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WORKING PAPER SERIES

MORTALITY INEQUALITY: NEW EVIDENCE FROM AUSTRALIA

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NON-TECHNICAL SUMMARY

In the last 50 years, there have been substantial increases in longevity worldwide. Girls (boys) born in Australia today are expected to live to 85.0 (80.9) years – 10.8 (13.3) more years than those born 50 years ago (ABS 2020). These numbers place Australia's combined male and female life expectancy sixth-highest in the world, above countries with similar per-capita GDP, such as the US, UK and Canada.

However, these are average life expectancy figures, across diverse populations. There is growing evidence that these gains are not being shared equally among the rich and the poor. In wealthy countries such as Canada and the US, rich people are living longer than poor people, and for some age and gender groups these differences have been increasing over time (Baker et al 2019; Milligan and Schirle 2018; Currie and Schwandt 2016a, 2016b; Chetty et al 2016).

In this paper, we examine the evolution of longevity trends in Australia during the period 2001-2018. More specifically, our research questions are: (i) Is there inequality in mortality rates across people with different levels of lifetime income and access to economic resources in Australia, and if so, (ii) how has this inequality changed over time? Moreover, (iii) what are the social and economic factors underlying the trends?

Our findings for all-cause mortality inequality over the period 2001-18 are three-fold. First, for many age groups among both males and females, there is no significant change in the level of mortality inequality. While a zero result, it should not be considered a negative result. Second, for middle-aged Australians mortality inequality is increasing. For men, this can largely be explained by differences in mortality rates across urban and rural populations, however this is not the case for women. Third, for teenagers and young people, there is a convergence in death rates between the rich and the poor.

Looking at specific causes of death provides further insight into these trends. For middle-aged males, it appears that diabetes is the major factor generating higher mortality inequality, and for women it is cancer. We find that for young people, the greater equality is driven largely by falling mortality due to external causes of death. There has also been a welcome convergence between male and female death rates due to these external causes of death, particularly due to motor vehicle accidents. This cause-specific data also reveals trends that are not picked up by the all-cause results. One example is the positive development of decreasing mortality inequality for coronary heart disease, which is a leading cause of death for adults over 45, and particularly men.

Examining data on the number of per capita doctors in different regions suggests that there are inequalities in access to healthcare across different regions in Australia, and there has been no significant improvement on this front from 2001-18. This problem may be contributing to the persistent and growing diabetes mortality inequality that exists for males aged 45-54. Our analysis suggests that improving access to doctors in poor regions and regional Australia is an avenue policymakers could target if seeking to reduce mortality inequalities.

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ABSTRACT

Life expectancy in Australia has been rapidly increasing. On average, children born today are expected to live 12 years longer than those born in the 1970s. However, there is growing evidence that these gains are not being shared equally among the rich and the poor. In this paper we examine the evolution of mortality inequality in Australia between 2001 and 2018. Using a spatial inequality model and combining data from several administrative data sources, we document significant mortality inequality between the rich and the poor in Australia. For most age groups, mortality inequality has remained unchanged over the last twenty years. However, mortality inequality is increasing for middle-aged men and women. In part, this can be explained by improvements in longevity which favour urban over rural Australians. Another driving factor we identify is differential access to healthcare in rich and poor regions. For young Australians, the results are more promising; mortality rates between the rich and the poor are converging for teens and young adults. Although, compared to the US, Australia's socioeconomic gradient of mortality is flatter for adults above 25, the fact that mortality inequality is increasing for some is a development that warrants greater attention from policymakers.

