,900. Hong Kong Census and Statistics Department [Internet]. Report on Annual Earnings and Hours Survey 2021. 2022 Mar. Available from: https://www.censtatd.gov.hk/en/data/stat_report/product/B1050014/att/B10500142021AN21B0100.pdf
221. Wong SC et al. Infection of healthcare workers despite a high vaccination rate during the fifth wave of COVID-19 due to Omicron variant in Hong Kong. Infection Prevention in Practice. 2023 Mar; 5(1): 100261. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9705264/
222. As above.
223. Wong N. South China Morning Post [Internet]. Coronavirus: Hong Kong residents wait up to 39 hours for ambulance as health care system buckles under strain of COVID-19 cases. South China Morning Post [Internet]. 2022 Mar 1. Available from: https://www.scmp.com/news/hong-kong/society/article/3168736/coronavirus-hong-kong-residents-wait-39-hours-ambulance
224. Chan K, Cheung L. South China Morning Post [Internet]. COVID-19 patient waits 20 hours in A&E as Hong Kong hospitals become overwhelmed. South China Morning Post [Internet]. 2022 December 27. Available from: https://www.scmp.com/video/coronavirus/3204671/COVID-19-patient-waits-20-hours-ae-hong-kong-hospitals-become-overwhelmed
225. Yeung N. et al. Feeling anxious amid the COVID-19 pandemic: Factors associated with anxiety symptoms among nurses in Hong Kong. Frontiers in Psychology. 2021 October 1; 12: 748575. Available from: https://www.frontiersin.org/articles/10.3389/fpsyg.2021.748575/full#:~:text=facilitate%20well%2Dbeing.-,Conclusion,anxiety%20symptoms%20among%20those%20nurses.

A countermeasure approach that targets healthcare workers could have a significant effect in mitigating overall economic costs as well as COVID-19 impacts on public health. This is demonstrated by the disproportionate costs of COVID-19 infections among healthcare workers against the backdrop of an increasingly constrained talent market.

7.4.3 Vulnerable populations

COVID-19 illness in Hong Kong's vulnerable populations represents a minimum impact of HKD ~16.1 billion p.a. on Hong Kong's economy. These populations are at greater risk of severe COVID-19 disease and are more heavily reliant on the healthcare system than others. Populations that have received particular attention throughout the pandemic include those over 60 years old and those with comorbidities.

COVID-19 in Hong Kong's older population (60 years old and above) could have an economic impact of HKD ~12.6 billion p.a. (~30% of the combined annual impact). This is significant on a per-person basis too, at HKD ~5,732. Despite representing ~25% of confirmed cases, the older population represents a significantly higher proportion of deaths, with ~96% of deaths due to COVID-19 occurring in people over 60 years old.[226] This is unsurprising, as the prevalence of comorbidities is particularly high in this age group. 70% of the elderly in Hong Kong have at least one chronic disease.[227]

Costs from those with comorbidities in the younger, working-age population could also have a disproportionate impact of HKD ~3.5 billion p.a. Just one comorbidity doubles the risk of severe COVID-19,[228] subsequently increasing the likelihood of hospitalization and prolonging time off work to recover. This could be a reality for ~24% of people in Hong Kong.[229]

Given that ~39% of combined direct and indirect costs are borne by these vulnerable populations, countermeasures that reduce the duration of illness and/or time to recovery for this group alone could significantly mitigate the costly impacts of COVID-19. Countermeasures may include ongoing vaccination, community measures, and/or the use of oral antivirals. Indeed, infections in individuals eligible for oral antivirals account for HKD ~16.1 billion p.a. in economic costs or ~39% of the total economic costs to Hong Kong.

7.4.4 Long COVID

Long COVID[230] has a potential minimum impact of HKD ~15.9 billion p.a. on Hong Kong's economy. Individuals who develop this condition experience prolonged productivity losses (increasing 'indirect costs') and rely on health services (increasing 'direct costs').

Direct costs due to long COVID collectively amount to at least HKD ~1.2 billion (HKD ~2,731 per person), which is largely the cost of consultations. This figure is driven by the incidence, relative complexity, and duration (90 days) of long COVID. When case complexity and duration are factored in, this could mean ~2.6 million healthcare consultations are required for this cohort alone.[231] Therefore, long COVID represents a substantial burden on the health system, both in terms of capacity requirements and economic costs.

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226. Coronavirus website of the Hong Kong authorities (figures from the Centre for Health Protection of the Department of Health; and the Hospital Authority). Statistics on 5th Wave of COVID-19 [Internet]. 2023 Jan. Available from: https://www.coronavirus.gov.hk/pdf/5th_wave_statistics/5th_wave_statistics_20230129.pdf
227. Hong Kong SAR Department of Health, Elderly Health Service. Coping with Chronic Illness [Internet]. 2023 Feb. Available from: https://www.elderly.gov.hk/english/healthy_ageing/mental_health/coping_with_chronic_illness.html
228. Liu B. et al. High risk groups for severe COVID-19 in a whole of population cohort in Singapore. BMC Infectious Diseases. 2021 July 16; 21(1): 685. Available from: https://bmcinfectdis.biomedcentral.com/articles/10.1186/s12879-021-06378-z
229. Hong Kong SAR Census and Statistics Department [Internet]. Special Topics Report, Report No. 63: Persons with disabilities and chronic diseases. December 2021. Available from: https://www.censtatd.gov.hk/en/EIndexbySubject.html?pcode=C0000055&scode=380
230. Also commonly described as 'post-COVID 19 syndrome', long COVID describes the prolonged duration of COVID-19 symptoms beyond twelve weeks after the initial infection.
231. Estimating ~432,000 long COVID cases, where each case could require 6 consultations on average over the 90-day period of long COVID illness.

Productivity losses from long COVID could amount to HKD ~14.7 billion p.a. (HKD ~33,799 per person and ~40% of all indirect costs). By a significant margin, the largest contributor is productivity losses arising from long COVID in the working-age population (HKD ~9.2 billion p.a. or ~63% of indirect costs from long COVID). To illustrate this further, an adult with long COVID, despite being well enough to work, could still lose the equivalent of 46 work days over a three-month period of illness while their productivity is impaired.[232]

Given the large share (~38%) of total economic costs that long COVID imposes on the Hong Kong economy, any countermeasures that can reduce the incidence and/or duration of this condition would contribute a great deal to mitigating economic costs associated with the pandemic. As evidence surrounding the incidence and course of long COVID is nascent, with conservative estimates placing incidence at 5% and duration at 90 days, it may emerge that these impacts are underestimates.

232. Based on an average of nine days of sick leave and reported reductions in productivity while working, due to long COVID.

8. Shaping The Future: Our Toolkit For Averting The Neglected Economic Burden of COVID-19

8.1 The Countermeasures Toolkit

In the face of the significant economic costs of COVID-19, there exists access to a wide range of countermeasures to address this burden. As illustrated in Exhibit 42, countermeasures include community measures such as social distancing as well as the utilization of vaccines and therapeutics, including oral antivirals.

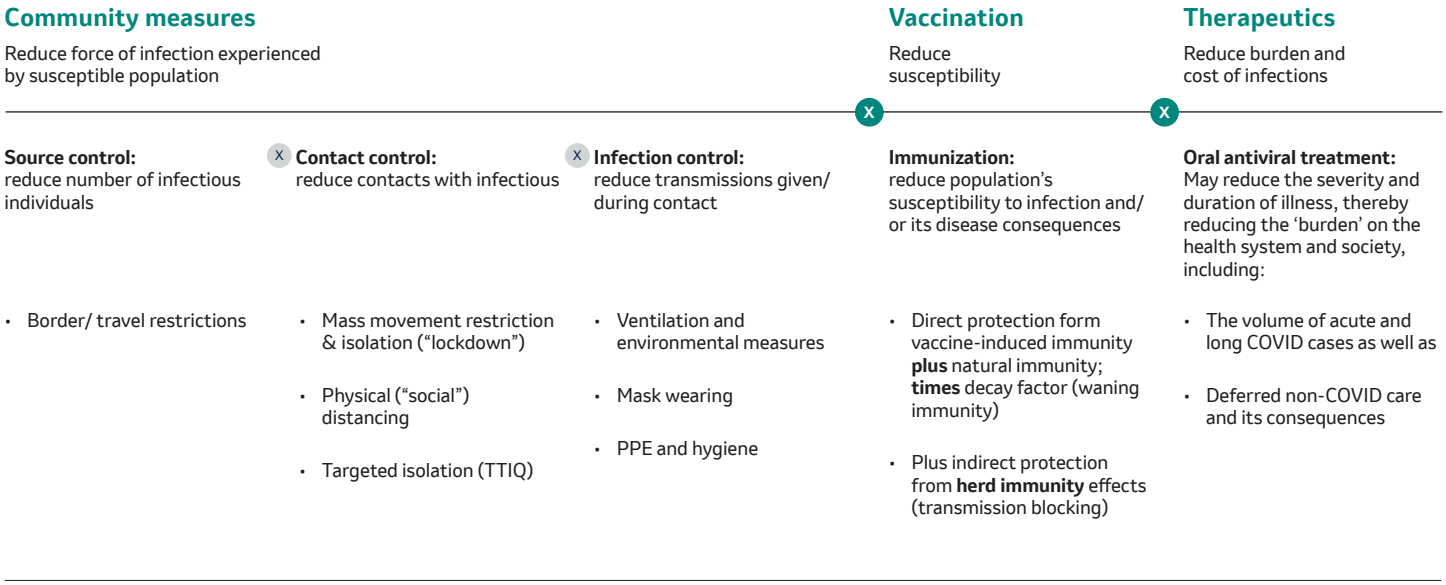
However, despite significant ongoing economic costs, uptake of these countermeasures has been incomplete and uneven across markets. Examples of incomplete uptake include variable adherence to isolation requirements in markets where these are still required, waning uptake of booster vaccination doses, and variable awareness and availability of oral antivirals. There is an opportunity for policymakers to consider the optimal utilization of the full set of countermeasures available to mitigate the continued economic and societal impact of COVID-19.

