Mortality during the COVID-19 Pandemic in Australia

Know C-19 Initiative

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Exec Summary

The COVID-19 pandemic has had a profound impact on global health and well-being and exacerbated pre-existing inequities. Global life expectancy declined for the first time in the 70 years for which there have been global estimates. Economically, the global impact was estimated at $3.3 trillion USD in 2020. Australia's response to COVID-19 offers crucial lessons for future pandemic prevention, preparedness and response (PPPR).

The full scale of the global mortality impact is reflected in excess mortality estimates, with the model from The Economist indicating approximately 27 million deaths globally (range: 19-36 million) by mid-2024. The pandemic burden continues, with an estimated 3.5 million excess deaths occurring in the most recent 12 months of this modelling period.

This report aims to evaluate patterns of excess mortality, the difference between observed and expected deaths, in Australia and comparable countries and analyse trends according to two distinct phases of the public health response. Through our comprehensive analysis, we found that Australia's approach resulted in far lower loss of life than many other developed countries. The estimated total excess between January 2020 and November 2024 is 31,000 (17,000-44,000) lives. If Australia had experienced the same mortality rates as the United Kingdom or United States, 55,000 more lives would have been lost between 2020 and 2023 than Australia experienced in that time.

In 2020-2021, countries, including Australia that implemented swift public health and social measures (PHSM) such as border closures, targeted lockdowns, physical distancing and comprehensive testing, tracing and isolation (TTI) not only limited COVID-19 transmission but also reduced deaths from influenza and other causes. This success was particularly striking when compared to countries like the United States and United Kingdom, which had been ranked higher in the 2019 Global Health Security Index prior to the pandemic yet went on to experience significantly higher mortality.

However, Australia's strategic transition from an aggressive suppression strategy to living with COVID with a focus on protection of those at higher risk of death in late 2021 and early 2022 revealed significant challenges. The emergence of the highly transmissible Omicron variant, and its subsequent sub-variants, which continuously evaded the protection of vaccination and past infection, coupled with eased restrictions, led to widespread transmission and substantial excess mortality which continues.

Several factors distinguished successful country-level responses. These elimination / low transmission strategies utilised early border controls, robust testing and contact tracing systems, clear science-based communication, and benefited from high public co-operation. Australia’s geographic isolation provided distinct advantages, but other island nations, such as Japan and Taiwan, built on lessons from previous health emergencies, including the 2003 SARS-1 pandemic to bolster their pandemic responses. By prioritising clean indoor air (ventilation strategies and masks), ensuring continued access to testing and infection management, and maintaining high vaccination coverage, these countries were able to act swiftly and effectively to control transmission, which in turn helped mitigate excess mortality even with reduced PHSM in place.

Five years since the declaration of COVID-19 as a pandemic, Australia continues to experience the ongoing burden impact of COVID-19 on health and economic productivity.

There is a need for continued and better application of sustainable, low-impost public health strategies; (1) continued vaccination (2) breathing clean indoor air through ventilation or masking (3) community-based testing and acting on the result (isolation and/or treatment). There is urgency for continued research and innovation to develop new tools that curb transmission in the face of an evolving virus, long COVID. Beyond COVID-19, the same investment is needed to best protect against future, unknown pathogen threats.

The findings underscore four priorities for future pandemic preparedness (PPPR):

1. **Invest in pandemic preparedness.** The cost of inadequate preparation has been demonstrated in the significant numbers of lives lost. Australia must strengthen its pandemic detection and response capacity through sustained political commitment, international cooperation and reform (pandemic treaty) and investment in public health systems, workforce and infrastructure centred on an independent, transparent and properly resourced Australian Centre for Disease Control that collaborates with leading scientific institutions.
2. **Act swiftly and decisively.** Effective pandemic management requires swift action to contain outbreaks before they become pandemics. During an emergency response, rapid decision-making is required based on available and evolving evidence rather than waiting for complete certainty, with early interventions that apply a precautionary approach consistently producing better mortality outcomes.
3. **Address inequity.** Future pandemic planning must explicitly support and prevent impacts in priority communities and people at higher risk of worse outcomes due to structural disadvantage. Approaches must place communities at the centre, and include tailored health communication, enhancing health care access and appropriate social and economic support measures.
4. **Sustainable responses.** COVID-19 impacts are ongoing, and pandemics have long tails. Building trust through sustained community partnerships and engagement is fundamental. Pandemic fatigue should be actively addressed as the response transitions from the emergency phase, along with mis- and dis-information. Developing integrated surveillance systems that inform communities through timely and transparent data build trust. There is much to gain from "passive controls" that don't require behaviour change, like we do for waterborne infections. This involves implementing and optimising clean indoor air strategies for airborne infections.

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Definitions

Excess Mortality- The difference between observed deaths during a specific period and expected deaths based on historical trends. This is a comprehensive measure that captures both direct COVID-19 deaths and indirect pandemic effects, including undiagnosed COVID-19 cases, and broader mortality impacts.

P-Score- A standardised measure representing excess deaths as a percentage of expected deaths. Calculated as (observed deaths - expected deaths) ÷ expected deaths × 100. A P-Score of 5% indicates that actual deaths were 5% higher than expected. The cumulative P-Score represents this percentage accumulated over time, providing a running total of pandemic impact.

Negative Binomial Model- A statistical approach used to model count data (like deaths) when the variance exceeds the mean (overdispersion). This model is more flexible than simpler approaches like Poisson regression, making it particularly suitable for mortality data with significant natural variation.

Serfling Method- A cyclical regression technique that fits sinusoidal (wave-like) functions to capture seasonal variations in mortality. This method, used by the Australian Bureau of Statistics, models expected deaths by accounting for regular seasonal patterns in mortality.

Mortality Displacement- Also known as the "harvesting effect," this refers to the temporary reduction in mortality following a period of high mortality. Occurs when a significant mortality event (like a severe influenza season) disproportionately affects those who were already vulnerable, resulting in lower-than-expected deaths in subsequent periods.

Test-Trace-Isolate (TTI) Strategies- An integrated public health approach for infectious diseases outbreaks, including COVID-19, combining testing to identify cases, contact investigation (tracing) to find exposed individuals, and isolation of exposed individuals to prevent further transmission.

Age-Standardised Mortality- A mortality rate adjusted to account for differences in age distribution when differences in population age structure make comparisons invalid, by normalising mortality to a standard population.

Calibration Period- The historical timeframe of data used to train statistical models for predicting expected deaths. Different calibration periods (e.g., 2013-2019 versus 2015-2019) can affect excess mortality estimates if they contain different baseline trends or seasonal patterns.

1 Introduction

The COVID-19 pandemic was an unprecedented challenge for public health systems worldwide, resulting in significant mortality and widespread societal disruption. Economically, global GDP was reduced by 3.3% in 2020, a reduction equating to approximately $3.3 trillion USD[1]. The impact of the pandemic resulted in the first yearly decline in global life expectancy since systematic tracking began in 1950[2].

The full death toll of COVID-19 globally has been substantial, with excess mortality models from The Economist estimating approximately 27 million deaths worldwide (certainty range: 19-36 million) by mid-2024. This burden continues to accumulate, with an estimated 3.5 million excess deaths occurring in the most recent twelve-month period of this modelling. These figures demonstrate that the pandemic remains an ongoing public health challenge [3], well after the transition from the emergency phase.

Australia, like other nations, experienced considerable difficulties during this period, including significant loss of human life alongside economic, social, and healthcare system impacts. Beyond the acute impact of the disease, long COVID is an ongoing burden affecting both individual health and economic productivity[4]. The mortality burden was felt disproportionally by Australians who were born overseas, Aboriginal and Torres Strait Islanders and those residing in areas of socioeconomic disadvantage[5].

Effective public health policies rely upon careful planning, implementation, and finally, retrospective learnings from past policies and outcomes. As the pandemic transitions from the acute emergency phase, understanding what worked, what did not work, and why, is vital for improving future pandemic prevention, preparedness and response (PPPR) capabilities.

While reported COVID-19 deaths provide a valuable indicator of the pandemic's direct impact, they significantly underestimate its full mortality burden. Official COVID-19 death counts are limited by testing availability, reporting practices, diagnostic criteria, and attribution methodologies—all of which varied considerably across jurisdictions and over time. Australian Bureau of Statistics (ABS) data suggests that COVID-19 was a contributing factor in many deaths where it wasn't recorded as the primary cause, highlighting the limitations of relying solely on reported COVID-19 mortality figures[6, 7].

1.1 Excess Mortality as a Comprehensive Measure

Excess mortality—the difference between observed deaths during the pandemic and expected deaths based on historical trends—offers a more comprehensive and standardised measure than reported deaths attributed to COVID-19. By comparing observed all-cause mortality to expected mortality under normal conditions, we can better understand the full impact of the pandemic, including its direct and indirect effects.

This approach captures both direct COVID-19 deaths and indirect pandemic effects, including:

- Deaths directly attributed to COVID-19
- Undiagnosed COVID-19
- Post-acute sequalae of COVID (or long COVID), where previous infection increases mortality risks for an extended duration
- Deaths due to system impacts such as delayed access to necessary care.

There are other potential contributors, worldwide TB deaths for instance saw an increase due to the challenges that the pandemic period placed on health systems in low and middle income countries[8].

In Australia, The Actuaries, in their report titled 'How COVID-19 has Affected Mortality in 2020 to 2023' determine that the reasons above explain the vast majority of the excess deaths with limited contribution from causes such as suicide, road accidents, alcohol-induced and vaccine-related deaths[9].

For this report, expected deaths will be those which were likely to have occurred without the COVID-19 pandemic. When observed deaths exceed the expected number, the result is classified as excess deaths; conversely, if observed deaths are lower, it is referred to as negative excess mortality.

The calculation of expected mortality relies on establishing a robust baseline from historical mortality trends. This process is challenging, as it requires the careful selection of an appropriate historical period, is affected by demographic changes such as population ageing and growth and is also affected by long-term improvements in mortality. Additionally, external events like conflicts, severe disease outbreaks, heatwaves, and natural disasters can distort historical data, further complicating baseline calibration.

Excess mortality can also be used to compare outcomes between countries and jurisdictions. However, the different mortality rates inherent to different population age structures and sizes will distort the comparison if not adjusted for. The P-score is a common technique to create directly comparable metrics between countries. Defined as excess deaths divided by expected deaths, the P-score utilises the fact that expected deaths already account for population structures. A P-score of 5% can be interpreted as actual deaths being 5% greater than expected deaths during the period.