Keywords: mortality, inequality, Australia

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1. Introduction

Life expectancy is a key indicator of population health and well-being. It reflects the effectiveness of health systems, the adoption of healthy-living behaviours and the prevalence of disease in the community, as well as the availability and distribution of economic resources. In the last 100 years, there have been substantial increases in longevity worldwide. However, there is growing evidence that these gains are not being shared equally across different socio-economic groups. There is a body of literature finding that, in wealthy countries such as Canada and the US, rich people are living longer than poor people, and for some age and gender groups these differences have been increasing over time (Baker et al 2019; Milligan and Schirle 2018; Currie and Schwandt 2016a, 2016b; Chetty et al 2016). Further, country experiences vary and are shaped by institutions and policy choices (Banks et al 2021a). The COVID-19 pandemic has also highlighted the inequalities in mortality rates, it is well documented that groups with lower socioeconomic status have been disproportionately affected.

In this paper, we are the first to analyse the evolution of mortality rates in Australia, a rich OECD country with universal health care and a relatively generous social safety net. Life expectancy in Australia has improved dramatically for both sexes over the last century. Girls (boys) born in Australia today are expected to live to 85.0 (80.9) years – 10.8 (13.3) more years than those born 50 years ago (Australian Bureau of Statistics (ABS) 2020). These numbers place Australia's combined male and female life expectancy sixth highest in the world, above countries with similar per-capita GDP, such as the US, UK and Canada. However, these gains may not have been equally shared. For example, the Australian Bureau of Statistics (ABS) showed that life-expectancy of indigenous population is approximately 8 years lower than non-indigenous population (ABS 2018). This stark difference illustrates profound diversity across the population. Apart from this, little is known about the differences in longevity between socio-economic groups in Australia.

In this paper, we examine the evolution of age-gender-cause specific mortality rates and inequality using the approach proposed by Currie and Schwandt (2016a). This approach examines inequality through comparison of similar sized geographic areas ranked by relative deprivation. An important advantage of the method is it allows researchers to examine all deaths for an entire population, rather than being limited to a focus on adults with income or education data.

We show that overall, across all age groups for both genders, there has been a clear and significant reduction in rates of mortality since 2001. This reduction in the level of mortality has been accompanied by broadly stable inequality in mortality rates between more and less-advantaged areas over the period from 2001-2018. However, there are two notable exceptions. First, for middle aged males and females, we find a significant increase in mortality inequality with the largest increases evident for the 45-54 age groups. Second, in a positive development, there is a significant decrease in mortality inequality for Australia's youth.

Our examination of mortality by causes of death shows that the increase in mortality inequality for middle-aged Australians can be attributed to an increase in diabetes deaths for males and cancer deaths for females. On the other hand, decreasing in mortality inequality for youth is driven by greater declines in deaths due by accidents, and particularly land transport accidents in low socioeconomic areas relative to high socioeconomic areas.

We also investigate whether access to healthcare plays a role in this concerning development in mortality outcomes for middle-aged Australians. We find that over 2001-18, there are consistently more doctors per capita in richer regions than poorer regions of Australia. Furthermore, there is no evidence of any improvement in equalising the number of doctors across these regions over time. As such, we suggest difficulty in accessing healthcare could play an important role in the divergence of death rates between rich and poor regions. Our findings suggest policymakers should prioritise improving access to healthcare in poorer regions as a potential way to reduce health and mortality inequalities across Australia.

The remainder of the paper is structured as follows. In the next section we briefly review the literature, followed by a description of our data in Section 3 and methodology in Section 4. We present our results in Section 5, followed by a discussion and international comparison in Section 6. We conclude in Section 7.

2. Literature Review

There is a large economics literature[1] examining the relationship between income and health outcomes, extending back before the contribution of Grossman (1972). Although the "two-way multiple feedbacks between health and income" (Smith 1999, p.149) are well recognized, the models usually tie higher

[1] This relationship has been investigated not only by economists, but also in a vast epidemiological literature. For example, the seminal 'Whitehall' studies of British civil servants (Marmot et al 1991, Reid et al 1974) uncovered a steep inverse relationship between social class and morbidity and mortality.

lifetime income to increased longevity due to increases in consumption and investment in health inputs. The main empirical challenge in studying inequality in mortality is the lack of data on "lifetime" income for deceased and non-deceased individuals.