When used widely, such countermeasures have been very effective at containment and suppression of the COVID-19 virus, while managing to limit economic costs. For the five markets in focus (Australia, Taiwan, South Korea, Singapore, and Hong Kong), the countermeasures employed during the first phase of the pandemic (2020 to 2021) were generally very successful. The number of reported cases and deaths in each market were among the lowest in the developed world. However, border closures, social-distancing requirements, strict contact tracing, and mask-wearing mandates still imposed significant hardships on affected communities. The successful rollout of vaccines afforded an easing of many restrictions in 2022, although the immunity conferred was found to wane over time. The resulting reduced population immunity has been challenging, as novel variants have emerged, including Omicron.

Oral antivirals have been added to response toolkits. The necessarily short-term nature of restrictive community measures and the remaining health threat of COVID-19 led this group of markets to broaden their approaches to include oral antivirals.

The three categories of countermeasures and their differing potential to mitigate the economic costs of COVID-19 are summarized in Exhibit 42 below.

Exhibit 42: The countermeasure toolkit



8.1.1 Community measures – reducing the force of infection

Community measures were central to managing the impact of COVID-19 globally, particularly during the initial phases of the pandemic before the development and roll-out of vaccines and therapeutics. Community measures reduce the 'force' of infection through three potential levers:

- **Source control** to reduce the number of infectious individuals, such as travel/border restrictions.
- **Contact control** to reduce contact between healthy and infectious individuals, including 'lockdowns', 'social' distancing, and targeted isolation (TTIQ).
- **Infection control** to reduce infection transmission during contact, including mask-wearing and ventilation measures.

While protecting population health, there are significant challenges and economic frictions associated with community measures. Community measures typically depend on a high degree of collaboration from a market's population, as many perceive social 'freedoms' as being forgone for mask-wearing, lockdowns, and other mandates. As such, monitoring and encouraging adherence to community measures can be resource intensive for authorities. However, they pose broader economic frictions too. For example, the high cost of productivity loss when businesses are forced to close due to revenue losses (especially food and accommodation services) or reduced labor headcounts.

2022 saw a shift away from community measures in the management of COVID-19. This was driven by an epidemiological course of COVID-19 that was considered to be less severe, widespread vaccine uptake, and increasing access to antivirals in some markets.

8.1.2 Vaccines – reducing population susceptibility

COVID-19 vaccines have had a significant benefit to economies, in addition to health outcomes for individuals. Each of the markets studied has achieved high rates of vaccination relative to international peers, with 83-96% of their respective populations having received two doses.[233,234,235,236] By reducing the population's susceptibility (both directly for the recipient of the vaccine and indirectly by reducing the risk of onward transmission),[237] vaccines have the potential to reduce the volume and severity of infections. This lessens the overall costs borne by the health system and costs that arise from productivity losses due to COVID-19 illness. In Australia for example, COVID-19 vaccines have curbed the economic costs of COVID-19 by AUD ~181 billion.[238]

COVID-19 vaccines highlighted the benefits of rapid and widespread access to medical innovations once they were authorized or approved. The adaptability of health technology assessment (HTA) processes to meet an urgent public need was particularly celebrated. In light of this, stakeholders in the policy and scientific communities are calling for reforms that place greater emphasis on broader social and economic benefits in the assessment of and investment in vaccines and medicines.[239]

The evolution and roll-out of COVID-19 vaccines may be an ongoing investment to combat new variants and sub-variants of COVID-19 capable of evading conferred immunity.

8.1.3 Therapeutics – reducing the burden

Therapeutics have the potential to further curb the economic impact of COVID-19, in both markets with largely vaccinated populations and those with lower vaccination rates. Therapeutics such as antivirals are so far typically limited to high-risk categories. These include older populations and adults with comorbidities/chronic illnesses. For these populations, therapeutics may reduce the chances of being hospitalized or dying from disease, and subsequently the costs due to productivity losses and burden on health systems.[240]

There may be an opportunity to broaden the use of therapeutics. Currently, populations that are eligible for oral antivirals could represent ~40-50% of the economic impact of COVID-19 across the five markets studied, assuming high levels of uptake. Given the challenges associated with community measures, and that these markets have already achieved high vaccination coverages, investment in therapeutics for a broader population, if found to be efficacious for a wider cohort in reducing time to symptom resolution, could be a subsequent consideration in market responses.

233. Holder J. New York Times [Internet]. COVID Vaccinations tracker. 2023 Mar 13. Available from: https://www.nytimes.com/interactive/2021/world/covid-vaccinations-tracker.html
234. Government of Hong Kong Special Administrative Region [Internet]. Hong Kong Vaccination Dashboard. 2023 Feb 5. Available from: https://www.covidvaccine.gov.hk/en/dashboard
235. Ministry of Health Singapore[Internet]. Vaccination Statistics. 2023 Feb 1. Available from: https://www.moh.gov.sg/COVID-19/vaccination/statistics
236. Commonwealth Department of Health [Internet]. Vaccination Numbers and Statistics. 2023 Mar 31. Available from: https://www.health.gov.au/our-work/COVID-19-vaccines/vaccination-numbers-and-statistics
237. Edwards KM, Orenstein WA. UpToDate [Internet]. COVID-19 Vaccines, Impact on Transmission Risk. [cited 2023 Feb 27]. Available from: https://www.uptodate.com/contents/COVID-19-vaccines#H1606921902
238. Medicines Australia [Internet]. New report indicates COVID-19 vaccines saved Australia's economy. 2022 Dec 19. Available from: https://www.medicinesaustralia.com.au/media-release/new-report-indicates-COVID-19-vaccines-saved-australias-economy/
239. Medicines Australia [Internet]. New report indicates COVID-19 vaccines saved Australia's economy. 2022 Dec 19. Available from: https://www.medicinesaustralia.com.au/media-release/new-report-indicates-COVID-19-vaccines-saved-australias-economy/
240. Centers for Disease Control and Prevention [Internet]. COVID-19 Treatments and Medications, 2023 Feb 10. Available from: https://www.cdc.gov/coronavirus/2019-ncov/your-health/treatments-for-severe-illness.html

8.2 Utilization Profile: Countermeasures In Australia

Exhibit 43: Summary of countermeasures in Australia

	Community measures	Vaccination	Therapeutics
2022	• **Mask wearing** - compulsory mask-wearing for public transportation and airports was in place until September • **Isolation** - mandatory isolation requirements for individuals that test positive was repealed in October • **TTIQ** - testing and tracing was pared back by individual states over Q4 2021 and Q1 2022	• All Australians aged 5+ years or 6+ months in the at-risk population are eligible for a government-subsidized COVID-19 vaccination • As of December 2022, ~65 million doses have been administered nationally with 96% of 16+ year olds receiving 2 doses, 72.4% receiving 3 doses, and ~5.4 million receiving a fourth	• Antivirals Lagevrio and Paxlovid were listed on the Pharmaceutical Benefits Scheme (PBS) in March and May respectively • Eligible cohorts include 70+ year olds. 50+ year olds with 2 risk factors, First Nations people who are 30+ with 1 risk factor, and 18+ year olds who are moderately to severely immunocompromised
2020-21	• **Border restrictions** - international borders were closed until November 2021 and some interstate (WA) until February 2022 • **Mass movement restriction and isolation** - bans on non-essential gatherings and "lockdowns" were implemented to varying degrees and durations (e.g., from a few days to months) across Australian states from March 2020 to October 2021	• Between September and May, the Australian government entered agreements with 5 vaccine manufacturers purchasing a total of ~315 million vaccines (manufactured overseas and locally) • Roll-out commenced in February 2021 • By December 2021, ~43 million doses were administered nationally with ~19 million people receiving 2 doses	

As of December 23, 2022.[241,242,243,244.]

241. Australian Government Department of Health and Aged Care [Internet]. COVID-19 Vaccines facts. 2023 Mar 20. Available from: https://www.health.gov.au/our-work/COVID-19-vaccines/is-it-true
242. Australian Government Department of Health and Aged Care [Internet]. Oral COVID-19 treatments. Available from: https://www.health.gov.au/health-alerts/COVID-19/treatments/eligibility#:~:text=This%20will%20take%20effect%20from,symptoms%20from%20COVID%2D19%20begin.
243. Knowlton C. TimeOut Magazine [Internet]. A timeline of COVID-19 in Australia, two years on. 2023 Feb 20. Available from: https://www.timeout.com/melbourne/things-to-do/a-timeline-of-COVID-19-in-australia-two-years-on
244. Australian National Audit Office [Internet]. Australia's COVID-19 Vaccine Rollout. 2022 Aug. Available from: https://www.anao.gov.au/work/performance-audit/australia-COVID-19-vaccine-rollout

8.3 Utilization Profile: Countermeasures In Taiwan

Exhibit 44: Summary of countermeasures in Taiwan

	Community measures	Vaccination	Therapeutics
2022	• **Isolation** - there is a 5 day mandatory isolation period for those who test positive for COVID-19 • **Mask wearing** - masks are required to be worn in public spaces	• As of December 2022, ~60 million doses administered with 88% of the population receiving 2 doses • People aged 50 to 64 and people 18 or older who need to travel abroad eligible to receive Moderna's second- generation Spikevax COVID-19 vaccine dose as a booster shot • People between 12-17 age can get a Novavax COVID-19 vaccine as a first. second, or booster shot	• Oral antivirals became available in Q2 2022 • Eligible cohorts include those 65+ years old and 18+ year olds at high risk of severe Illness
2020-21	• **Border restrictions** - international borders were closed from March 2020 to October 2022 • **Testing and contact tracing** - a contact tracing program was implemented to track travel and contact history of confirmed COVID-19 cases; a digital home quarantine monitoring system implemented for travelers	• Roll-out commenced in August 2021 • Compulsory for medical personnel, airline or ship crew members, care facility employees, workers at airports and other ports of entry	