1.2 Australia's Pandemic Experience

Australia's initial pandemic response was distinctive and characterised by two phases that reflect changes in the 3 pillars of public health responses: vaccination, public health and social measures (PHSM) and testing, tracing and isolation (TTI). The early phase (2020-21) involved swift and decisive public health responses guided by an "aggressive suppression" strategy that pursued the elimination of community transmission, prior to achieving high rates of primary vaccination (2 doses) in the population. This involved stringent PHSM with international border closures, physical distancing and periods of localised restrictions (lockdowns) coupled with extensive TTI. This strategy was transitioned through a phased plan for reduction of PHSM aligned with vaccination coverage targets (an (National Transition Plan). The rapid emergence of the highly transmissible Omicron variant in November 2021 expedited this transition and precipitated a strategy change. This second or later phase (2022 onwards), called ‘living with COVID-19’ involved managing COVID-19 like other infectious diseases (e.g. non-pandemic influenza) by focusing only on those most at-risk of severe acute COVID-19 through vaccination and antiviral medications, and no focus on community transmission reduction. This involved the cessation of PHSM and TTI with an emphasis on “personal responsibility” for preventive measures. We have conducted a detailed description and analysis of Australia’s pandemic response in Burnet Institute’s submission to the Australian Government’s COVID-19 inquiry (December 2023)[10].

March 11, 2025, marks five years since the World Health Organization declared COVID-19 a pandemic[11]. Whilst the pandemic emergency ended in 2023 the SARS-CoV-2 virus continues to evolve and cause impacts including long COVID and ongoing deaths.

2 Methods

This report aims to evaluate excess mortality patterns in Australia and comparable countries and analyse trends according to two distinct phases of the public health response: early phase (2020-21) and the later phase (2022 onwards). Due to data availability, the report will analyse comparative mortality between countries for the first four years, 2020-2023 inclusive and for Australia from 2020 to November 2024. While mortality represents only one dimension of pandemic impact—with long-term morbidity, economic effects, and social disruption equally important—it remains a fundamental metric for assessing public health interventions and protecting population health. Understanding the mortality impact of these public health strategies across two phases provides valuable insights into their effectiveness and can inform future public health responses and pandemic preparedness.

2.1 Excess Mortality Model Selection

There are numerous estimates of excess mortality for Australia produced by reputable sources such as the ABS, the World Health Organization (WHO), The Economist, the Actuaries Institute, and independent researchers such as Karlinsky and Koback. Each group employs a distinct methodology and calibration period to calculate expected—and therefore excess deaths, resulting in notable variations in their estimates. A summary of the different methods used to estimate excess mortality is in **Table 1**.

As shown in **Figure 1**, the Economist model estimates approximately 8,000 more deaths than the Actuaries Institute and the ABS by the end of 2023.

The ABS, Australia's official statistical agency, utilises the Serfling method to model seasonal baseline mortality. This cyclical regression technique fits sinusoidal functions to capture seasonal variations in deaths and is calibrated using data from 2013 to 2019[12].

The WHO model is calibrated on mortality data from 2015 to 2019 utilising a spline-based function for yearly trend and average monthly temperature to account for seasonal fluctuations. The WHO has not made model predictions beyond 2020 and 2021.

Both The Economist and the estimates provided by Karlinsky and Koback rely on linear regression models, also fitted on 2015-19 data.

Table 1: Summary of count-based methods used to calculate excess deaths.

Agency	Calibration Period	Long term trend	Within year variation
ABS	2013 - 2019	Linear	Cyclical regression (Serfling)
WHO	2015 - 2019	Spline-based	Temperature
The Economist	2015 - 2019	Linear	Month/Week
Karlinsky and Koback	2015 - 2019	Linear with Gaussian Noise	Month/Week
Actuaries Institute	2015 - 2019	Linear on specific cause of death	Week

The Actuaries Institute, through its Mortality Working Group, produces regular excess mortality updates. Their analyses utilise granular cause-specific death data from the ABS that is not publicly available. In late 2023, the Institute began incorporating expected COVID-19 deaths in the expected deaths. This change complicates direct comparisons with models that utilise pre-pandemic data.

Appendix A details the analytical method used to determine the most appropriate model for Australian excess deaths. To summarise, the choice of a count-based modelling method itself did not have a substantial impact on the overall prediction, but the choice of calibration period did. An analysis of the underlying factors contributing to mortality, i.e., population age-group sizes and group-specific mortality rates showed that consistent trends in the data aligned more closely with the slope from the 2013 to 2019 calibration period compared to the models using fewer years. For consistency with the ABS, we have used the Serfling method.

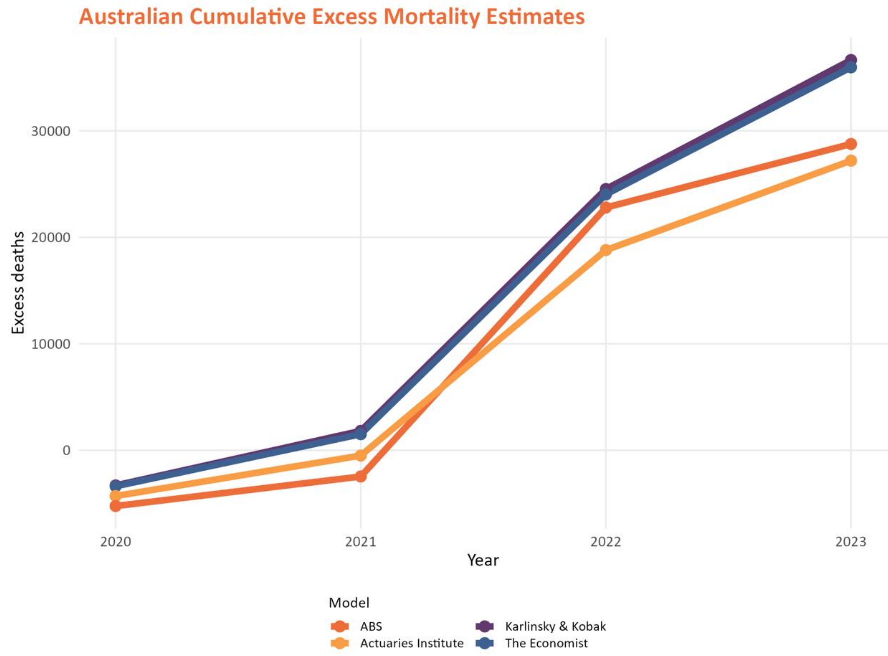

Figure 1: Cumulative excess mortality by 2023 was 8,000 higher in the international count-based models. Data sources: Web report actuals from the Actuary Institutes and ABS. GIT repository code for Karlinsky and Koback and the Economist

3 The mortality burden of COVID in Australia

Using the Serfling model calibrated on 2013-2019 data, we estimate Australia’s excess mortality at 31,000(17,000-44,000) between 2020 and November 2024. This section examines how Australia's public health responses shaped mortality outcomes during distinct phases of the pandemic and identifies key factors that influenced these patterns.

Early Phase (2020-2021)

Australia's initial response to COVID-19, in the “pre-vaccination” phase was characterised by strong PHSM including stringent border controls, comprehensive testing and contact tracing, targeted lockdowns during outbreaks and financial support for those impacted. On 20 March 2020, Australia closed its borders to all non-residents and non-citizens, with returning travellers subject to 14-day supervised quarantine from 28 March 2020.

During this early phase, Australia agreed on and pursued an aggressive suppression or elimination strategy with implementation determined by the states and territories[13]. This approach resulted in minimal community transmission through most of 2020 and early 2021, with localised outbreaks contained through aggressive public health measures.

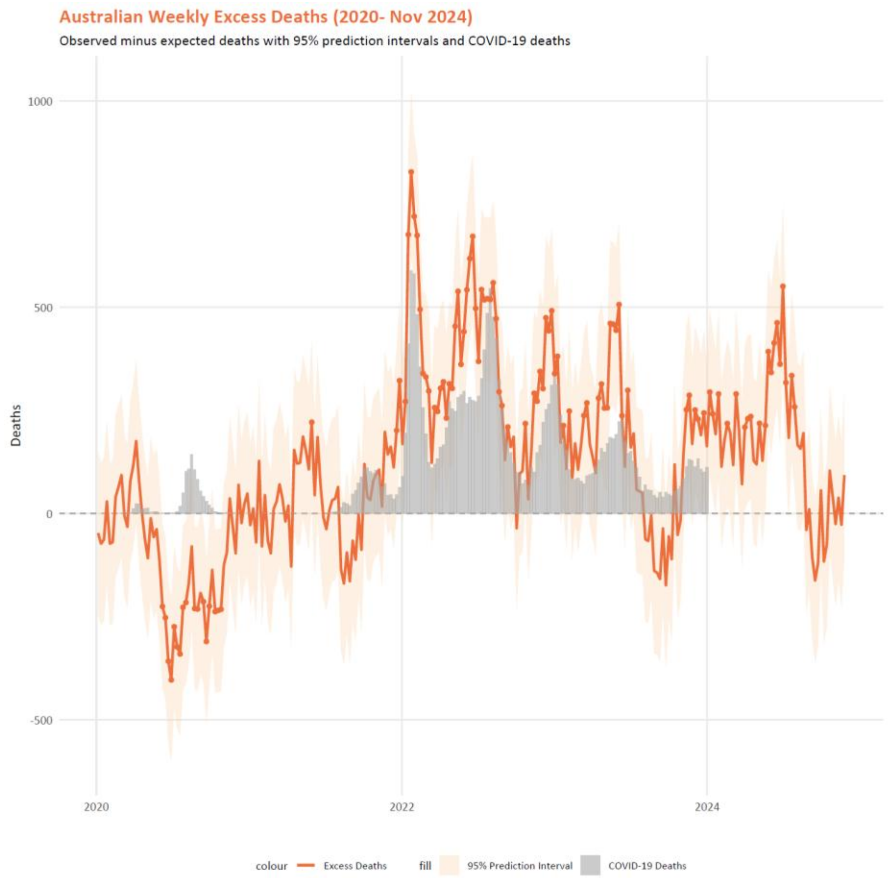

Figure 2: Weekly excess deaths in Australia were consistently above zero for most of 2022 and 2024. COVID attributable weekly deaths are not yet available for 2024. Data sources: Weekly deaths from ABS for 2013&14, 2022&2023 and 11 months of 2024, Short Term Mortality fluctuations 2015-21. Covid deaths from ABS.

As shown in **Figure 2**, Australia experienced negative excess mortality (-3,100) during much of 2020-2021.

The negative excess mortality in 2020 and 2021 was due to several factors, including: reduced respiratory disease mortality: the virtual elimination of seasonal influenza through border closures, physical distancing, and heightened infection prevention and control practices, which significantly reduced typical winter mortality. The 2020 influenza season saw fewer than 50 deaths[14] compared to 953 in 2019[15]. This is more than 90% reduction.