To overcome this and to answer the research question of whether there is inequality in mortality relating to lifetime income and access to economic resources, researchers use two main approaches. The first is to use administrative data to link mortality records with an individual's lifetime earnings or level of education (see for example, Olshansky et al 2012, Pijoan-Mas and Ríos-Rull 2014, Montez and Berkman 2014, National Academies of Sciences, Engineering and Medicine 2015, Milligan and Schirle 2018). Although a strength of this approach is the use of a measure of actual income, the cost is problems of sample selection related to the survey frame – for example, individuals with low labour force attachment, younger cohorts of adults, and children are excluded as they lack income or education data in these surveys.

The second approach is to classify people into groups based on a proxy for income or economic resources more generally. Seminal papers by Currie and Schwandt (2016a, 2016b) use this second approach, using an individual's place of residence as a proxy for income and socioeconomic status. Using data for 1990, 2000 and 2010 from the US, they find that regions with lower poverty generally have lower mortality, consistent with other studies. They also find falling mortality inequality among infants, children and young adults, attributable to declining mortality among the poorest groups. However, among older age groups, mortality inequality increased.

Baker et al (2019) follow this methodology, analysing mortality inequality for Canada as well as the US. In Canada between 1990 and 2010, mortality inequality was trending upwards for men over 24 and women over 14, widening longevity differentials between the rich and the poor, but was stable for people of youngest ages.

A seminal paper by Chetty et al (2016) investigates mortality inequality in the US using a dual approach; investigating life expectancy by household income and local area – both of which are obtained from merging income tax data with mortality records. With regards to income, they found that, for the entire income distribution, higher income is associated with greater life expectancy. Furthermore, between 2001 and 2014 inequality in life expectancy has been increasing. With respect to geography, they again found mortality inequality across local areas. How do they explain this geographical variation? The authors suggest that "…low-income individuals tend to live longest (and have more healthful behaviours) in cities with highly educated populations, high incomes, and high levels of government expenditures…" (Chetty et al 2016, p.1764). As such, there may be characteristics of certain neighbourhoods which affect the health outcomes of everyone in that region. For example, a richer neighbourhood may have better schools and parks, or safer public transport (Baker et al 2019). Hence, one benefit of using a spatial approach as opposed to an individual approach is that the regression estimates will capture some of these positive spill-over effects.

Turning away from North America, Banks et al. (2021b) analyse mortality inequality for England. Their results show increasing mortality inequalities for elder age groups. Banks et al (2021a) review findings for eight European countries and suggest that experiences vary across countries and are shaped by their histories, institutions and policy choices. We contribute to this literature, by analysing the evolution of mortality rates in Australia, a rich OECD country with universal health care and a relatively generous social safety net. Australia also provides an interesting comparison to other developed countries that have similar per-capita GDP, such as the US, UK and Canada, since it has the life expectancy above these countries. To our best knowledge, our study is the first Australian study that comprehensively examines the mortality inequality using Currie and Schwandt (2016a, 2016b) approach[2].

3. Data

We combine administrative cause- and age- specific mortality data with socioeconomic indicators from the Australian Census as well as health workforce data to investigate mortality inequality trends in Australia over the period 2001-18. The mortality and socioeconomic data are aggregated to the regional unit of geography based on place of usual residence.

Our selected unit of geography is the Statistical Area Level 3 (SA3), using the 2011 Australian Statistical Geography Standard (ASGS). SA3s are ABS structures that cover the whole of Australia without gaps or overlaps (ABS 2016b). Their main purpose is to classify regional areas with similar economic and social characteristics. In bigger cities, SA3s often align closely with larger Local Government Areas (LGAs). There

[2] An earlier Australian study by Turrell and Mathers (2001) measures mortality inequality in two earlier periods (1985-87 and 1995-97) using three broad age groups: 0-14, 15-24 and 25-64. Despite finding higher mortality in more disadvantaged regions, their results regarding the change in mortality inequality are mixed. Their results show a decrease in female mortality inequality for all age groups in the study. For males, there was an increase in mortality inequality for those under 25, with a small decrease for those aged 25-64.

are 351 SA3s in Australia and they typically have populations between 30,000 and 130,000 persons (ABS 2016b)[3].