As of December 23, 2022.[245]

245. Ministry of Health and Welfare [Internet]. COVID-19 Timely Border Control. 2022 Jul. Available from: https://covid19.mohw.gov.tw/en/cp-4774-53783-206.html

8.4 Utilization Profile: Countermeasures In South Korea

Exhibit 45: Summary of countermeasures in South Korea

	Community measures	Vaccination	Therapeutics
2022	• **Isolation** - there is a 7-day mandatory isolation period for those who test positive for COVID-19 (although this is likely to be reduced in 2023) • **Mask wearing** - masks are required to be worn indoors • **Social distancing** - as of April 2022, all social distancing restrictions have been lifted • **Border restrictions** - until October 2022, inbound travelers were required to quarantine for 2 weeks	• Population aged 12 or more have access to vaccination. • Since August, the second COVID booster shot available for people aged 50 or more, as well as immunosuppressed individuals from 18 or more, from 4 months after the last booster shot • As of December, ~130 million doses have been administered with ~86% of population receiving 2 doses and ~80% receiving 3	• 3 antivirals are approved by South Korea MFDS (Remdesivir, Paxlovid, and Molnupiravir) • Eligible cohorts include those 60+ years old and 18+ year olds at high risk of severe illness
2020-21	• Border restrictions - South Korea maintained testing and quarantining procedures at its border. • TTIQ: South Korea implemented a national program of testing, contact tracing and quarantining of positive cases that was underpinned by its Epidemic Intelligence Service.	• Roll-out commenced in February 2021 with vulnerable and highly exposed groups • By October 2021, 70% of all citizens were vaccinated > 5,000 nursing home residents and workers younger than 65 would receive the AstraZeneca vaccines on Feb 26, 2021	

As of December 23, 2022.[246,247,248,249]

246. KDCA [Internet]. Report on 2 years of COVID-19 in South Korea, 2022 Jan. Available from: https://www.kdca.go.kr/board/board.es?mid=a20602010000&bid=0034&list_no=718713&act=view
247. Ministry of Health and Welfare [Internet]. 2022 Apr. Available from: https://www.mohw.go.kr/react/al/sal0301vw.jsp?PAR_MENU_ID=04&MENU_ID=0403&page=1&CONT_SEQ=371078
248. South Korea MFDS press release [Internet]. 2022 Aug. Available from: https://www.medifonews.com/mobile/article.html?no=169660
249. Google News [Internet]. COVID-19 map. Available from: https://news.google.com/covid19/map?hl=en-AU&mid=%2Fm%2F06qd3&gl=AU&ceid=AU%3Aen&state=7

8.5 Utilization Profile: Countermeasures In Singapore

Exhibit 46: Summary of countermeasures in Singapore

	Community measures	Vaccination	Therapeutics
2022	• **Social gatherings** - no group size limit as of April 2022 • **Mask wearing** - compulsory in indoor settings until August 2022; currently optional except for healthcare facilities, residential care homes, ambulances, and public transport • **Isolation** - from October 2022, self-isolation required for 72 hours, can exit if ART negative, or on day 7 (for fully vaccinated) or on day 14 (for unvaccinated/partially vaccinated) • **Border restrictions** - non-fully vaccinated travelers no longer required to undergo 7 days in home quarantine as of August 2022	• As of January 2023: - 92% of Singaporeans have received at least one vaccination dose - 83% have minimum protection (3 x mRNA or Novavax/Nuvaxovid, or 4 x CoronaVac) - 49% have up-to-date vaccination (minimum protection and last dose received within one year) • Vaccinations available to all (above 6 months of age) - can walk into Joint Testing and Vaccination Centres - ≥80 years old can walk into any Polyclinic to receive vaccination	• Nirmatrelvir/ritonavir (Paxlovid) and molnupiravir (Lagevrio) granted interim authorization by Singapore Health Sciences Authority in February and April 2022 respectively - Eligibility criteria include ≥60 years old or ≥18 years old with one risk factor (e.g. chronic kidney disease. serious heart conditions. immunosuppression, diabetes, COPD, obesity, active cancer) • Remdesivir may be considered in patients with severe (or at high risk of severe) disease
2020-21	• **Social gatherings** - no household visitors or group gatherings during circuit breaker (~April 2020), group size limited throughout most of 2020 and 2021 • **Border restrictions** - international borders closed to all short-term visitors in March 2020, with returning Singapore residents needing to undertake 14 days quarantine • **Contact tracing** - government implemented TraceTogether program for community contact tracing, including an app enabled by Bluetooth	• Vaccination program commenced December 2020 - first Asian market to launch - Healthcare workers prioritized • Elderly eligible for vaccinations from January 2021 • Vaccinations available to population (≥12 years old) from June 2021	

As of February 6, 2023.[250,251,252,253]

250. Ministry of Health Singapore [Internet]. COVID-19 updates and statistics. Available from: https://www.moh.gov.sg/covid-19/
251. The Straits Times [Internet]. Timeline of S'pore's measures over the last 2 years. Available from: https://www.straitstimes.com/singapore/two-years-of-twists-and-turns-a-timeline-of-singapores-covid-19-measures
252. Ministry of Health Singapore [Internet]. COVID-19 Vaccination Registration. Available from: https://www.vaccine.gov.sg/
253. National Centre for Infectious Diseases [Internet]. Treatment Guidelines for COVID-19. Available from: https://www.ncid.sg/Health-Professionals/Diseases-and-Conditions/Documents/Treatment%20Guidelines%20for%20COVID-19%20v10.1%20-for%20circulation_Final%20%5B29-8-2022%5D.pdf

8.6 Utilization Profile: Countermeasures In Hong Kong

Exhibit 47: Summary of countermeasures in Hong Kong

	Community measures	Vaccination	Therapeutics
2022	• **Mask wearing** - remains compulsory in both indoor and outdoor settings • **Isolation** - mandated isolation lifted January 2023 - Previously required for positive cases either in hospital or at community isolation facilities - Close contacts required 14 days of home quarantine (February 2022) • **Social distancing** - As at December 2022, maximum group gathering size of 12 people	• Two vaccinations available - Comirnaty and CoronaVac - Three doses recommended: additional fourth dose recommended for >50 years old and immunocompromised • 93% of the population have had two vaccine doses; 84% have received three doses	• Hospital Authority has made available nirmatrelvir/ritonavir (Paxlovid) and molnupiravir (Lagevrio) in February 2022 - Eligibility criteria include ≥60 years old, or at high risk of medical illness. or with chronic illnesses
2020-21	• **Border restrictions** - international borders closed for 2020-21, only opened to passengers from Mainland China, Taiwan or Macao in March 2022 • **Contact tracing** - LeaveHomeSafe app launched in November 2020 for contact tracing	• Secretary for Food and Health authorized Fosun Pharma/BioNTech (Comirnaty) and Sinovac Biotech Limited (CoronaVac) vaccines in Hong Kong on 25 January and 18 February 2021 respectively	

As of February 6, 2023.[254, 255, 256, 257, 258, 259]

254. The Government of the Hong Kong Special Administrative Region [Internet]. COVID-19 Thematic Website. Available from: https://www.coronavirus.gov.hk/eng/index.html
255. Ancheta T. Timeout [Internet]. Things you need to know about Hong Kong's social distancing restrictions. 2023 Mar 3. Available from: https://www.timeout.com/hong-kong/things-to-do/things-you-need-to-know-about-hong-kongs-social-distancing-restrictions
256. Cheung E, Heung S. South China Morning Post [Internet]. Exodus of COVID-19 patients from isolation centres as Hong Kong ends compulsory isolation. 2023 Jan 30. Available from: https://www.scmp.com/news/hong-kong/health-environment/article/3208447/private-doctors-prepare-surge-covid-19-patients-hong-kong-ends-mandatory-isolation
257. The Government of the Hong Kong Special Administrative Region [Internet]. Government relaxes certain social distancing measures. Available from: https://www.info.gov.hk/gia/general/202212/20/P2022122000646.htm
258. The Government of the Hong Kong Special Administrative Region [Internet]. COVID-19 Vaccination Programme. Available from: https://www.covidvaccine.gov.hk/en/dashboard
259. News.gov.hk [Internet]. COVID-19 antiviral eligibility relaxed. Available from: https://www.news.gov.hk/eng/2022/07/20220729/20220729_170528_537.html

9. Conclusion

The overwhelming evidence from our analysis is that the direct and indirect costs of COVID-19 will continue to be a substantial drain on economies across Asia Pacific, far greater than is commonly recognized. Even in an optimistic scenario, the pandemic will still affect individuals, families, businesses, and markets in a myriad of ways that should inform policymaking. In the more severe Pandemic 2.0 scenarios, COVID-19 could make a dent in GDP of between 2.2% (Australia) and 5.5% (South Korea), figures that could easily make the difference between economic growth or recession.

At a more granular level, our findings highlight the often overlooked impacts of the pandemic. While the direct costs of medical treatment for COVID-19 are significant, in fact, these are dwarfed by the total price of indirect costs, especially loss of productivity. Similarly, while policymakers' financial focus tends to be on the working-age population, in fact, infections among older people and children also contribute significantly to productivity losses and other economic costs. Finally, certain cohorts of people are likely to be disproportionately impacted, notably health and logistics professionals, those affected by long COVID, and vulnerable populations.[260] These kinds of considerations can no longer be ignored or minimized by responsible policy-makers.