By mid-2021, Australia's pandemic response began a significant transition. On 2 July 2021, the National Cabinet adopted a four-phase plan to reopen Australia, linking reopening milestones to vaccination coverage[16]. This marked a strategic pivot from elimination toward "COVID normal", an approach that would accept some community transmission while relying on vaccination to minimise severe outcomes[17].

Australia's vaccination programme commenced on 22 February 2021, significantly later than countries like the United Kingdom(UK) (8 December 2020) and the United States (US) (14 December 2020). The initial rollout was hampered by supply constraints, with only 8% of the population receiving a second dose by 1 July 2021[18]. The vaccination rate accelerated substantially in the second half of 2021, reaching 80% double-dose coverage among eligible Australians (16+ years) by November 2021.

Later phase (2022-2023)

The first detection of the Omicron variant in late 2021 coincided with Australia's reopening. This marked an inflection point in Australia's pandemic experience. Border restrictions for vaccinated travellers were eased in November 2021, with most domestic restrictions relaxed by December 2021 as states and territories achieved vaccination targets.

The timing of these policy changes, coupled with Omicron's increased transmissibility, led to increased incidence. COVID-19 cases surged from an average of approximately 1,500 daily cases in December 2021 to over 100,000 daily cases by January 2022[19]. Testing infrastructure was overwhelmed, with symptomatic individuals often unable to access either PCR or rapid antigen tests.

As **Figure 3** demonstrates, the cumulative P-score shifted from negative to positive with a sharp rise in 2022 and continued through 2023, although at a reduced rate, with waves of Omicron and subsequent sub variants. The cumulative P Score reached 3.5% by the end of 2023, equating to 23,757 (12,473-33,132) excess deaths. Several factors contributed to this shift:

- With most restrictions removed and national plan to scale-back community-wide public health interventions in combination with a highly transmissible Omicron variant, a large proportion of the population were infected in a short period[16, 20]. While vaccination reduced the case fatality rate, the sheer volume of infections led to significant mortality.
- Despite high overall vaccination rates (95.9% of the population aged 16+ with two doses by April 2022), coverage was uneven across geographic and demographic groups[18].
- Waning immunity became evident, particularly among higher risk populations vaccinated early in the rollout.
- Public health messaging shifted from societal elimination to individual responsibility. Mask mandates were lifted in most settings, isolation requirements for positive cases were progressively reduced from 14 days to 5 days by September 2022, and isolation requirements were eventually removed entirely by October 2023.
- The reopening of borders and relaxation of measures saw the return of influenza and other respiratory pathogens, creating additional mortality pressure which had not been present in 2020 and 2021.

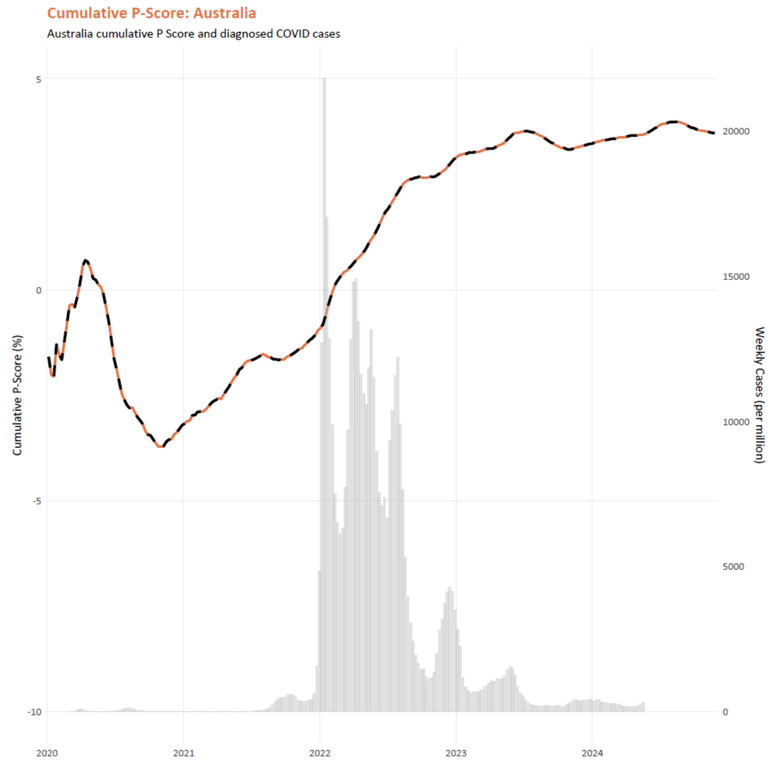

Figure 3: Monthly cumulative P-Score (%, line) compared to weekly cases (per million) Australia, 2020-2024 Data sources: Weekly deaths from ABS for 2013&14, 2022&24, Short Term Mortality fluctuations 2015-21. Covid cases from Our World in Data.

The pandemic's impact has not been distributed equally across Australian society with rates of vaccination and mortality showing significant disparities among at-risk populations[5]. The rates of vaccination following a second dose are considerably lower for Australian's born overseas and those residing in areas in the lowest socioeconomic quintile[21].

People born overseas experienced 1.4 times the mortality rate of Australian-born residents, highlighting potential barriers to healthcare access, information, and preventive measures among culturally and linguistically diverse communities. Socioeconomic status emerged as an even stronger determinant of risk, with Australians in the lowest socioeconomic quintile suffering 2.8 times the COVID-19 mortality rate of those in the highest quintile[5]. Aboriginal and Torres Strait Islander peoples also bore a disproportionate burden, with 1.8 times the age-standardised mortality rate of the non-Indigenous population. These patterns mirror international experiences where pandemic impacts magnified existing social and health inequities, underscoring the importance of community-centred approaches, engaging locally with targeted public health interventions.

Excess mortality in 2024

The analysis presented in this report primarily utilises mortality data up to December 2023 for international comparisons. This is due to the amount of time needed to record deaths. Some countries are able to do so more quickly than others, and while 2023 data may still be missing some deaths, the vast majority will be present.

More recent ABS data, available as of February 2025, provide insights into excess mortality through November 2024, and for Australia alone the models have been run on this period of 2024.

The 2024 data reveal that Australia continues to experience significant excess mortality, with over 7,600(4,100-10,700) excess deaths in the eleven-month period, this is the essentially the same number excess deaths as in the first eleven months of 2023. It is not yet known whether this level of mortality is likely to continue going forward but what is clear is that Australia has seen extensive loss of life due to COVID 19 and the continued significant burden warrants ongoing action.

4 International comparisons of excess death estimates

Country-level excess mortality trends are shaped by the interplay between PHSM, vaccination coverage and variant evolution. An understanding of these trends can inform effective strategies for future pandemics. International comparisons must be carefully interpreted in the context of different geography, demographic structures, health system capacity and cultural factors such as adherence to health measures and trust in government. There are many variables which interact and statistical attribution to specific factors has not been pursued in this report. The intent is instead to identify, countries, actions and trends which can provide insight for Australia's current and future pandemic response actions.

There were nine countries chosen for comparison based on their ability to offer insights or lessons into how Australia should or shouldn't approach a pandemic. To facilitate meaningful comparison, each of these countries needed to have consistent and high-quality data capture of deaths and have at least five years of deaths data available. Beyond the data requirement, the countries needed to have either similarity to Australia in geography or approach or have a well-documented, and varied, approach to the pandemic response. Taiwan, South Korea, Japan and New Zealand were chosen due to their geographic similarities. The UK, US, Italy, Sweden and Germany each had well documented and distinct responses to the pandemic, especially during 2020 and 2021.

To compare Australia against selected countries, we calculate the cumulative P-score using the Serfling model. This technique was applied to weekly (or monthly for Japan) data from the Human Mortality Database (HMD). The number of years utilised in the calibration period was the number of years present in the data between 2013 and 2019, up to a maximum of seven. This was seven for all countries excepting Japan, US and UK which had only five years available.

Through this analysis, we found that country trends in excess mortality were similar based on approach to disease control, including:

- **Delayed or inconsistent responses** – Countries that reacted slowly or implemented uneven measures, leading to higher excess mortality.
- **Proactive and controlled responses** – Countries that adopted early, stringent interventions, resulting in lower excess mortality.
- **Mixed responses** – Countries that changed strategies over time, leading to fluctuating excess mortality trends.

4.1 Delayed or inconsistent responses

First, we compare Australia's cumulative P-score to countries with high excess mortality in 2020 (**Figure 4**). There is a marked difference in excess mortality between the US, UK, Sweden and Italy compared to Australia, with each of these four countries experiencing high excess mortality through 2020 and 2021. **Table 2** at the end of this section converts the different P-Scores into the number of Australian lives that would have been lost should the mortality burden been the same as the comparator country.

Early Phase (2020-2021)

Italy was one of the first European epicentres of COVID-19, facing an outbreak that quickly overwhelmed its healthcare system. The initial containment efforts were reactive to the unfolding situation, and by the time lockdowns in the northern regions of Lombardy and Veneto were implemented, the virus had already spread to other parts of the country[22]. Limited communication between central authorities and local law enforcement resulted in inconsistent enforcement of restrictions. Meanwhile, outbreaks were unintentionally fuelled by changes to management of the healthcare system, including transferring of non-critical hospital patients to aged care facilities, increasing infection risk among the most at-risk elderly populations[23].

By March 2020, Italy recorded the highest COVID-19 mortality rate of any country[24, 25]. As the first Western country to face the pandemic at

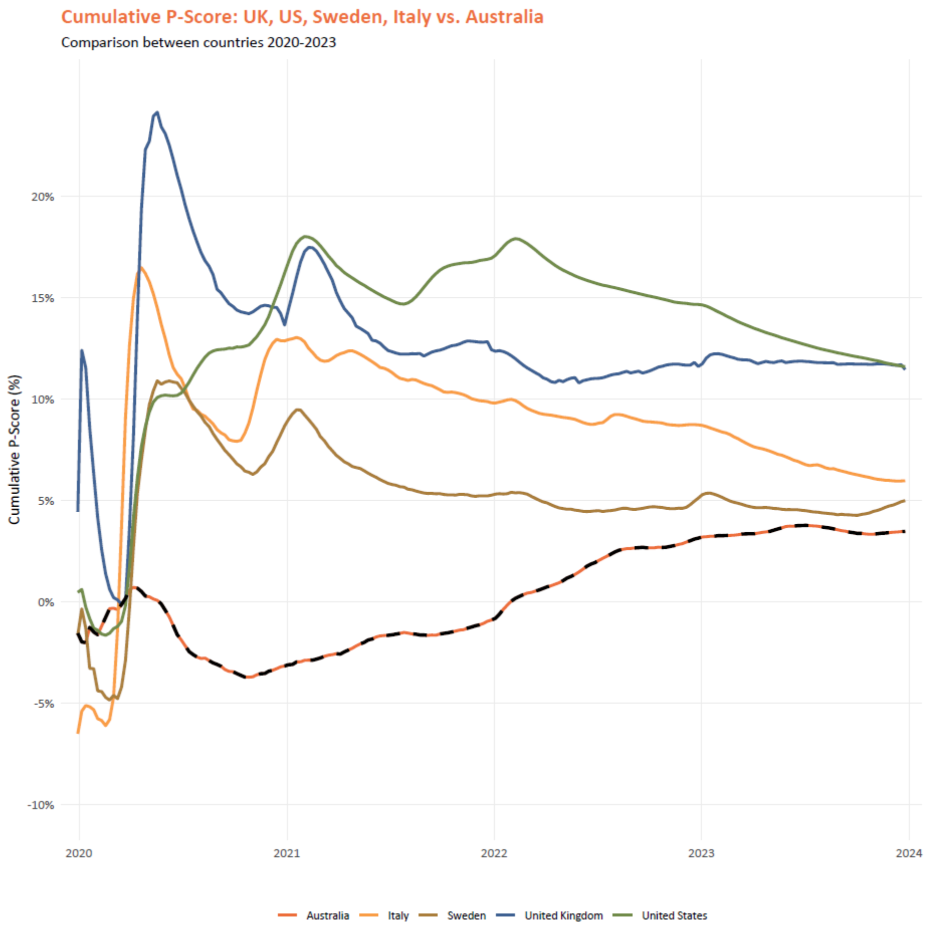

Figure 4: Monthly cumulative P-Score (%) of the United Kingdom (UK), United States (US), Sweden, Italy and Australia, 2020-2023

this scale, Italy did not have the benefit of learning from others' experiences.