Mortality Data

Mortality data were obtained by special agreement with the Australian Institute of Health and Welfare (AIHW). Registration of deaths is compulsory in Australia and information collected on death certificates is certified by a medical practitioner or coroner. Mortality data contain the number of deaths occurring in four separate three-year periods: 2001-03, 2006-08, 2011-13 and 2016-18. The mortality data is organised by geography, gender and age group (ages 0-4, 75+ and ten-year age groups for intervening ages). To account for changes in the age structure within age groups, we age-standardise mortality rates by the age group bands for all years using the population data from the first year included in our analysis (2001). The data also contain information on the cause of death data coded by the ABS to the International Classification of Diseases and Related Health Problems (ICD) (ABS 2019a). The full list of these causes is presented in Table A1 in the Appendix.

The heat maps in Figure 1 show the spatial inequality evident in the mortality data, demonstrating the change in the mortality rate between 2001-03 and 2016-18 for each SA3. Specifically, the blue regions indicate the mortality rate has fallen between the two periods, whereas the red regions indicate an increase in the mortality rate. As expected, mortality rates fell in most SA3s, however, even amongst these SA3s there is still considerable variation in the extent of the decrease. For example, for males in Greater Sydney (Panel (c)), SA3s in the eastern and north-eastern suburbs (generally accepted to be the richer suburbs) appear to have experienced larger drops in mortality than other suburbs. Further, gains appear to have been greater for men than for women, indicating a convergence of male longevity to that of females and consistent with the international experience (Banks et al 2021, Goldin and Lleras-Muney 2019).

Poverty Measures

We obtain population counts and socioeconomic indicators at the SA3 level from the Census. We utilise three different measures to rank SA3s from richest to poorest. First, the percentage of people aged 15

[3] This includes non-spatial SA3s such as Migratory, Offshore and Shipping codes. There are 333 spatial SA3s. Our sample is made up of 328 SA3s since we exclude those with very small populations.

years and over in each SA3 whose highest level of educational attainment is Year 11 or lower, a measure used by Currie and Schwandt (2016a, 2016b) and Baker et al (2019). Second, the percentage of people in each SA3 with household income below the poverty line[4]. Last, to explore inequality in mortality with respect to a broader set of economic resources, we use the Index of Relative Socioeconomic Disadvantage (IRSD) produced by the ABS (ABS 2018a). This index is particularly useful because it captures several socioeconomic characteristics.[5] These different rankings are highly correlated with each other. In the Appendix (Figure A1 to A3) we provide heat maps showing the spatial and time variation in these three rank variables.

Healthcare Data

Healthcare data is obtained upon agreement from both the AIHW (2001-12) and the Department of Health (2013-18). Specifically, we collect data on the number of doctors in each SA3.[6]

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[4] We use a poverty line or low-income cut-off to capture households in poverty based on the Henderson poverty line (inclusive of housing costs) for a couple household with two dependents. As Census income data is collected in binned ranges, we needed to adjust the poverty line cut offs. In 2001 and 2006 our selected cut-off is a weekly household income of less than $500 and in 2011 and 2016 the cut-off is a weekly household income of less than $800 (dollar values in nominal terms). See https://melbourneinstitute.unimelb.edu.au/publications/poverty-lines.

[5] For example, it includes variables such as the percentage of households without an internet connection, the percentage of people who do not speak English well and the percentage of employed people classified as Labourers.