9.1 Economic costs

In our base case scenario across each of the markets studied, total economic costs range from 0.6% to 1.6% of the markets' GDPs, with:

- 86%-96% of costs across markets due to productivity losses (indirect costs) through missed work by both (i) adults as a result of their own illness or while caring for dependents (children and over-60/65 year-olds[261]); as well as (ii) elderly in the workforce affected by COVID-19, and
- 4%-12% of costs across markets borne directly by the health system (direct costs), in both inpatient and outpatient settings.

In a Pandemic 2.0 scenario, economic costs could rise up to 5.5% of GDP. This assumes transmission rates that result in two to three times the number of infections per year than in the base case and a severity that results in two to six times the number of hospitalizations than in the base case. At the lower end of the spectrum, a Normal 2.0 scenario might feature around 65% fewer infections over the course of a year than in the base case and 75% fewer hospitalizations.

Regardless of the scenario, these economic costs fall unevenly. Health and logistics workforces, those affected by long COVID, and vulnerable populations[262] are all likely to be disproportionately impacted. For example, in Singapore, COVID-19 illness in vulnerable populations contributes SGD ~1.7 billion p.a. in the base case scenario, while an SGD ~1.9 billion p.a. in cost (~52% of total economic costs) results from infections in people eligible for oral antivirals, who tend to be older and/or affected by comorbidity. These broad patterns are common across the markets studied.

At the same time, the health workforce is impacted by high levels of absenteeism due to COVID-19 and a high risk of infection, with consequences for health system capacity and quality of care. In Australia, for example, economic costs arising from these disruptions to the health workforce could total AUD ~2.3 billion p.a., or ~9% of the total economic cost (base case scenario). Those affected by long COVID are impacted most significantly, with the value of lost work and health system resource use in Australia totaling AUD ~8.6 billion p.a., or around one-third of all economic costs.

260. Broadly, those over 60-65 (market-dependent), regardless of comorbidity, and adults under 60 with one or more comorbidities.
261. In South Korea and Hong Kong, the retirement age is 60, while in Australia, Taiwan, and Singapore it is 65.
262. Broadly, those over 60-65 (market-dependent), regardless of comorbidity, and adults under 60 with one or more comorbidities.

9.2 How can we mitigate COVID-19 and reduce its overall cost?

Fortunately, a range of countermeasures remain available to mitigate the economic costs of COVID-19. These can be categorized as community measures (including source, contact, and infection control), vaccines, and therapeutics.

Keep community measures on the table and keep innovating

Many of the most effective measures in tackling COVID-19 have been at the community level, including the introduction of digital tools for tracking and analyzing the spread of the virus. Learning from successes elsewhere in the world and developing new, innovative approaches to the social impact of the disease will be vital to ongoing mitigation and cost reduction. Indeed, other measures, such as lockdowns and social distancing measures, can also play an important role in blunting infection volumes. However, while these measures are effective in protecting population health, they also impose significant challenges and economic frictions and should not be treated as a first resort.

Continue vaccinating and developing new vaccines

By reducing individuals' susceptibility to the virus, COVID-19 vaccines have provided a significant benefit to economies and greatly facilitated reopening. In doing so, vaccines have highlighted the benefits of rapid and widespread access to medical innovations. Keeping up the momentum of vaccinations and acquiring new vaccines to address fresh strains and accommodate particular needs is essential to reduce the ongoing incidence and cost of COVID-19.

Inclusion of therapeutics

Therapeutics such as oral antivirals have the potential to further curb the economic impact of COVID-19 by helping to reduce the disease burden. There may also be an opportunity to broaden the use of therapeutics, given that ~40-50% of economic costs could be borne by those who are eligible, while only a small proportion of infected individuals (~3%) currently receive them. As the world accepts COVID-19 as endemic, there is opportunity for reducing the severity of its symptoms and thereby softening its blow to productivity.

As has been described, the costs of the pandemic are substantial and wide-ranging and are often not fully recognized in traditional evaluations of its economic impacts. Policy-makers who respond to the scale of the challenge by strengthening their toolkit of countermeasures will be in a strong position to mitigate the high costs of the continuing pandemic, ensuring that their populations and economies are adequately prepared for all eventualities.

Appendix: Assumptions

Australia

Exhibit A1: Key overall assumptions

1st Level	Parameter Name	Value	Source	Commentary
Total economic costs of COVID-19	Total annual COVID-19 infections	19,844,050	Institute of Health Metrics Evaluation, The University of Washington	Q4 2022 infections per million, annualized
	Total COVID-19 deaths	1,064	Institute of Health Metrics Evaluation, The University of Washington	Reported daily deaths, 2022, annualized
	Proportion of infections that are detected	18%	Institute of Health Metrics Evaluation. The University of Washington	

Exhibit A2: Key direct cost assumptions

3rd Level	4th/5th Level	Parameter Name	Value	Source	Commentary
Inpatient	Moderate	Hospitalization rate	0.55%	• Institute for Health Metrics and Evaluation	• Total 2022 hospitalizations / total # infections
		Ward admission rate	95.00%	• Commonwealth & State Health Departments; • Australian Institute of Health and Welfare report on admitted patient activity	• Calculation based on admission data 2020-22 • Published ICU admission rate for 2020-21
		Ward length of stay	11 days	• AIHW Report on COVID-19 admitted activity	• Range of 9-12 days given; rounded mid-point chosen
		Ward bed day cost	$700	• AIHW Report on health expenditure 2019-20 • Independent Hospital and Aged Care Pricing Authority	• Calculation based on total public hospital spending and admitted bed davs • Combined ward and ICU bed day cost of $1.270
	Severe	ICU admission rate	5.00%	• Commonwealth & State Health Departments; • Australian Institute of Health and Welfare report on admitted patient activity	• Calculation based on admission data 2020-22 • Published ICU admission rate for 2020-21
		ICU length of stay	15 days	• AIHW Report on COVID-19 admitted activity	• Range of 10-20 days given
		ICU bed day cost	$5,250	• Medical Journal of Australia study of 36 ICUs' costs per patient day	• 2013-14 mean figure of $4,375 indexed

Exhibit A2: Key direct cost assumptions (continued)

3rd Level	4th/5th Level	Parameter Name	Value	Source	Commentary
Outpatient	Acute	Proportion of infections that visit an ED	0.1%	• Australian Institute of Health and Welfare report on the impact of COVID-19 on 2020 emergency department activity	• Calculated weekly ED attendances per weekly infections volume
		Cost per Emergency Department visit	$800	• Independent Hospital and Aged Care Pricing Authority	• Total cost of a non-admitted ED attendance for COVID-19 2019-20
		Proportion of infections that visit a GP	3-12%	• Journal of Primary Care and Community Health • Calculation based on known volumes of AV prescriptions	• Study of visits to ~1,200 primary care centres across the US in 2020 for treatment of COVID illness; divided by number of infections
		Cost per GP visit	$97	• Medicare benefits schedule • AIHW Report on health expenditure 2019-20	• Accounts for value of MBS item and average practice gap fee
	Chronic	Incidence of Long COVID	5.00%	• Australian National University Evidence from the COVID-19 Impact Monitoring Survey Series, August 2022	• Estimate of incidence in Australia of 4.7%; implies 700.000 annual cases

Exhibit A3: Key indirect cost assumptions

3rd Level	4th/5th Level	Parameter Name	Value	Source	Commentary
Infected working-age	Acute - well enough to work	Proportion of acute working-age infections well enough to work (outpatients)	98.85%	• The Institute for Health Metrics and Evaluation (IHME) • See direct cost assumptions	• Inpatient (1.15%) is based on IHME hospitalization rate + proportion of infections that require hospital in the home (HITH) (see direct cost assumptions) • The remainder (98.85%) is outpatient
		Proportion of acute working-age infections that are asymptomatic	25%	• Healthline (2020) and Global Systematic review (n=28 studies) (2021)	Mid-point taken from: • 20% in Healthline 2020 • 28-31% in Systematic review 2021
		Proportion of people who cannot work from home	39%	• ABC (2022)	• ~61% (workers reporting tasks that can be performed at home) in 2022
		Duration of acute illness	12 days	• Medline (2022)	• 10-14 days for mild to moderate illness
		Proportion of illness days that people take as sick leave	25% (~3 days)	• Wall Street Journal (2022) • Cost-analysis for COVID-19 in Australia (Cook 2021 and Kompas 2020)	• WSJ (2022) - 3-4 days taken off • Cook (2021) - 3-13% of infections take ~10 days off work (includes both inpatient and outpatient illness) • Kompas (2020) - average 18.5 sick days off work (includes both inpatient and outpatient illness)
		Productivity loss on days worked while ill	35%	• European Respiratory Society	• Cross-sectional study of positive COVID-19 diagnosis 3 months after discharge of resolution of acute disease. Uses WPAI. 35% work impairment for non-hospitalised and 10% for hospitalised, 20% overall; make conservative estimate that long-COVID symptoms cause same level of productivity loss as when working with acute illness
	Long COVID	Rate of long COVID	5%	• ANU (2022) • Global Burden of Disease Long COVID Collaborators (2022)	• ANU survey of 3,510 adult Australians - 4.7% had or currently have long-COVID syndrome with symptoms lasting 3 months or more • Collaborators review of 54 studies - 6%
		Duration of long COVID	90 days	• NSW Government (2022)	