In 2019, the US and UK were ranked first and second on the "Global Health Security Index", meaning they were determined to be the most prepared for a pandemic based on infrastructure available[26]. However, despite Italy's experience, and their extent of US resources and infrastructure, the US were unable to mount a cohesive or consistent response.

Federal officials politicised public health measures, downplaying scientific advice and causing confusion amongst the public[27]. The US Centers for Disease Control and Prevention (CDC) were accused of inconsistent messaging on masks early in the pandemic[28]. This, combined with an underinvestment in public health infrastructure, prevented the implementation of effective TTI strategies.

Furthermore, COVID-19 exposed societal inequities, with cultural and linguistically diverse populations facing hospitalisation and death rates considerably higher than white populations[29]. The US experience demonstrated that abundant resources alone cannot overcome politicised public health messaging, fragmented leadership, and entrenched inequities during a crisis.

The UK also failed to implement timely measures[30]. Through January and February, authorities issued travel advisories and traced contacts of early cases, but the government was slow to adopt the strict measures seen in some other neighbouring countries. With cases rising and outpacing their limited contact tracing capacity, the UK stopped trying to contain the virus and instead focused on preparing the health system and building 'herd immunity' by allowing the virus to spread in a controlled manner. [31] This approach proved catastrophic, leading to surging hospitalisations and deaths. By mid-March, the UK abruptly reversed course and implemented one of Europe's strictest lockdowns. This delay between first detected cases and mobility restrictions (53 days) was the longest in Europe, resulting in preventable deaths and prolonged economic disruption[10].

As shown in **Figure 4**, both the UK and US recorded extensive loss of life in 2020 with cumulative P-scores peaking above 15%. This is a stark illustration of how preparedness rankings failed to translate to effective pandemic responses in the early phase of the pandemic.

Rather than a delayed response, Sweden opted for a different, more liberal strategy of voluntary recommendations. Settings such as schools and aged care were kept open, and mask-wearing was not enforced[32]. This response has been highly controversial, and there is continued disagreement in the literature about its effectiveness[33, 34]. Similar to Italy, many COVID-19 fatalities occurred in aged care facilities, though some have argued that this was a result of improper implementations of protective measures by local authorities rather than a flaw in the strategy[35, 36]. During the waves in 2020, the case and death rates in Sweden were significantly higher than its Nordic neighbours[37].

As vaccines became available in 2021, all four countries made this central to their strategies while gradually withdrawing all restrictions. The UK championed one of the world's fastest vaccination campaigns[38], while Italy implemented Europe's strictest vaccine requirements through its comprehensive Green Pass system. Sweden maintained its distinctive light-touch approach but achieved comparable vaccination rates through voluntary compliance.

Later phase (2022 onwards)

The scaling back of COVID response and the emergence of the Omicron variant led to swathe differences in P-score gradually narrowing from early 2022, as both natural infection and vaccination conferred extensive immunity to the populations.

At the end of 2023, the cumulative P-score in the US and UK remained above 10%, reflecting a substantial loss of life over a prolonged period. In the US, the politicization of COVID-19 measures, especially vaccination, has led to the ongoing mortality burden with significant disparities in vaccination coverage based on political affiliation and state of residence[39]. The European countries that we compared, excepting the UK, fared better, with cumulative excess mortality in Italy and Sweden reducing to 6% and 5% respectively.

Table 2 converts the rates of excess mortality to the number of Australian deaths that would have occurred if Australia had the same cumulative P-Score as each of the other countries. If Australia saw the same level of mortality as the UK or the US across this period, more than 55,000 additional lives would have been lost.

Table 2: P-scores converted to Australian figures. If Australia saw the same level of excess mortality as the US, an additional 44 thousand lives would have been lost.

Country	Cum. P-score - Dec 2023	P-score converted to Australian mortality	Difference
Australia	3.5%	23,757	-
Sweden	5.0%	34,176	10,419
Italy	6.0%	40,904	17,146
UK	11.5%	78,508	54,750
US	11.6%	79,449	55,692

4.2 Proactive and controlled responses

Early Phase (2020-2021)

New Zealand, Taiwan and Japan maintained cumulative P-scores similar to Australia's throughout the pandemic, meaning the number of lives lost to the pandemic was roughly equivalent once adjusted for the differences between each country's population (**Figure 5**). The island nations' geographic isolation made border controls more effective at preventing viral introduction. Yet, their low excess mortality was due to more than just geography. These nations implemented early, decisive public health measures that emphasised suppression or elimination strategies during the initial pandemic waves.

There are unique differences in the implementation of these island nations' selection of PHSM to support their pandemic strategies. New Zealand committed to full virus suppression through swift lockdowns, rigorous contact tracing, and high public compliance, keeping case numbers and deaths consistently low throughout 2020 and 2021. Taiwan employed a more technology-centred approach, drawing on its 2003 SARS experience to deploy real-time monitoring and digital contact tracing systems. [40]

Japan maintained effective pandemic control through a distinctive approach that differed from both New Zealand and Taiwan. Rather than imposing strict lockdowns, Japan relied on its collectivist cultural identity, which includes mask-wearing practices and public cooperation[41, 42]. The government worked within their existing

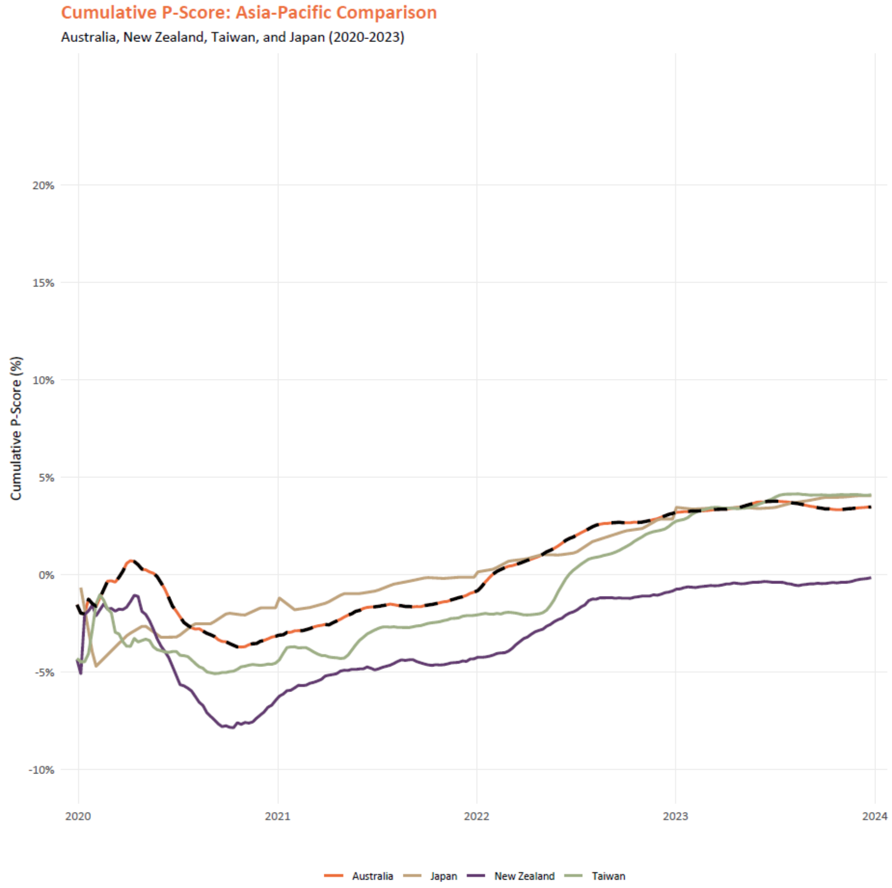

Figure 5: Monthly cumulative P-Score (%) of New Zealand, Taiwan, Japan and Australia, 2020-2023

constitution and issued recommendations based on the '3Cs' principles — avoid closed spaces, crowded places, and close-contact settings[43].

This strategy proved effective, despite Japan having the world's highest proportion of at-risk older adults[44]. Like Taiwan, Japan's SARS experience shaped early interventions that aligned with cultural norms[45]. Japan and Taiwan faced a greater threat than Australia due to much higher population densities (Japan has 343 people/km^2 and Taiwan has 673 people/km^2, while Australia has 3.3 people/km^2)[46]. This density differential is further amplified in urban centres like Tokyo (4,306 people/km^2) and Taipei (8,861 people/km^2), compared with Sydney (2,204 people/km^2)[47].

Across all four countries, PHSM, supported by targeted social and financial support measures[43], contributed to fewer road accidents, reduced occupational fatalities, decreased air pollution, and lower rates of respiratory infections like influenza[48, 49].

Later phase (2022 onwards)

Enabled by successful vaccination rollouts in 2021 and with an eagerness to socially re-open, each country transitioned from containment just as the Omicron variant emerged with increased transmissibility. Omicron rendered previous measures considerably less effective. In October 2021, after New Zealand achieved 90% vaccination coverage, the government began easing its PHSM, acknowledging that both the variant's transmissibility and vaccine protection made previous elimination strategies unnecessary[50]. Similarly, Taiwan's April 2022 pivot occurred once 80% of the population had received at least one vaccine dose[51].