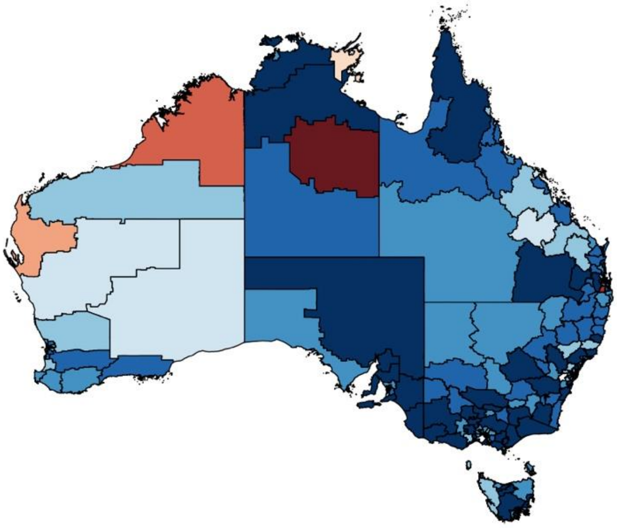
[6] The data from 2001-12 is provided for SA3s as defined by the 2011 ASGS consistent with our mortality and Census data. The data from 2013-18, however, provides the number of doctors in SA3s as defined by the 2016 ASGS. We use ABS geographical correspondence data to reassign it to 2011 SA3s codes. The ABS defines the quality of correspondence between the 2011 and 2016 SA3s as 'good', with 96.9% of SA3s remaining effectively unchanged (ABS 2016b).