Taiwan

Exhibit A4: Key overall assumptions

3rd Level	4th/5th Level	Value	Source	Commentary
Total economic costs of COVID-19	Total annual COVID-19 infections	19,809,716	The Institute for Health Metrics and Evaluation (IHME) (released November 18, 2022)	• August 2022 annualized • Note: IFR ratio is 0.06% (2x that of Australia). IHME corrects to ensure reported deaths reflect actual deaths due to COVID-19
	Total COVID-19 cases	8,628,255		
	Total COVID-19 deaths	11,844		

Exhibit A5: Key direct cost assumptions

3rd Level	4th/5th Level	Parameter Name	Value	Source	Commentary
Inpatient		Hospitalization rate	0.39%	• Institute for Health Metrics and Evaluation	• Oct 2022 hospitalizations / total # infections
		Number of admissions	77,258	• Calculation	• Total infections (~19.8m) multiplied by hospitalization rate
	Moderate	Ward admission rate	90%	• Institute for Health Metrics and Evaluation	• IHME-modelled number of required hospital beds versus number of required ICU beds
		Ward length of stay	11 days	• NHI Annual Statistical Report, 2021	• Average LOS in public hospitals in 2021
		Ward bed day cost	NT$9,308	• NHI Annual Statistical Report, 2021	• Cost of total stay divided by average length of stay for public hospitals; includes co-payment
	Severe	ICU admission rate	10%	• Institute for Health Metrics and Evaluation	• Modelled number of required ICU beds as proportion of required hospital beds
		ICU length of stay	7 days	• NHI Annual Statistical Report 2021	• Average ICU LOS in public hospitals in 2021
		ICU bed day cost	NT$11,243	• Taipei Veterans General Hospital	• Average ICU bed day cost in 2021; includes co-payment
	Severe (cont.)	Proportion of ICU admissions requiring subacute care	50%	• Institute for Health Metrics and Evaluation	• Modelled number of required ICU beds as proportion of required hospital beds
		Subacute length of stay	24 days	• NHI Annual Statistical Report 2021	• Average LOS for all subacute respiratory admissions = 24 days
		Subacute bed day cost	NT$10,243	• Taipei Veterans General Hospital • NHI Annual Statistical Report 2021	• Mid-point between ward and ICU bed day costs, reflecting same ratio as comparable markets; includes co-payment

Exhibit A5: Key direct cost assumptions (continued)

3rd Level	4th/5th Level	Parameter Name	Value	Source	Commentary
Outpatient	Acute	Number of acute outpatient infections	19,732,458	Calculation	• Total infections (~19.8 mn) minus number of hospital admissions
		Number of visits to the ECU per 1,000 infections (~500 reported infections)	1	Taiwan NHI; Australian Institute of Health and Welfare report on the impact of COVID-19 on 2020 emergency department activity	• Taiwanese data triangulated with Australian data; frequency of ED use is roughly equivalent
		Number of ECU visits per year for COVID	20,900	Calculation	• Number of acute outpatient infections multiplied by (~1/1000)
		Cost per Emergency Department visit	NT$4,314	NHI	• Includes cost to NHI (~70%) and co-payment (~30%)
		Proportion of total infections that visit a primary care clinic	3-12%	Journal of Primary Care and Community Health Calculation based on known volumes of OAV prescriptions	• Study of visits to ~1,200 primary care centers across the US in 2020 for treatment of COVID illness; divided by number of infections
		Cost per Clinic visit	NT$1,347	NHI	• Includes cost to NHI (~55%) and co-payment (~45%)
		Proportion of infections prescribed OAV	3.3%	Internal MSD - Taiwan team	• Calculated using known Lagevrio prescription volume and market share
		Number of infections prescribed medication	657,091	Calculation	• Number of acute outpatient infections multiplied by 3.3%

Exhibit A5: Key direct cost assumptions (continued)

3rd Level	4th/5th Level	Parameter Name	Value	Source	Commentary
Outpatient	Chronic	Incidence of Long COVID	5%	• Australian National University Evidence from the COVID-19 Impact Monitoring Survey Series, August 2022	• Taiwan-specific data not available; gives estimate of Long COVID incidence in comparable markets of ~5%; implies ~1m annual cases
				• South Korean Long COVID study published in BMC Infectious Diseases	• Gives further estimate of Long COVID incidence of 5% in comparable market
		Average duration of Long COVID	12 weeks	• World Health Organization	• Globally accepted consensus on duration of Long COVID of 12 weeks
		Average number of clinic visits per Long COVID patient	6	• Calculation	• 1 clinic visit per fortnight over 12-week illness

Exhibit A6: Key indirect cost assumptions

Parameter			Value	Source	Commentary
Age distribution of infections	Infected working-age		67%	• National Centre for High Performance Computing (NCHC) COVID-19 Global Epidemic Map (2021)	• Proportion of cases assumed as proxy for proportion of infections (2021 represents period of more frequent testing / detection) • Similar to Australia and South Korea
	Pediatric carers		21%		
	Elderly		12%		
Cross-cutting assumptions	Acute illness		100%		• Assume all COVID-19 infections experience short-term 'illness' which can be symptomatic or asymptomatic
	Long COVID		5%	• Australian National University Evidence from the COVID-19 Impact Monitoring Survey Series, August 2022	• Estimate of incidence in Australia of 4.7%; implies 700,000 annual cases
	Persistently asymptomatic		25%	• Magnitude of asymptomatic COVID-19 cases throughout the course of infection: A systematic review and meta-analysis (2021)	• March 2021 Systemic Review - 6071 cases, weighted pooled proportion of asymptomatic cases throughout course of infection was 25% (95% CI)
	Detected		44%	• The Institute for Health Metrics and Evaluation (IHME) (released November 18, 2022)	• Calculated based on cases divided by total infections
	Proportion of people who will isolate for fulltime period (5 days)		100%		• Assume 100% adherence to national mandate of 5-day isolation period (if detected and/or symptomatic)
Specific to working-age and elderly	Acute - well enough to work	Proportion of acute infections well enough to work	99.6%	• The Institute for Health Metrics and Evaluation (IHME)	• Modelled based on infection to hospitalization rate for August 2022 – 0.4% • Note: Taiwan has no HITH / home care

Exhibit A6: Key indirect cost assumptions (continued)

Parameter			Value	Source	Commentary
Specific to working-age and elderly	Acute - well enough to work	Proportion of people who can work from home	63%	• Taipei Times – poll of 1,210 employees (2022)	• ~63% of employees said they had experience working from home
		Duration of acute illness	12 days	• Medline (2022)	• 10-14 days for mild to moderate illness
		Average # of days taken as sick leave from work	2.4 days	• Health Awards Survey (2018) via Yahoo • Expedia 'Global Vacation Deprivation Report' (2020)	• In the 2018 Health Awards Survey, 42% of people have taken sick leave within a year, and the average number of days off is 2.4 days • This is 20% less than the ~3 days cited for Australia (and other markets) • According to Expedia's "2020 Global Vacation Deprivation Report", workers around the world took an average of 21.9 days off in 2019, while Taiwan ranked last in the world with only 14 days (30% less)
		Productivity loss on days worked while ill	35%	• European Respiratory Society	• Cross-Sectional study of positive COVID-19 diagnosis. 3 months after discharge or resolution of acute disease. Uses WPAI. 35% work impairment for non-hospitalized and 10% for hospitalized, 20% overall; make conservative estimate that long-COVID symptoms cause same level of productivity loss as when working with acute illness.
	Acute – too ill to work	Duration of acute debilitating (inpatient) illness	14.35 days	• See direct cost length of stay assumptions	• 11 days on ward (95%) and (5% severe) 18 ICU + Ward stepdown + 12 subacute (50% of severe for 24 days) = weighted average of ~11.95 days. • + Recovery time at home (off work) assumed to be ~2.4 days (same as outpatient) = ~14.35 days
	Long COVID – well enough to work	Average # of days taken as sick leave from work	7.2 days		• Based on same logic for acute illness, the number of days taken as sick leave has been reduced by 20% compared to the assumption made for Australia (~9 days / 10% of long COVID illness duration)

Exhibit A6: Key indirect cost assumptions (continued)

Parameter		Value	Source	Commentary
Specific to elderly	Proportion of elderly receiving / requiring care from a non-health professional working-age adult	98.5%	• National Development Council • National Statistics Survey (2020)	• ~1.5% (52,244) of total 65+ population live in institutions - nursing home and long-term care centers and therefore don't require full-time care form working-age adult while ill • Compared to 5% in Australia
	Proportion of elderly providing childcare while parents work	20%	• Impact of Caring for Grandchildren on the Health of Grandparents in Taiwan (2013)	• 79.7% of surveyed grandparents were non caregiver and the remaining 20.3% caregivers in MG, SG or NR households
	Proportion of elderly participating in the workforce	10%	• National Statistics Republic (2022)	• Average for 2022
Specific to pediatric	Average duration of acute illness	6 days	• Illness duration and symptom profile in symptomatic UK school-aged children tested for SARS-CoV-2 (2021)	• Mean duration of illness is 5-7 days • Assumed to be applicable across all markets (same virus)
	Average productive loss due to providing care for a child with acute mild / outpatient illness	25%	• Macquarie University (2021)	• Australian study of lockdown care coverage used as a p proxy and applicable across markets due to limited availability of data • Survey respondents spent 10.7 hours per week home-schooling (including feeding meals etc.) children, and one or more other adults spent an average of 3.4 hours with the same child = 14.1 hours total (2 hours on average per day)