As in Australia, Omicron, coupled with reduced intervention, saw a considerable increase in mortality and excess mortality in both Japan and Taiwan, which continued through 2023.

Both Taiwan and Japan had a greater recognition of the benefits of clean indoor air at reducing airborne spread in public places. Cultural differences in mask adherence and indoor air quality management emerged as significant differentiating factors by 2023. While Australia's mask usage dropped substantially, Japan maintained higher rates even after mandates ended[52].

Unlike Australia, which has no mandated indoor air quality standards relevant to the spread of infectious disease, both Taiwan and Japan have recognised the importance of indoor air quality through monitoring and regulatory requirements setting safe levels. In 2021 the Taiwan EPA implemented self-management IAQ certification program to accelerate improvements[53]. This program credited venues that met stringent criteria with a "Indoor Air Quality Self-Management" mark as either an Excellent or Good level.

Vaccination rates also dropped considerably more in Australia compared to Taiwan and Japan. Taiwan administered 64% more and Japan administered 91% more doses of COVID vaccine per person in 2023 compared to Australia[54].

4.3 Mixed responses

Germany and South Korea provide valuable case studies of countries whose initial COVID-19 responses were characterised by robust TTI strategies yet struggled with the Omicron variant (**Figure 6**). Both nations managed early outbreaks effectively, recording low excess mortality throughout 2020 and most of 2021. However, the detection of the highly transmissible Omicron variant in late 2021 necessitated a strategic shift toward adaptive mitigation strategies. Omicron's impact is visible in excess mortality; most notably in South Korea during the second quarter of 2022.

Early phase (2020-2021)

Germany's early response highlighted the strength of its public health infrastructure, empowering local services to rapidly scale up PCR testing and contact tracing[55]. Although Germany implemented moderate lockdown measures beginning in March 2020, these were far less stringent than in neighbouring countries such as Italy[55]. Effective public communication was a defining feature, with public figures praised for articulating the scientific rationale behind public health measures. This strategy contributed to Germany's relatively low case fatality rate compared to much of Western Europe, reflected in excess mortality (cumulative P-Scores) remaining around or below zero for substantial portions of 2020.

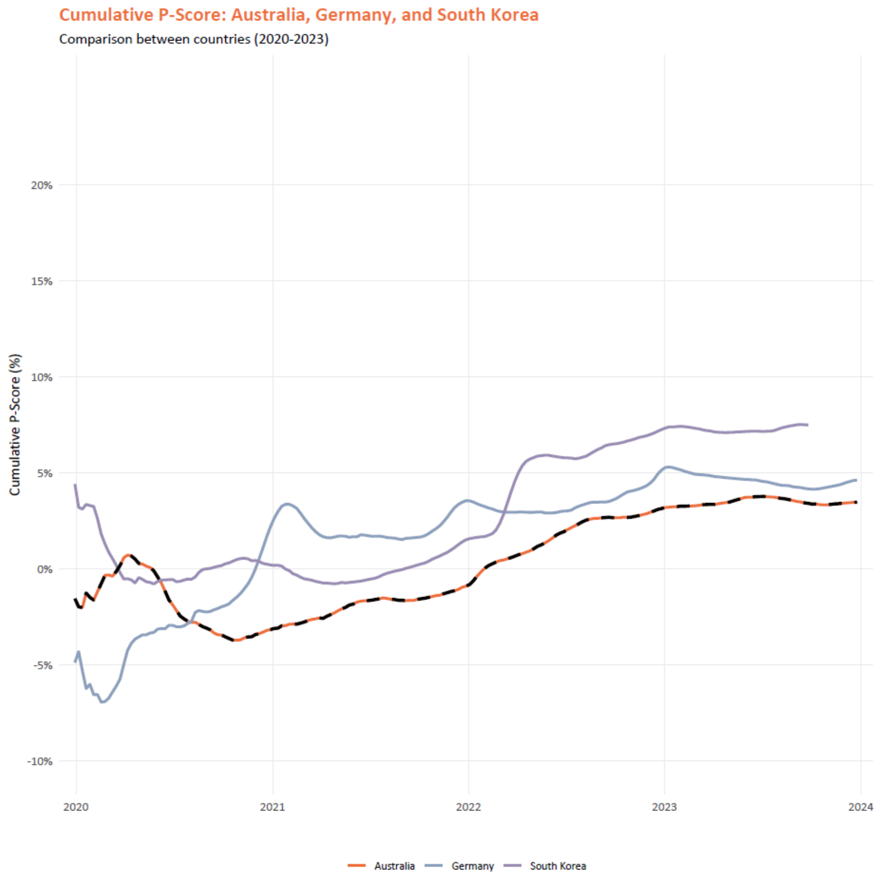

Figure 6: Monthly cumulative P-Score (%) of Germany, South Korea and Australia, 2020-2023

Likewise, South Korea set an early benchmark through its TTI, underpinned by extensive testing infrastructure, drive-through screening centres, and digital contact tracing methods[56]. Authorities leveraged mobile GPS data, credit card records, and CCTV footage to rapidly identify and isolate contacts, eliminating the need for broad lockdowns[56]. Complemented by high mask use and voluntary social distancing, this approach ensured exceptionally low COVID-19 mortality and very few excess deaths throughout 2020–2021. Strict border screening and targeted quarantine for incoming travellers limited disease importation further, solidifying South Korea's success during this phase[57].

Later phase (2022 onwards)

The rapid emergence of the Omicron variant severely undermined the previously effective TTI strategies in both Germany and South Korea. In Germany, repeated waves of infection (initially driven by Delta, followed by Omicron and its subvariants) forced policymakers into a delicate balancing act to reintroduce restrictions such as mask mandates, partial capacity limits, and targeted distancing rules while maintaining public support[58]. Despite earlier expansions of ICU capacity, Germany's healthcare system periodically experienced significant strain, particularly on hospital staffing[59]. These ongoing pressures resulted in a modest yet persistent rise in excess mortality, reflected in the increasing cumulative P-score throughout 2022.

South Korea experienced a more dramatic shift. Despite sustained high vaccination rates and widespread mask usage, the unprecedented scale of Omicron infections in early 2022 overwhelmed testing infrastructure and severely strained hospitals. The government adapted by shifting from exhaustive contact tracing to recommendations of self-treatment, with daily infections surging into the hundreds of thousands at the peak[60]. This wave drove a sharp increase in excess mortality, particularly during the second quarter of 2022. By mid-2022, high vaccine booster coverage allowed South Korea to relax restrictions, but the Omicron variant led to an overall surge in mortality[61].

5 Discussion

5.1 Overview of key findings

Official COVID-19 death statistics (reported COVID-19 deaths) provide insights into the pandemic's direct health impacts, but have significant limitations and miss many deaths and indirect consequences of COVID-19. Reported COVID-19 deaths relies on doctor certification of the cause of death. Undiagnosed cases, increased mortality risk from previous infection and deaths due to system impacts such as delayed healthcare access remain obscured in standard death counts. Excess mortality analyses address these limitations by comparing observed deaths to expected baseline figures, offering a more complete view of both direct and indirect pandemic impacts.

The method chosen to estimate excess mortality influences results. Demographic shifts, particularly population ageing and growth, further complicate these calculations. The variation in results from age-specific and count-based models underscores the importance of aligning modelling techniques with mortality trends and demographic realities. For Australia, our analyses suggest that using seven years (2013-2019) in the baseline, the same period used by the ABS, yields more reliable excess death estimates.

In the early pandemic (2020–2021), Australia experienced negative excess mortality, driven by PHSM and resulting reductions in seasonal influenza and road traffic fatalities. These factors kept death rates below historical expectations for much of this period. However, from early 2022 onwards, as restrictions eased and Omicron transmission became widespread, Australia experienced high excess mortality continuing well beyond 2022, with excess mortality remaining at high levels.

International pandemic responses varied widely, creating distinct excess mortality patterns. Countries with delayed or inconsistent PHSMs, including the United States, United Kingdom, Italy, and Sweden, experienced higher mortality early in the pandemic. Conversely, New Zealand, Taiwan, and Japan intervened swiftly with effective TTI systems, maintaining low excess mortality. Other countries, notably Germany and South Korea, initially contained outbreaks through robust testing and tracing, but could not sustain these successes after Omicron emerged.

5.2 Implications and key lessons

Several lessons emerge when comparing Australia's pandemic experience to countries like the US and UK. When facing public health threats that present imminent and severe population risk, governments must act swiftly and decisively. Prompt border closures, lockdowns, and other interventions can limit initial infection waves when implemented early. Australia's 2020 restrictions prevented excess deaths, demonstrating the value of precautionary action based on available evidence, even though adjustments were later needed.

Public health measures must adapt to evolving pathogen characteristics. While TTI strategies worked for early COVID-19 variants, later variants required different approaches. Policymakers must accept that adjustments to strategies are necessary as knowledge develops. This requires weighing risks against benefits, considering unintended consequences, and addressing inequities and human rights concerns. This necessitates virological surveillance, i.e. genomics.

Cohesive leadership guided by science rather than politics is essential. Australia's future pandemic preparedness requires sustained investment in public health infrastructure, such as the Australian Centre for Disease Control (ACDC), to provide centralised expertise and coordination capacity. Clear, consistent messaging from trusted authorities builds public confidence; fragmented, politically motivated approaches undermine effective interventions. Strong and independent governance must build robust health infrastructure with resources for surge capacity, surveillance, and targeted community-based interventions.

COVID-19 remains a public health challenge, with excess mortality persisting despite vaccination and widespread prior infections. Protecting at-risk populations requires ongoing efforts: improving indoor air quality, increasing vaccine uptake, and addressing "pandemic fatigue." The pandemic's disproportionate impact on overseas-born Australians, Aboriginal and Torres Strait Islander peoples, and socioeconomically disadvantaged groups highlights the need for targeted strategies that address underlying health inequities in future pandemic planning.

Investment can occur in improvements that require limited or no behaviour change such as prioritising engineering and administrative measures such as improving indoor air quality.

Australia's geographical isolation and lower population density offer advantages for future pandemic responses, but require reinforcement through planning and proactive policies. Lessons from Japan and Taiwan, which emphasize clean indoor air and continued vaccination, provide strategies Australia can integrate into its public health framework, particularly through Indo-Pacific Health Security Initiative collaboration.

5.3 Strengths and limitations

This report utilises multiple modelling approaches to identify an appropriate method for Australian excess deaths. Australia’s relatively comprehensive and timely mortality data, including detailed demographic breakdowns, enabled an in-depth assessment. International comparisons further contextualised Australia’s experience globally using the excess mortality P-score, which accounts for differences in population size, age structure, and life expectancy.

This analysis has several limitations. First, we took an observational approach to assess the association between excess mortality and phases of PHSM. There may be other associations with excess mortality that were not described or evaluated that accounted for these trends. We assumed that trends in mortality rate prior to 2020 would have continued in a linear fashion without the pandemic.

Additionally, comparator countries were selected based on available data quality and narrative progression of public health responses rather than a systematic approach, potentially limiting the broader applicability of our findings.

Mortality could change for several reasons other than COVID-19, so our baseline model that we compare actual deaths against becomes weaker over time. Also, while P-score captures many differences between countries, it does not capture all that are relevant to pandemic risk. For example, population density increases the risk of large outbreaks and is not adjusted for. Interpretation of differences between countries that have significantly different population density should be done cautiously.

This report has focused on countries with high quality and consistent data capture, limiting analysis to the end of 2023. However, further data limitations may remain, such as unexpectedly long delays in data capture and data errors that could cause true deaths to be missed in our analysis.

6 Recommendations

6.1 A continued sustainable public health response to COVID-19

Five years since the declaration of COVID-19 as a pandemic, Australia continues to experience the ongoing burden impact of COVID-19 on health and economic productivity.

There is a need for continued and better application of sustainable, low-impost public health strategies:

1. Continued vaccination to reduce the risk of severe acute COVID-19 and long COVID-19. This includes matching boosters with circulating variants, and strategies to promote vaccine uptake.
2. Breathing clean indoor air through ventilation (improved indoor air quality). Ventilation or interventions to improve indoor air quality removes infectious particles and pathogens from the air. If ventilation is inadequate, individuals can protect themselves using a high-quality respirator (N95 or KN95 mask).
3. Community-based testing using rapid diagnostics (RATs). This allows immediate action on the result if positive through self-isolation and/or seeking antiviral treatment.

There is urgency for continued research and innovation to develop new tools that curb transmission in the face of an evolving virus, long COVID. Beyond COVID-19, the same the same investment is needed to best protect against future, unknown pathogen threats.

6.2 Priorities for pandemic preparedness

1. Invest in pandemic preparedness

The cost of inadequate preparation has been demonstrated in the significant numbers of lives lost. Effectively managing future health crises requires Australia to strengthen its capacity to detect, respond to, and mitigate pandemics. Three key elements are:

1. **Sustained political commitment**. As the Independent Panel in their June 2024 call to action state, 'with collective vision, political will to overcome deficits in trust, leadership, accountability and investment, COVID-19 can be the last pandemic of such devastation[62].
2. **Sustained and substantial investment in public health systems, workforce and infrastructure.** This can be achieved through an independent and transparent national CDC that works in partnership with jurisdictions and leading scientific institutions. The Australian CDC is vital for building cohesive disease surveillance, strengthening pandemic detection and response capabilities. Investment in programs such as genomic and wastewater surveillance allow for better local detection, while also contributing valuable data to global surveillance efforts.
3. **International cooperation and reform**. The establishment of better global systems and rules for early pandemic detection and response. This includes the pandemic treaty and amended international health regulations. For Australia,

regional partnerships and capability building in the Pacific and Asia are key. This collaboration allows for early detection of emerging threats before they occur locally.

The success of Taiwan demonstrates how previous pandemic experience and investment in public health systems can inform rapid, effective and coordinated responses.

2. Act swiftly and decisively

Effective pandemic management requires swift action to contain outbreaks before they become pandemics. During an emergency response, rapid decision-making is required based on available and evolving evidence rather than waiting for complete certainty.

As demonstrated by the contrasting experiences of countries with early interventions versus delayed responses, the timely implementation of border controls, TTI, and appropriate restrictions significantly reduced mortality early in the pandemic. Decision-makers must be willing to act on the best available evidence rather than waiting for certainty, recognising that measures can be adjusted as the situation evolves and more data becomes available.

3. Address inequities

The pandemic emphasised and exacerbated existing health inequities both globally and in Australia where people born overseas experienced 1.4 times the mortality rate of Australian-born residents, The lowest socioeconomic quintile has 2.8 times the COVID-19 mortality rate of those in the highest quintile[5] and Aboriginal and Torres Strait Islander peoples has 1.8 times the mortality rate of non-Aboriginal Australians. One of the most notable contributors is lower rates of vaccination. Future pandemic planning must explicitly support and prevent impacts in priority communities and people at higher risk of worse outcomes due to structural disadvantage. In COVID-19, this included lower income groups, people with disability, First Nations communities, residential aged care and some multi-cultural communities. Approaches must place communities at the centre, and include tailored health communication, enhancing health care access and appropriate social and economic support measures.

4. Sustainable responses

COVID-19 impacts are ongoing, and pandemics have long tails. Building trust through sustained community partnerships and engagement is fundamental. Pandemic fatigue should be actively addressed as the response transitions from the emergency phase, along with mis- and dis-information. Developing integrated surveillance systems that inform communities through timely and transparent data build trust.

The experience of countries like Japan and Taiwan demonstrates that continued attention to these factors can mitigate ongoing excess mortality even after the acute emergency phase. Response measures should be calibrated to evolving risk levels, considering both direct health impacts and broader societal considerations.

There is much to gain from "passive controls" that don't require behaviour change, like we do for waterborne infections. This involves implementing and optimising clean indoor air strategies for airborne infections.

Similarly, countries like Japan and Taiwan, which prioritised indoor air quality improvements, experienced better long-term pandemic outcomes. Investment is required to advance research in clean indoor air and progress the development of national air quality standards.

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8 Appendix A – Excess mortality model determination

As noted previously, there is a substantial difference in the number of cumulative deaths between models with the ABS model calculating 8,000 less deaths between 2020 and 2023 than the economist and Karlinsky and Koback.

The differences between model predictions could be affected by the selected input data and/or the model choice and its inherent modelling assumptions. We reviewed the input data for each of the models and found no inconsistencies that could have led to differences in model outputs.

To assess the impact of model choice on prediction, we programmed three count-based mortality models (**Figure 7**). As previously noted, data was not available to replicate the model from the Actuaries Institute:

- Linear Regression with covariate for week as used by the Economist (Regression)
- Linear Regression with covariate for week and Gaussian Noise as proposed by Karlinsky and Koback (Regression + Noise)
- Serfling model as utilised by the ABS (Serfling_mod)

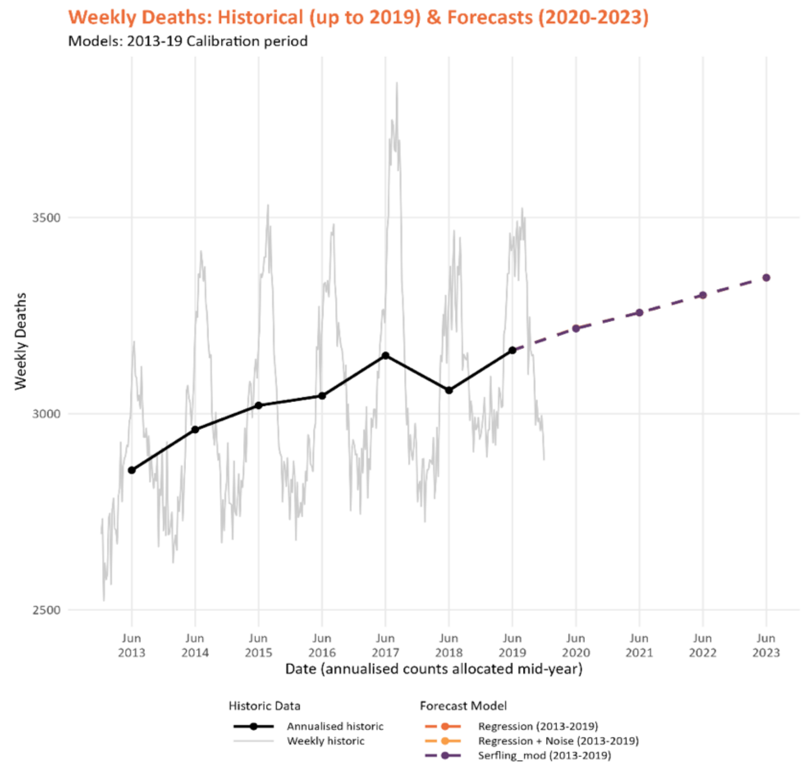

Figure 7: Different count models calibrated on the same period of data resulted in nearly identical predictions. Data sources: Weekly deaths from ABS for 2013&14, Short Term Mortality Fluctuations 2015-19. Note: Forecasts smoothed to remove the impact of 53 weeks in the 2020 calendar year.

The WHO model was excluded due to its reliance on temperature as a predictor which doesn't capture Australian seasonality well. Furthermore, the spline function performs poorly on the five years of

Australian data due to reasonably high interannual variability. This limitation was also documented for Germany[63]. When we compared the selected count-based models on identical input data from 2013-2019, we found the differences in predictions were negligible. In **Figure 7**, the predicted trajectories from the three models almost perfectly overlap.

8.1 Identifying the Appropriate Fit Period

One major difference between the methodologies of the ABS versus Karlinsky & Koback and The Economist was the duration of historic data given to the model to fit its counterfactual baseline model.

To test the impact of the calibration period on expected deaths estimates, the same model was run using three different baseline ranges: 2013–19, 2014–19, and 2015–19. As shown in **Figure 8**, there is a substantial difference in the slope of the resulting forecasts, highlighting how sensitive excess mortality estimates are to the chosen historical window. This difference underlies the gap between the Australian Bureau of Statistics (using 2013–19) and The Economist (using 2015–19), whose contrasting baselines produce divergent projections for expected—and therefore excess—deaths.

Such variability in results aligns with existing research, which demonstrates that changing reference periods can materially alter mortality estimates[64].

To best understand which calibration period is most appropriate, it is necessary to understand underlying data such as abnormal periods of mortality, trends in population size, population ageing and mortality rates.