South Korea

Exhibit A7: Key overall assumptions

3rd Level	4th/5th Level	Value	Source	Commentary
Total	Total COVID-19 infections	51,740,000	World Bank (population data) The Institute for Health Metrics and Evaluation (IHME) (released November 18, 2022)	• Assume a rate of 1 infection per person per year (average of last 6 months in South Korea)
	Total COVID-19 cases	10,348,000	The Institute for Health Metrics and Evaluation (IHME) (released November 18, 2022)	• Assume case detection rate continues from Q4 2022 – 20%
	Total COVID-19 deaths	15,522	The Institute for Health Metrics and Evaluation (IHME) (released November 18, 2022)	• Assume infection fatality rate continues from Q4 2022 – 0.03%

Exhibit A8: Key direct cost assumptions

3rd Level	4th/5th Level	Parameter Name	Value	Source	Commentary
Inpatient	Acute	Hospitalization rate	0.3%	Institute for Health Metrics and Evaluation	• Reflects infection and hospitalization rates in Q3-4 2022
		Number of admissions	155,220	Calculation	• Total infections (~51.7m) multiplied by hospitalization rate
	Moderate	Ward admission rate	90%	Institute for Health Metrics and Evaluation	• IHME-modelled number of required hospital beds versus number of required ICU beds
		Ward length of stay	10 days	South Korea National Assembly Budget Office	• Average COVID LOS Q1-2 2020; revised down from 13 to account for ICU admissions and variant severity
		Ward bed day cost	₩265,909	South Korea National Assembly Budget Office	• Total cost per inpatient day (borne by NHI and government under infectious diseases control and prev. act)
	Severe	ICU admission rate	10%	Institute for Health Metrics and Evaluation	• Modelled number of required ICU beds as proportion of required hospital beds
		ICU length of stay	7.5 days	Hospital Insurance Review and Assessment Service report	• Average ICU LOS at 17 university hospitals 7.43 days
		ICU bed day cost	₩650,000	National Health Insurance Service	• Total daily inpatient treatment costs per severe COVID cases ₩650,000

Exhibit A8: Key direct cost assumptions (continued)

3rd Level	4th/5th Level	Parameter Name	Value	Source	Commentary
Inpatient	Severe (cont.)	Proportion of ICU admissions requiring subacute care	50%	Annals of Intensive Care, published journal article	• Modelled number of required ICU beds as proportion of required hospital beds
		Subacute length of stay	20 days	Calculation (2 x 10 days)	• Ratio of rehabilitation to ward LOS in comparable markets is ~2
		Subacute bed day cost	₩320,000	Calculation (1.2 x ₩ 266,000)	• Ratio of rehabilitation to ward LOS in comparable markets is ~1.2

Exhibit A8: Key direct cost assumptions (continued)

3rd Level	4th/5th Level	Parameter Name	Value	Source	Commentary
Outpatient	Acute	Number of acute outpatient infections	51,584,780	Calculation	• Total infections (~51.74mn) minus number of hospital admissions
		Number of visits to the ECU per 1,000 infections (~500 reported infections)	1	Australian Institute of Health and Welfare report on the impact of COVID-19 on 2020 emergency department activity	• Limited RWE; figure from comparable population and health system can be applied
		Number of Emergency Department visits per year for COVID	54,637	Calculation	• Number of acute outpatient infections multiplied by (~1/1000)
		Cost per Emergency Department visit	₩204,752	2021 Annual survey of Emergency Medical Service Users (MOHW)	
		Proportion of total infections that visit a primary care clinic	2%	Journal of Primary Care and Community Health	• Study of visits to ~1,200 primary care centers across the US in 2020 for treatment of COVID illness; divided by number of infections
		Cost per Clinic visit	₩16,970	National Health Insurance Corporation report on COVID-19 costs, 2020-22	• Cost of a basic COVID-19 consultation, excluding testing costs
		Proportion of infections prescribed OAV	1.9%	Internal MSD – South Korea team Institute for Health Metrics and Evaluation	• Calculated using known 2022 OAV prescription volumes and infections
		Number of infections prescribed medication p. a.	959,477	Calculation	• By comparison, 852,000 OAV prescriptions have been written in 2022

Exhibit A8: Key direct cost assumptions (continued)

3rd Level	4th/5th Level	Parameter Name	Value	Source	Commentary
Outpatient	Chronic	Incidence of Long COVID	5%	South Korean Long COVID study published in BMC Infectious Diseases	• Gives estimate of Long COVID incidence of 5%
		Average duration of Long COVID	≥12 weeks	World Health Organization	• Globally accepted consensus on duration of Long COVID being symptoms that persist ≥12 weeks
		Average number of clinic visits per Long COVID patient	6	Calculation	• 1 clinic visit per fortnight over 12-week illness

Exhibit A9: Key indirect cost assumptions

Parameter			Value	Source	Commentary
Age distribution of infections	Infected working-age		57%	• South Korea Disease Control and Prevention Agency (KDCA)	• Based on age distribution of cumulative cases until November 22, 2022 which are used as a proxy for infection proportions
	Pediatric carers		24%		
	Elderly		19%		
Cross-cutting assumptions	Acute illness		100%		• Assume all COVID-19 infections experience short-term 'illness' which can symptomatic or asymptomatic
	Long COVID		5%	• Australian National University Evidence from the COVID-19 Impact Monitoring Survey Series, August 2022	• Estimate of incidence in Australia of 4.7% • Consistent across multiple global sources (with estimates ranging from 5-50%)
	Persistently asymptomatic		25%	• Magnitude of asymptomatic COVID-19 cases throughout the course of infection: A systematic review and meta-analysis (2021)	• March 2021 Systemic Review - 6071 cases, weighted pooled proportion of asymptomatic cases throughout course of infection was 25% (95% CI)
	Detected		20%	• The Institute for Health Metrics and Evaluation (IHME) (released November 18, 2022)	• Calculated based on cases divided by total infections for December 2022
	Proportion of people who will isolate for full time period (7 days)		100%		• Assume 100% adherence to national mandate of 7 day isolation period (if detected and/or symptomatic)
Specific to working-age and elderly	Acute - well enough to work	Proportion of acute infections well enough to work	99.7%	• The Institute for Health Metrics and Evaluation (IHME)	• Proportion of people who are outpatients used as proxy • Based on Q4 2022 hospitalization rate; no inclusion of HITH as community service centers have all closed down

Exhibit A9: Key indirect cost assumptions (continued)

Parameter			Value	Source	Commentary
Specific to working-age and elderly	Acute - well enough to work	Proportion of people who can work from home	32%	• Statista (combination of sources) (2021)	• Around half the value for Taiwan and Australia • Other sources quote 4-12% (even lower) • Aligned to culture of small business in South Korea
		Duration of acute illness	12 days	• Medline (2022)	• 10-14 days for mild to moderate illness; assumed consistent across all markets
		Average # of days taken as sick leave from work	2 days	• Hankyoreh 'South Koreans take the fewest number of sick days among OECD markets' (November 2020)	• In a survey conducted by OECD, South Korea workers reported just 2 days taken off sick in a year. This was lowest among member OECD markets (e.g., in US and UK it is 4 and 4.4 days respectively) • The assumption used for Australia is 3 and Taiwan is 2.4
		Productivity loss on days worked while ill	35%	• European Respiratory Society	• Cross-Sectional study of positive COVID-19 diagnosis. 3 months after discharge or resolution of acute disease. Uses WPAI. 35% work impairment for non-hospitalized and 10% for hospitalized, 20% overall; make conservative estimate that long-COVID symptoms cause same level of productivity loss as when working with acute illness.
	Acute – too ill to work	Duration of acute debilitating (inpatient) illness	12.88 days	• See direct cost length of stay assumption	• 10 days on ward (95%) and (5% severe) 17.5 ICU + Ward stepdown + 10 subacute (50% of severe for 20 days) = weighted average of ~10.875 days • + Recovery time of assumed ~2 days (same as outpatient) = ~12.88 days
	Long COVID – well enough to work	Average # of days taken as sick leave from work	6 days	• European Respiratory Society	• 2021 Cross Section study of patients at 3 months who had missed 10% of work time due to health if non-hospitalized. • Reduce to 2/3 of 10% of working days, proportional to the assumption for acute illness.

Exhibit A9: Key indirect cost assumptions (continued)

Parameter		Value	Source	Commentary
Specific to elderly	Proportion of elderly receiving / requiring care from a non-health professional working-age adult	90%	• Medical World News – OECD health statistics analysis (2022)	• Long-term care recipients refer to those aged 65 or older who receive paid long-term care services (facility services or home-based services) in South Korea. • In home long-term care 7.4% and in facility 2.6% (total 10%) which was lower than OECD average (in home 10.4%, facility 3.6%)
	Proportion of elderly providing childcare while parents work	30%	• Longitudinal patterns of grandchild care (2022)	• Approximately 30% of South Korean grandparents who have adult children going to their places of employment have provided grandchild care at some point in their lives, and South Korean grandparents who provide care for their grandchildren report doing so for an average of 52 h per week
	Proportion of elderly participating in the workforce	19%	• Wise Person Article (2021) • KOSIS (2022)	• By job status, 54.1% of workers aged 65 or older were temporary workers, 28.1% were full-time workers, and 17.7% were daily workers. • 60+ in November 2022 was 6,189 of 28,421 thousands employed persons • Total population 60+ is ~15.4 million • Calculation = (0.281*6.19 million + 0.25*0.719*6.19 million) / 15.4 million = ~19% participation rate (compared to 10 to 15% in Australia and Taiwan)
Specific to pediatric	Average duration of acute illness	6 days	• Illness duration and symptom profile in symptomatic UK school-aged children tested for SARS-CoV-2 (2021)	• Mean duration of illness is 5-7 days • Assumed to be applicable across all markets (same virus)
	Average productive loss due to providing care for a child with acute mild / outpatient illness	50%	• Macquarie University (2021)	• Australian study of lockdown care coverage used as a proxy and applicable across markets due to limited availability of data • Survey respondents spent 10.7 hours per week home-schooling (including feeding meals etc.) children, and one or more other adults spent an average of 3.4 hours with the same child = 14.1 hours total (2 hours on average per day) • Assume double care coverage is required for sick child