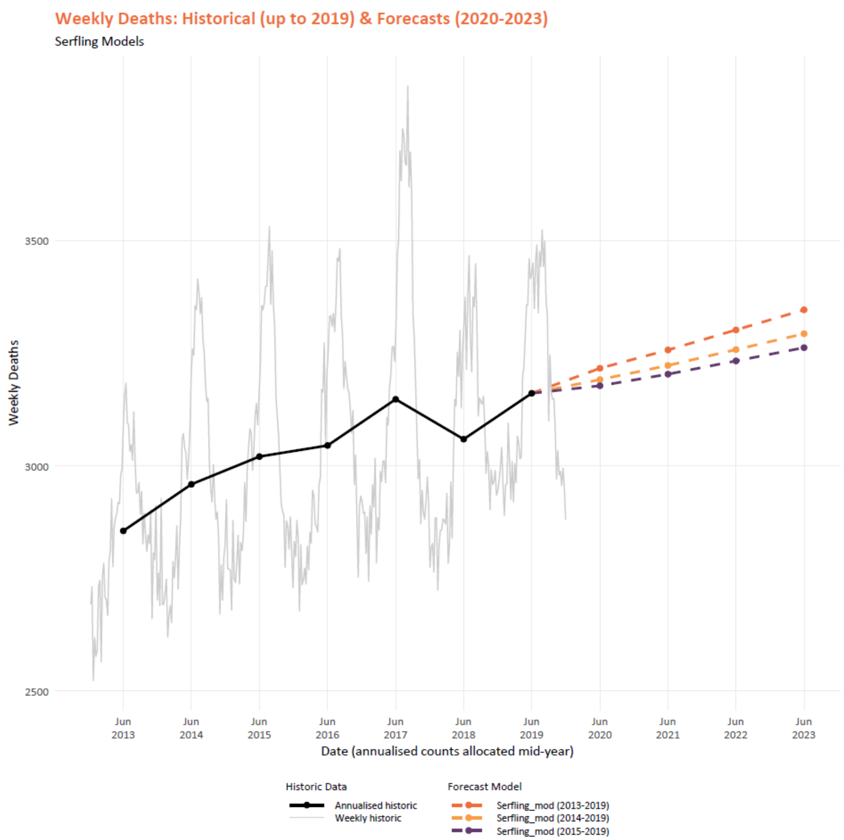

Figure 8: Expected death estimates diverge substantially based on the choice of calibration period. Data sources: Weekly deaths from ABS for 2013&14, Short Term Mortality Fluctuations 2015-19. Note: Forecasts smoothed to remove the impact of 53 weeks in the 2020 calendar year.

8.2 Underlying trends in Australian mortality

There is a trade-off between shorter and longer periods for calibration. When shorter periods are used, any abnormal fluctuations in each year have a larger impact on model predictions than when a longer period is used.

In 2017, Australia experienced a more severe influenza season than usual with 1,255 deaths, up from 464 in 2016, which increased mortality for older age groups[65]. Due to these increased deaths, there was likely mortality displacement in 2018[65]. These abnormal years may cause models that are trained on less data to miss the overall trends (**Figure 9**). The yearly rates of seasonal influenza deaths are approximately 10 times lower than COVID pandemic yearly excess deaths.

Models trained on longer time periods also have their limitations. Over time, changes in mortality rate and population structures occur. Australia experienced an example of this between the 2000s and 2010s, when the rate of mortality improvements accelerated due to public health initiatives targeting causes such as smoking. Calibrating a model using data before the 2010s would incorrectly decrease the projected rate of mortality improvements, because the trends in those years are no longer relevant.

Another key challenge is data availability. Through the Human Mortality Database (HMD), weekly data is available back to 2015; before this time, it is yearly. The ABS, through its excess mortality reports, made available weekly data back to and including 2013. This data availability limits model choices, especially when seeking to produce a model on numerous countries, many of which have far less data than Australia.

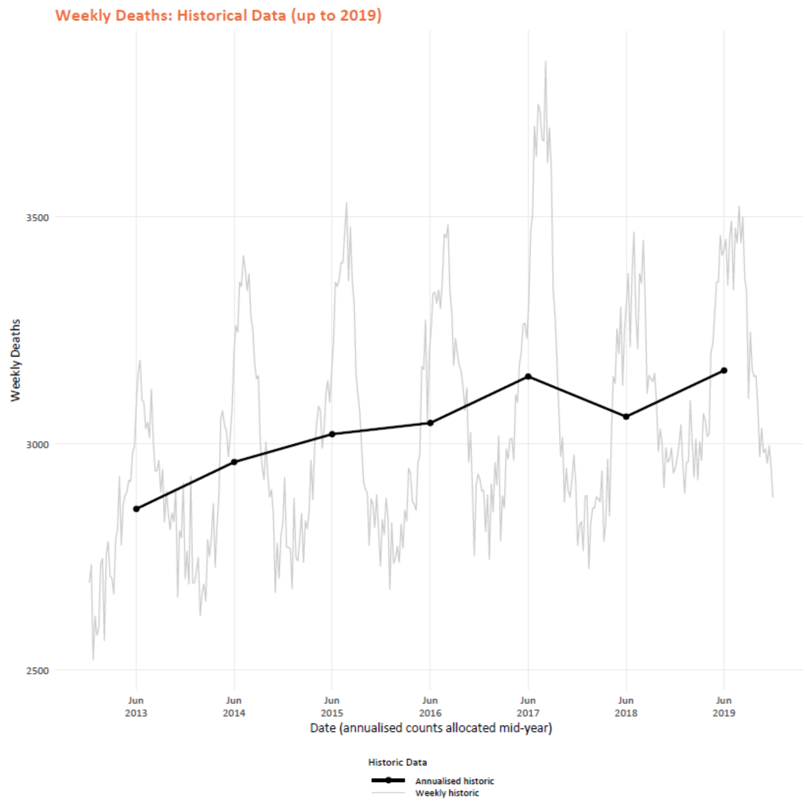

Figure 9: Prior to the pandemic, trend in deaths in Australia show a slight upward trend. 2017 is noticeably higher due to a severe flu season. Data sources: Weekly deaths from ABS for 2013&14, Short Term Mortality Fluctuations 2015-19. Yearly data prior to 2013 from the Human Mortality Database.

Australia has seen relatively stable trends in underlying factors influencing mortality. These factors can broadly be broken down into Population Growth, Population Ageing, and mortality rate.

Figure 10 shows consistent quarterly population growth, reflecting a steady influx of migrants and natural increase. While occasional fluctuations occur, the overall trajectory has remained upward over the past decade.

Figure 11 shows Australia's ageing population, with the proportion of older adults steadily increasing. This demographic shift has implications for healthcare services, pension systems, and broader social support structures.

Figure 12 shows a downward trend in age-standardised mortality, highlighting ongoing health gains and improvements in living conditions. However, the pace of this decline has slowed in the most recent decade, suggesting that the benefits of earlier health interventions may be tapering.

While underlying mortality rates are declining, the combination of growth and ageing leads to a steady increase in total deaths each year. Due to the stability of underlying population rates and structures, models can reasonably utilise longer lengths of calibration data without falsely weighting years which have obsolete underlying data.

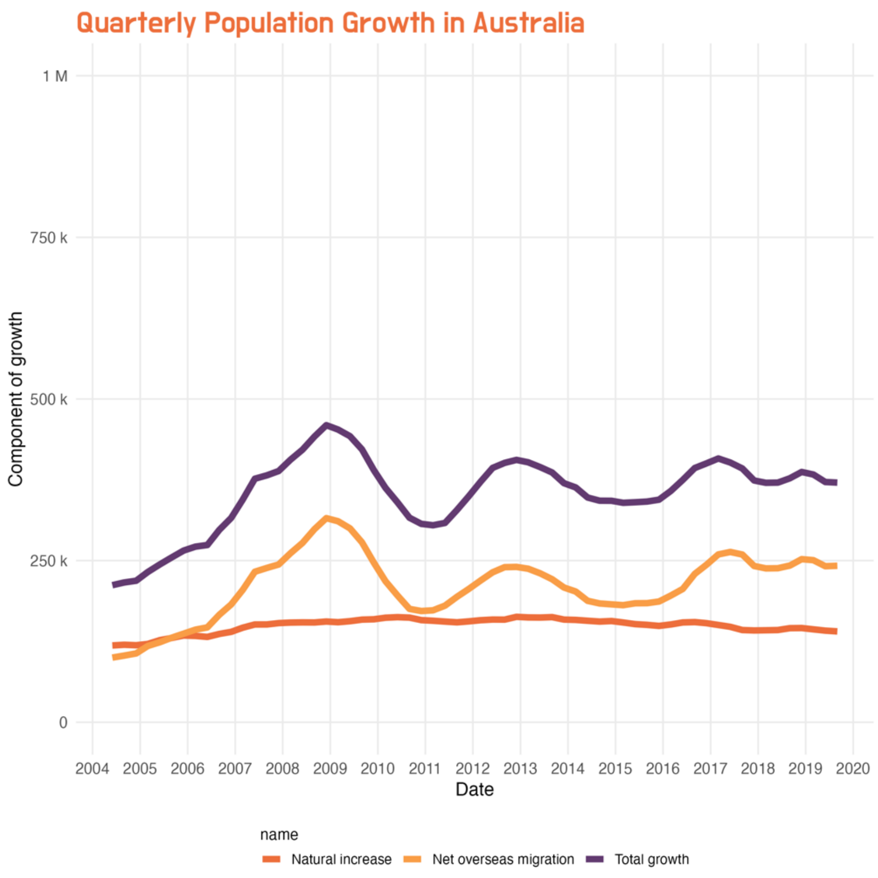

Figure 10: Pre-pandemic population growth was relatively consistent. Data sources: Quarterly population growth from Australian Bureau of Statistics

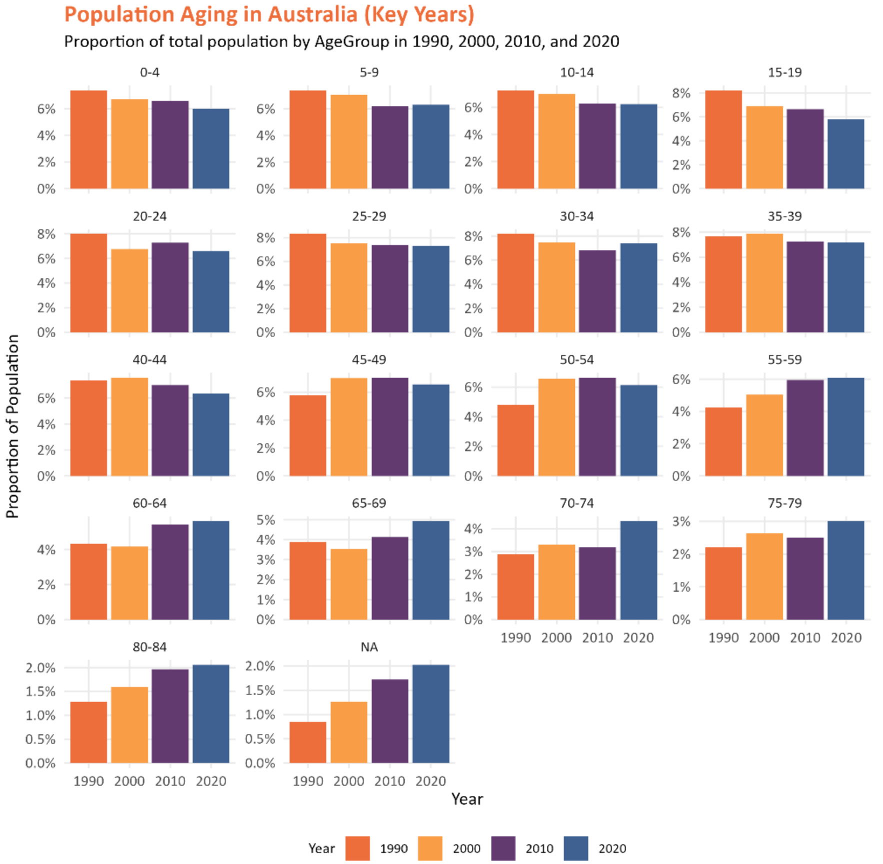

Figure 11: Australia's population is aging. Data sources: Age and sex specific yearly population from Human Mortality Database up to 2021, ABS for 2022 &23