Singapore

Exhibit A10: Key overall assumptions

3rd Level	4th/5th Level	Value	Source	Commentary
Total	Total COVID-19 infections	3,272,126	The Institute for Health Metrics and Evaluation (IHME) (released December 16, 2022)	• ~Q4 2022 annualized • Note: IFR ratio is 0.008%. IHME corrects to ensure reported deaths reflect actual deaths due to COVID-19
	Total COVID-19 cases (detected)	1,161,709		
	Total COVID-19 deaths	263		

Exhibit A11: Key direct cost assumptions

3rd Level	4th/5th Level	Parameter Name	Value	Source	Commentary
Inpatient		Hospitalization rate	0.25%	Institute for Health Metrics and Evaluation	• Rolling average hospitalization rate for Q4 2022
		Number of admissions	8,180	Calculation	• Total infections (~3.27m) multiplied by hospitalization rate
	Moderate	Ward admission rate	90%	Institute for Health Metrics and Evaluation	• IHME-modelled number of required hospital beds versus number of required ICU beds
		Ward length of stay	5.7 days	SingHealth	• Average length of stay of 177,000 admissions to SingHealth, 2019-20
		Ward bed day cost	$1,019	• Sample of 8 Singapore hospitals • MoH Inpatient Doctor Attendance benchmark • SingHealth	• Daily costs including ~$470 accommodation, ~$300 medical and nursing care costs, ~$245 pathology
	Severe	ICU admission rate	10%	Institute for Health Metrics and Evaluation	• Modelled number of required ICU beds as proportion of required hospital beds
		ICU length of stay	8 days	MoH	• Midpoint of LOS estimates for ICU stay with Omicron variant
		ICU bed day cost	$2,273	• MoH • The Straits Times	• MoH estimates the total cost of an ICU stay at $25,000 for a Delta case with average LOS of 11 days = $2,273/day

Exhibit A11: Key direct cost assumptions (continued)

3rd Level	4th/5th Level	Parameter Name	Value	Source	Commentary
Inpatient	Severe (cont.)	Proportion of ICU admissions requiring subacute care	50%	• Annals of Intensive Care • British Medical Journal	• 45-50% of COVID patients admitted to ICU required rehabilitation or subacute care
		Subacute length of stay	12 days	Proceedings of Singapore Healthcare	• 12-day duration of COVID-specific inpatient rehabilitation
		Subacute bed day cost	$1,119	• SingHealth • MoH	• ~$820 unsubsidized accommodation cost, ~$300 medical and nursing care costs

Exhibit A11: Key direct cost assumptions (continued)

3rd Level	4th/5th Level	Parameter Name	Value	Source	Commentary
Outpatient	Acute	Number of acute outpatient infections	3,263,946	Calculation	• Total infections (~3.3mn) minus number of hospital admissions
		Proportion of total infections that visit an Emergency Department	0.1%	• COVID Journal study of attendances to SGH in 2019-20 • Australian Institute of Health and Welfare	• Singaporean data triangulated with Australian data
		Number of ED visits per year for COVID	3,457	Calculation	• Number of acute outpatient infections multiplied by 0.1%
		Cost per Emergency Department visit	$120	• SingHealth • The Straits Times	• Emergency department attendance fees of $120-$140
		Proportion of infections prescribed OAV	0.3%	• MoH • The Straits Times	• ~3,200 prescriptions made in first ~3 months of 2022, annualized and divided by number of annual infections
		Number of infections prescribed medication	10,000	Calculation	• ~3,200 prescriptions made in first ~3 months of 2022, annualized
		Number of GP visits	~60,000	Calculation	• Assumption that 1 in 6 GP visits for COVID results in an OAV prescription
		Cost per GP visit	SGD 62	SingHealth	• Full/unsubsidized cost of a primary care visit

Exhibit A11: Key direct cost assumptions (continued)

3rd Level	4th/5th Level	Parameter Name	Value	Source	Commentary
Outpatient	Chronic	Incidence of Long COVID	5%	Singapore National Centre for Infectious Diseases	• Estimates incidence of long COVID to be ~5% among vaccinated population and ~10% among unvaccinated population
		Average duration of Long COVID	12 weeks	World Health Organization	• Globally accepted consensus on duration of Long COVID of 12 weeks
		Average number of clinic visits per Long COVID patient	6	Calculation	• 1 clinic visit per fortnight over 12-week illness

Exhibit A12: Key indirect cost assumptions

Parameter		Value	Source	Commentary
Age distribution of infections	Working-age	64%	• Department of Statistics Singapore – Singapore Residents By Age Group, Ethnic Group and Sex (last updated 27 Sep 2022)	• Assume mirrors population age demographics
	Pediatric carers	19%		
	Elderly	17%		
Cross-cutting assumptions	Acute illness	100%		• Assume all COVID-19 infections experience short-term 'illness' which can be symptomatic or asymptomatic
	Long COVID – for working-age population	5%	• Australian National University Evidence from the COVID-19 Impact Monitoring Survey Series, August 2022	• Estimate of incidence in Australia of 4.7%; implies 700,000 annual cases
	Detected	36%	• The Institute for Health Metrics and Evaluation (IHME) (released December 16, 2022)	• Calculated based on cases divided by total infections for comparable timeframe as infections assumption
	Proportion of people who will isolate for required time period	100%		• Assume 100% adherence to guidelines for COVID-19 self-isolation
	Weighted average length of self-isolation	6.1 days	• Covid.gov.sg – Living with COVID-19	• As per protocol 2 – self-isolation of 72 hours, followed by continued self-isolation until ART returns negative OR until Day 7 (for vaccinated and children <12yo) OR until Day 14 (for unvaccinated / partially vaccinated) • Weighted average length of self-isolation calculated based on assumptions of: - 80% RAT positive at Day 3 with a reduction in % of RAT positive per day of subsequent isolation - 83% of population being fully vaccinated

Exhibit A12: Key indirect cost assumptions (continued)

Parameter			Value	Source	Commentary
Specific to working-age and elderly	Acute - well enough to work	Proportion of acute infections well enough to work	99.7%	• The Institute for Health Metrics and Evaluation (IHME)	• Modelled based on infection to hospitalization rate – assumes well enough to work if not hospitalized
		Proportion of people who can work from home	80%	• Singapore Business Review	• "8 in 10 Singapore employers allow their staff to work from home"
		Duration of acute illness	12 days	• Medline (2022)	• 10-14 days for mild to moderate illness
		Average number of days too ill to work / fully taken off work with COVID-19	3 days	• The Straits Times (2013) and Channel News Asia (2022)	• "Employees use up, on average, only about four days of their outpatient sick leave" but "68% did not take any leave for 12 months" • Assumes not all sick leave would typically be used in one illness, but residents may be more likely to take sick leave for COVID-19 • 3 days of 0% work (e.g. sick leave taken and/or too sick to work at all) assumed for each acute COVID-19 infection – in line with Australia
		Productivity loss on days worked while ill	35%	• European Respiratory Society	• Cross-Sectional study of positive COVID-19 diagnosis. 3 months after discharge or resolution of acute disease. Uses WPAI. 35% work impairment for non-hospitalized and 10% for hospitalized, 20% overall; make conservative estimate that long-COVID symptoms cause same level of productivity loss as when working with acute illness.
		Median monthly earnings	$5,070	• Ministry of Manpower	• Median Gross Monthly Income 2022
	Acute – too ill to work	Duration of acute debilitating (inpatient) illness	10.1 days	• See direct cost length of stay assumptions	• Weighted average LOS from direct model: 7.1 days • + Recovery time at home (off work) assumed to be ~3 days (same as outpatient)
	Long COVID – well enough to work	Average # of days taken as sick leave from work	9 days	• European Respiratory Society	• 2021 Cross Sectional study of patients at 3 months who had missed 10% of work time due to health if non-hospitalized

Exhibit A12: Key indirect cost assumptions (continued)

Parameter		Value	Source	Commentary
Specific to working-age and elderly	Proportion of elderly receiving / requiring care from a working-age adult who is not employed as their carer	70%	• Ministry of Social and Family Development Aging Families in Singapore 2010-2020; International Psychogeriatrics (Ha et al, 2018)	• 34% of households have at least one member >65yo; one in five households employs FDWs and nearly 50% of familial caregivers engage FDWs specifically to care for frail seniors • Assume FDWs in 10% of households (50% of one in five) are in households with elderly - ~30% of elderly are cared for by FDWs - Remaining 70% require care from a working-age adult who is not employed as their carer
	Proportion of elderly providing childcare while parents work	25%	• Health Promotion Board (2012)	• One in four rely on grandparents as main caregiver. 35% of seniors over the age of 55 look after their grandchildren on a regular basis.
	Proportion of elderly participating in the workforce	27%	• MRSD Labour Force report (2021)	• Participation rate is 33% for >65yo. ~66% of >65yo are full time. Adjust 33% down by 5.5% to account for part time work
	Median monthly income of elderly	$2,543	• MRSD Labour Force report (2021)	• Median monthly earnings for >60yo
Specific to pediatric	Average duration of acute illness	6 days	• Illness duration and symptom profile in symptomatic UK school-aged children tested for SARS-CoV-2 (2021)	• Mean duration of illness is 5-7 days • Assumed to be applicable across all markets (same virus)
	Average productive loss due to providing care for a child with acute mild / outpatient illness	25%	• Macquarie University (2021)	• Australian study of lockdown care coverage used as a proxy and applicable across markets due to limited availability of data • Survey respondents spent 10.7 hours per week home-schooling (including feeding meals etc.) children, and one or more other adults spent an average of 3.4 hours with the same child = 14.1 hours total (2 hours on average per day)