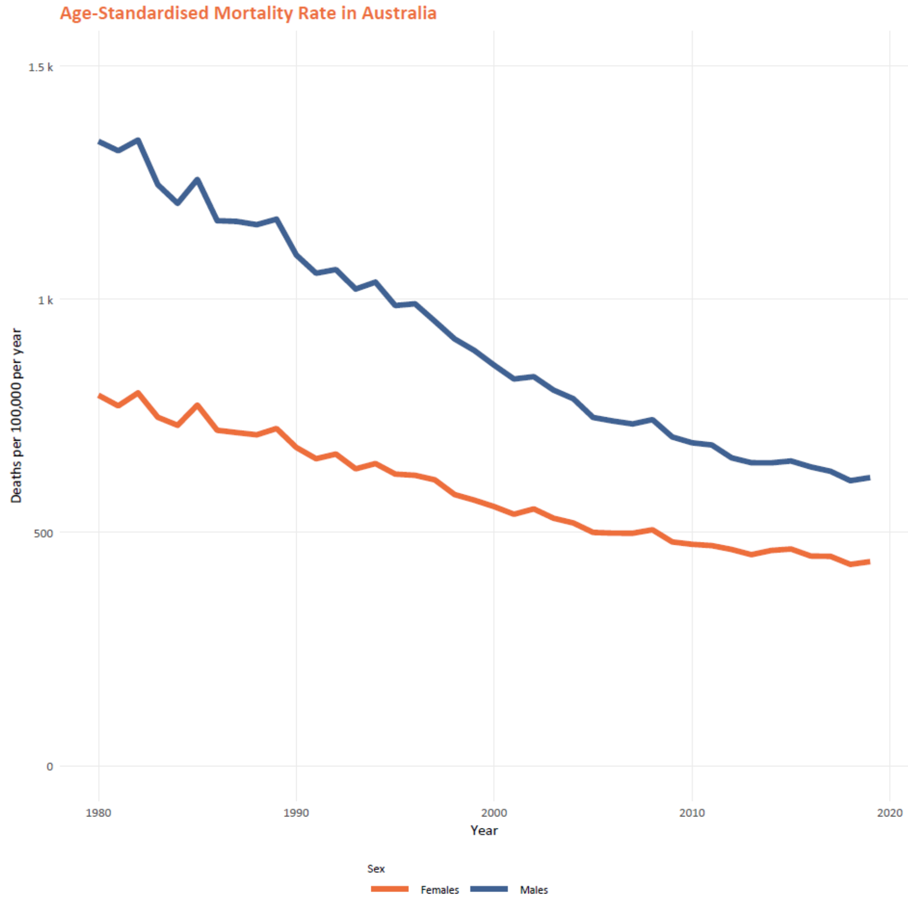

Figure 12: Mortality rates have been declining but the slope of decline has slowed. Data sources: Yearly Age Standardised Mortality Rates from Australian Institute of Health and Welfare

8.3 Age Specific Negative Binomial Model

To best capture the evolving trends in population size, age structure and mortality, our analysis explores a negative binomial model applied to five-year age groups by sex in Australia. This approach is well-established within the field of mortality modelling and has been widely adopted in recent epidemiological studies[66, 67].

This model predicts mortality rates per chosen age group and sex using the latest population data for the predicted years. While the count-based models treat the impact of population age, size and mortality rates as one input (all-cause deaths), age-specific models explicitly account for changes to these underlying inputs. Negative binomial was chosen over Poisson regression due to overdispersion in the data, which can lead to underestimation of standard errors and potentially misleading inferences.

The number of years used in the model fit period also materially impacted the negative binomial model predictions. To test the impact of the fitting window on the model predictions, we use annual data, which is available from public sources for considerably longer than the weekly data used in other models.

A significant reason why selecting the fitting period is so critical is Australia experienced a steeper annual decline in mortality rates before 2010 versus after 2010. Each dashed projection in **Figure 13** represents a model calibrated on a different number of years of data until 2019. The predictions are well-grouped, except for the model trained from 2015-2019, which is noticeably lower in yearly expected deaths.

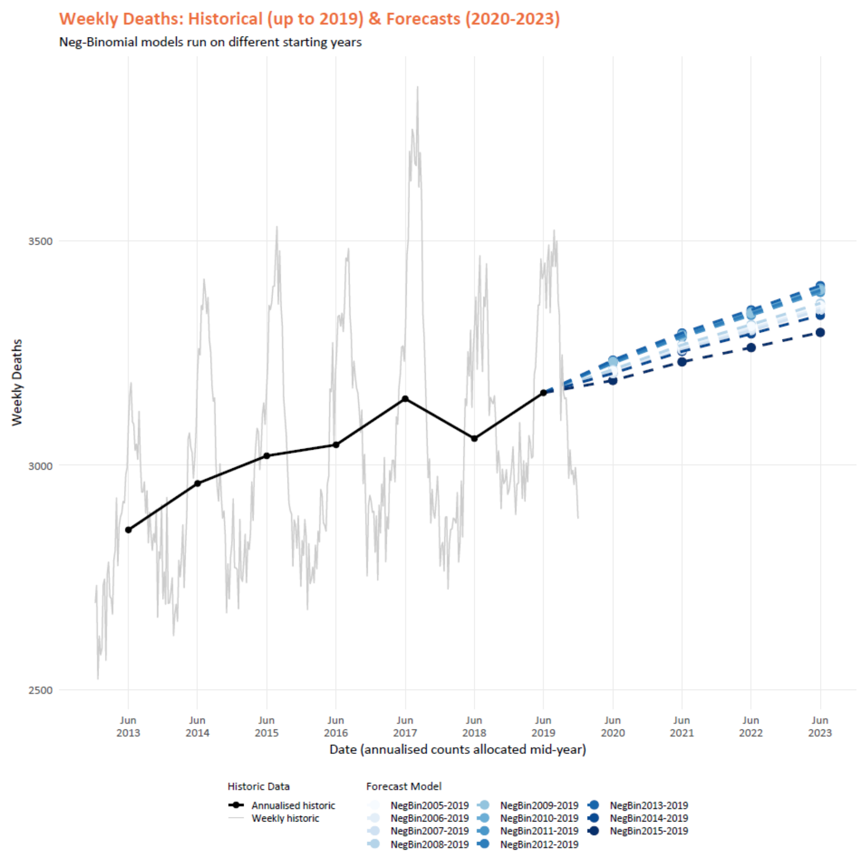

Figure 13: Negative Binomial forecasts vary slightly based on calibration period. 2015 is an outlier. Data sources: Weekly deaths from ABS for 2013&14, Short Term Mortality fluctuations 2015-19. Age and sex specific yearly population and mortality from Human Mortality Database up to 2021, ABS for 2022 &23

There are strengths and limitations of this type of stratified, rates-based model compared to a count-based model as utilised by ABS, Karlinsky and Koback and the Economist. The age-specific models require much more granular data as they need total deaths and population numbers, both split out into the smaller groups, which is less readily available. While the Human Mortality Database has this data for many countries, often updated frequently and as recently as 2023, it is not broken down into weekly numbers. This means that models fit to this data can only make predictions at annual frequencies. Furthermore, the weekly count of all-cause mortality is updated with more recent data than age-specific mortality, enabling count-based models to provide excess mortality estimates up to a more recent end date.

The relative strength in weekly predictions and timely updates makes count-based models more appealing for excess mortality analysis in the emergency phase of an outbreak or pandemic and also for between-country comparison where more granular data may be unreliable or difficult to source. This is also the case for our analysis, where we compare excess mortality between countries over time. For this reason, we will utilise an age-based model to understand underlying assumptions and inform our choice of count-based model for country comparison.

Figure 14 shows predictions from the age-specific model and from the Serfling models. Among the count-based models, the Serfling model calibrated with 2013-2019 data shows the closest alignment with the age-specific model. This will be the model used for cross-country comparison.

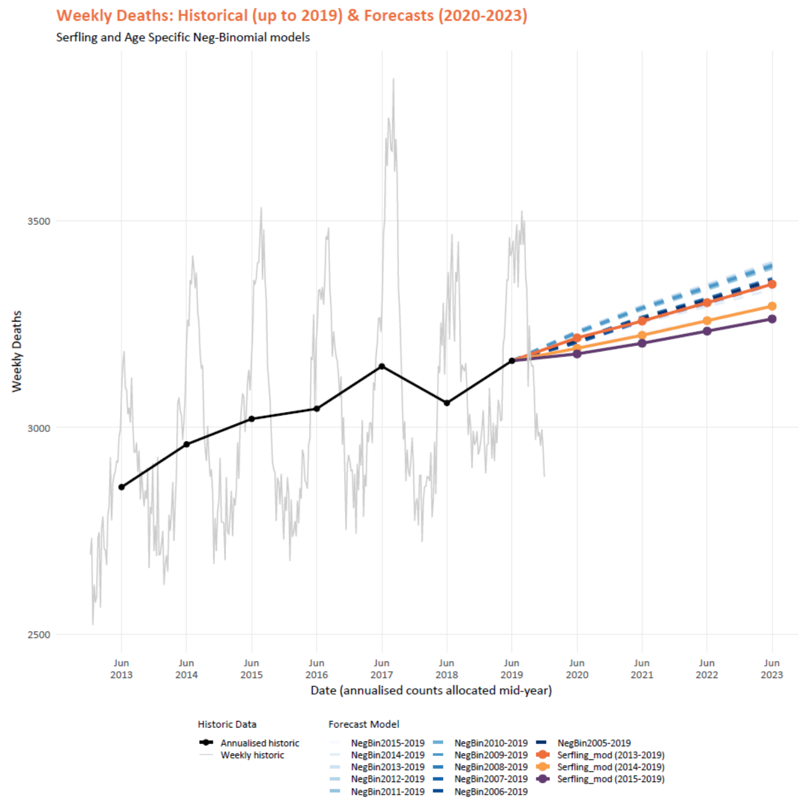

Figure 14: Serfling forecasts using 2013 in the calibration period have the closest alignment to forecasts from the age specific models. Data sources: Weekly deaths from ABS for 2013&14, Short Term Mortality fluctuations 2015-19. Age and sex specific yearly population and mortality from Human Mortality Database up to 2021, ABS for 2022 &23