Hong Kong

Exhibit A13: Key overall assumptions

3rd Level	4th/5th Level	Value	Source	Commentary
Total	Total COVID-19 infections	8,676,159	The Institute for Health Metrics and Evaluation (IHME) (released December 16, 2022)	• ~Q4 2022 annualized • Note: IFR ratio is 0.04%. IHME corrects to ensure reported deaths reflect actual deaths due to COVID-19
	Total COVID-19 cases (detected)	2,867,629		
	Total COVID-19 deaths	3,373		

Exhibit A14: Key direct cost assumptions

3rd Level	4th/5th Level	Parameter Name	Value	Source	Commentary
Inpatient		Hospitalization rate	0.41%	Institute for Health Metrics and Evaluation	• Rolling average hospitalization rate for Q4 2022
		Number of admissions	35,882	Calculation	• Total infections (~8.68mn) multiplied by hospitalization rate
	Moderate	Ward admission rate	91%	Institute for Health Metrics and Evaluation	• IHME-modelled number of required hospital beds versus number of required ICU beds
		Ward length of stay	6.4 days	Hong Kong Hospital Authority	• Average length of stay of 6.4 days for inpatients of general specialties over 2021-2022
		Ward bed day cost	HKD 5,100	Hong Kong Hospital Authority	• Daily un-subsidized cost for inpatient (general hospitals) – cost is all inclusive
	Severe	ICU admission rate	9%	Institute for Health Metrics and Evaluation	• Modelled number of required ICU beds as proportion of required hospital beds
		ICU length of stay	5 days	Journal of Emergency and Critical Care Medicine Queen Elizabeth Hospital, Hong Kong	• Mean ICU length of stay – assessment of 8,037 records over an 8 year period
		ICU bed day cost	24,000	Hong Kong Hospital Authority	• Daily un-subsidized cost for intensive care ward/ unit – cost is all inclusive

Exhibit A14: Key direct cost assumptions (continued)

3rd Level	4th/5th Level	Parameter Name	Value	Source	Commentary
Inpatient	Severe (cont.)	Proportion of ICU admissions requiring subacute care	50%	Annals of Intensive Care British Medical Journal	• 45-50% of COVID patients admitted to ICU required rehabilitation or subacute care
		Subacute length of stay	17.6 days	Hong Kong Hospital Authority	• Average length of stay for public inpatient rehabilitation services over a one year period
		Subacute bed day cost	HKD 6,000	Australian Independent Hospital Pricing Authority	• Hospital pricing authority data form comparable health system (Australian independent hospital pricing authority) indicates subacute bed day costs are approximately 1.2 times ward bed day costs

Exhibit A14: Key direct cost assumptions (continued)

3rd Level	4th/5th Level	Parameter Name	Value	Source	Commentary
Outpatient	Acute	Number of acute outpatient infections	8,640,277	Calculation	• Total infections (~8.68mn) minus number of hospital admissions
		Proportion of total infections that visit an Emergency Department	0.1%	Institute for Health Metrics and Evaluation Australian Institute of Health and Welfare	• Very limited data for Hong Kong; assumption based on triangulation of two sources in Australia
		Number of ED visits per year for COVID	9,151	Calculation	• Number of acute outpatient infections multiplied by 0.1%
		Cost per Emergency Department visit	HKD 1,230	Hong Kong Hospital Authority	• Full/un-subsidized cost per accident and emergency attendance
		Proportion of infections prescribed OAV	3.4%	Hong Kong Legislative Council	• Known ~300k prescriptions in 2022, divided by number of annual infections (~8.68mn)
		Proportion of total infections that visit a GP	~10%	Hong Kong Legislative Council Calculation based on known volumes of OAV prescriptions	• Assumes approximately 1 in 3 primary care visits for COVID results in an OAV prescription
		Cost per GP visit	HKD 445	Hong Kong Hospital Authority	• Full/unsubsidized cost per primary care visit
		Number of infections prescribed medication	293,769	Calculation	• Number of outpatient infections (~8.64mn) multiplied by the proportion of infections prescribed OAV (3.4%)

Exhibit A14: Key direct cost assumptions (continued)

3rd Level	4th/5th Level	Parameter Name	Value	Source	Commentary
Outpatient	Chronic	Incidence of Long COVID	5%	National Centre for Infectious Diseases	• Estimates incidence of long COVID to be ~5% among vaccinated population and ~10% among unvaccinated population
		Average duration of Long COVID	12 weeks	World Health Organization	• Globally accepted consensus on duration of Long COVID of 12 weeks
		Average number of clinic visits per Long COVID patient	6	Calculation	• Very limited data; 1 clinic visit per fortnight over 12-week illness

Exhibit A15: Key indirect cost assumptions

Parameter		Value	Source	Commentary
Age distribution of infections	Working-age	61%	• Statistics on 5th Wave of COVID-19 – Centre for Health Protection of the Department of Health, and the Hospital Authority	• Time period: 31 Dec 2021 to 29 Jan 2023
	Pediatric carers	13%		
	Elderly	25%		
Cross-cutting assumptions	Acute illness	100%		• Assume all COVID-19 infections experience short-term 'illness' which can be symptomatic or asymptomatic
	Long COVID – for working-age population	5%	• Australian National University Evidence from the COVID-19 Impact Monitoring Survey Series, August 2022	• Estimate of incidence in Australia of 4.7%; implies 700,000 annual cases
	Detected	33%	• The Institute for Health Metrics and Evaluation (IHME) (released December 16, 2022)	• Calculated based on cases divided by total infections for comparable timeframe as infections assumption
	Proportion of people who isolate while symptomatic	32%	• Bupa Hong Kong – Wellness@Work Research (2016)	• 68% of respondents who were sick in the past year still went into work while ill

Exhibit A15: Key indirect cost assumptions (continued)

Parameter			Value	Source	Commentary
Specific to working-age and elderly	Acute - well enough to work	Proportion of acute infections well enough to work	99.6%	• The Institute for Health Metrics and Evaluation (IHME)	• Modelled based on infection to hospitalization rate – assumes well enough to work if not hospitalized
		Proportion of people who can work from home	45%	• South China Morning Post (2022)	• "Only 45 per cent have that option to work from home"
		Duration of acute illness	12 days	• Medline (2022)	• 10-14 days for mild to moderate illness
		Average number of days too ill to work / fully taken off work with COVID-19	3 days	• The Straits Times (2013) and Channel News Asia (2022) – extrapolated from Singapore sources	• "Employees use up, on average, only about four days of their outpatient sick leave" but "68% did not take any leave for 12 months" • Assumes not all sick leave would typically be used in one illness, but residents may be more likely to take sick leave for COVID-19 • 3 days of 0% work (e.g. sick leave taken and/or too sick to work at all) assumed for each acute COVID-19 infection – in line with Australia's model also
		Productivity loss on days worked while ill	35%	• European Respiratory Society	• Cross-Sectional study of positive COVID-19 diagnosis. 3 months after discharge or resolution of acute disease. Uses WPAI. 35% work impairment for non-hospitalized and 10% for hospitalized, 20% overall; make conservative estimate that long-COVID symptoms cause same level of productivity loss as when working with acute illness.
		Median monthly earnings	$18,700	• Census and Statistics Department	• Median monthly wage May-Jun 2021
	Acute – too ill to work	Duration of acute debilitating (inpatient) illness	10.6 days	• See direct cost length of stay assumptions	• Weighted average LOS from direct model: 7.6 days • + Recovery time at home (off work) assumed to be ~3 days (same as outpatient)
	Long COVID – well enough to work	Average # of days taken as sick leave from work	9 days	• European Respiratory Society	• 2021 Cross Sectional study of patients at 3 months who had missed 10% of work time due to health if non-hospitalized

Exhibit A15: Key indirect cost assumptions (continued)

Parameter		Value	Source	Commentary
Specific to working-age and elderly	Proportion of elderly receiving / requiring care from a working-age adult who is not employed as their carer	85%	• Asian Education and Development Studies (Lam et al, 2021) • Research Office Legislative Council Secretariat – Research Brief 2016-2017	• 6.8% of elders institutionalized – 93.2% are not • Of those 93.2%, 9% have Foreign Domestic Workers who can care for them
	Proportion of elderly providing childcare while parents work	33%	• Environmental Research and Public Health (Chen et al, 2022)	• One in three parents in Hong Kong reported that their parents had helped them raise children; 25% of families received intensive childcare from parents, who were the principal child caregivers during the daytime • Assume 33% care for on average 2 days a week
	Proportion of elderly participating in the workforce	23%	• Census and Statistics Department • Research Office Legislative Council Secretariat – Research Brief 2016-2017	• Participation rate for >=65 years old is 13.8% (Oct-Dec 2022) • Participation rate for 60-64 years old is 45.5% • Assumption of 23% of 60+ years old participating in labor force based on weighted average as per population age demographics
	Median monthly income of elderly	$16,904	• Paylab	
Specific to pediatric	Average duration of acute illness	6 days	• Illness duration and symptom profile in symptomatic UK school-aged children tested for SARS-CoV-2 (2021)	• Mean duration of illness is 5-7 days • Assumed to be applicable across all markets (same virus)
	Average productive loss due to providing care for a child with acute mild / outpatient illness	25%	• Macquarie University (2021)	• Australian study of lockdown care coverage used as a p proxy and applicable across markets due to limited availability of data • Survey respondents spent 10.7 hours per week home-schooling (including feeding meals etc.) children, and one or more other adults spent an average of 3.4 hours with the same child = 14.1 hours total (2 hours on average per day)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