Figure 1: Change in three-year mortality rates between 2001-03 and 2016-18

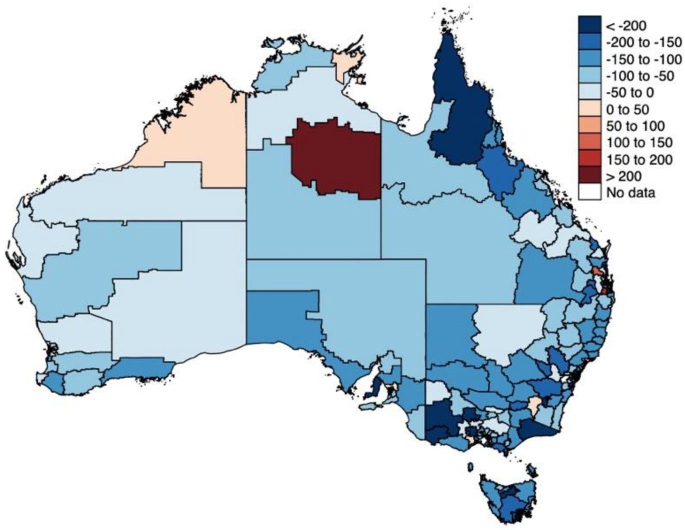
Measured in deaths per 100,000

Australia

Males

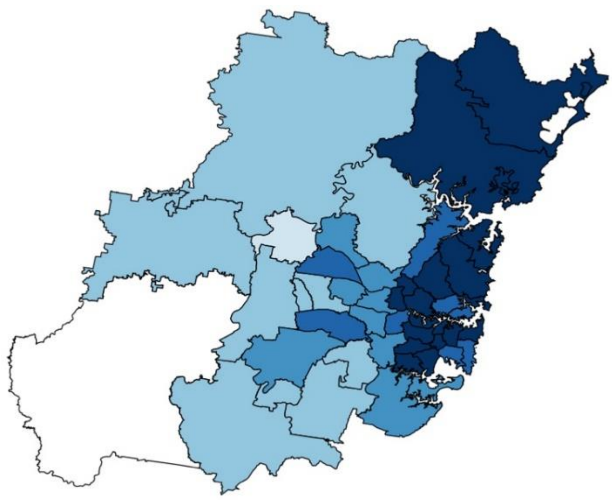


Females

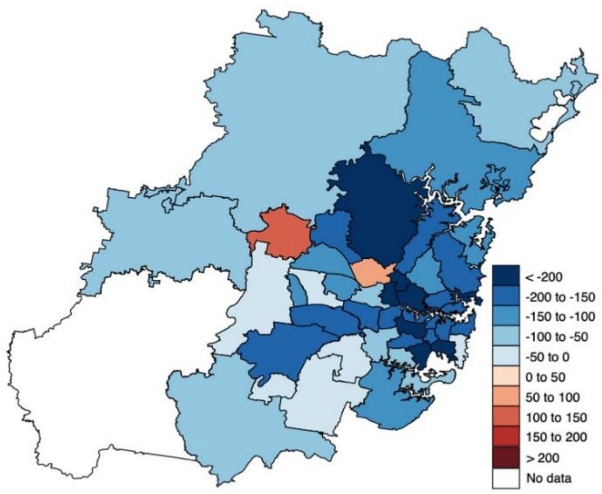


Greater Sydney

Males



Females



Notes: Australian map is excluding Christmas Island, Cocos (Keeling) Islands, Lorde Howe Island.
Source: Author's calculations using mortality data from 2001-2018.

4. Methodology

As discussed in the introduction we focus on mortality trends in groups of local regions, where the local regions in a group all have a similar poverty ranking according to our chosen socioeconomic indicator. To construct these groups, we first rank all SA3s by an indicator of socioeconomic status, and then divide the SA3s into 20 bins - each representing 5 per cent of the Australian population. The grouping of the areas into bins helps to overcome sampling issues related to migration (discussed further below), by ensuring that we always compare population groups of fixed size. We then study age-specific mortality rates by age and gender within each bin across four time periods. To simplify the description of our model, we will focus on the case where statistical areas are ranked by the proportion of their population living in poverty.[7] These statistical areas are ranked by their poverty rates *every five years* so that we can consistently compare mortality in the lowest and highest ranked slices of the population.

In the model, as given in Equation (1), the independent variable, denoted $Rank_{a,v,t}$, contains the percentile rank of each of our 20 SA3s groups, ordered from richest (rank 1) to poorest (rank 20), in each Census year. The dependent variable, $Mortality_{a,v,t}$ is the three-year mortality rate for age group a, in ventile v at time t. This is constructed by summing up the total number of deaths in a ventile (for a given age and gender group) over a three-year period and then dividing by the population of that ventile.

$$Mortality_{a,v,t} = \alpha + \beta Rank_{a,v,t} + \epsilon_{a,v,t} \quad \textbf{(1)}$$

The gradient β represents the relationship between socioeconomic disadvantage and mortality. If poor regions have higher levels of mortality than rich regions, and so there is mortality inequality, this would be captured by a positive β. Furthermore, a larger value of β indicates greater inequality. Alternatively, if mortality rates were equal across regions, then β would be equal to 0.

We estimate (1) using the four periods of data: 2001-03, 2006-08, 2011-13 and 2016-18. We do this separately for both men and women and for each of nine age ranges. It is important to note that this model does not establish a causal relationship of income on health, or more specifically on mortality.[8]

[7] As noted in the Data section, we use three socioeconomic indictors to rank the SA3s.

[8] In fact, causality could also run in the reverse direction. Morbidity and mortality are not only impacted by income differences; an individual's health status can also impact how productive they are throughout the life cycle and how many years of superannuation benefits are potentially collected in old age. This issue is a less of a problem since we

Rather, our aim is to capture the strength of the connection between lifetime income and economic resources and health and inform our understanding of mortality inequalities in Australia over the last 20 years.

Figure 2 is a stylised graph presenting hypothetical fitted regression lines in two periods, intended to aid interpretation of the results. Importantly, we are interested in both mortality inequality in a given period of time (the slope of the regression line) as well as the change in mortality inequality over time (the change in the slope). The blue line represents the earlier year (2001) and the green line represents the later year (2016). The green line is always below the blue line, corresponding with the general decline in death rates over the last 20 years.

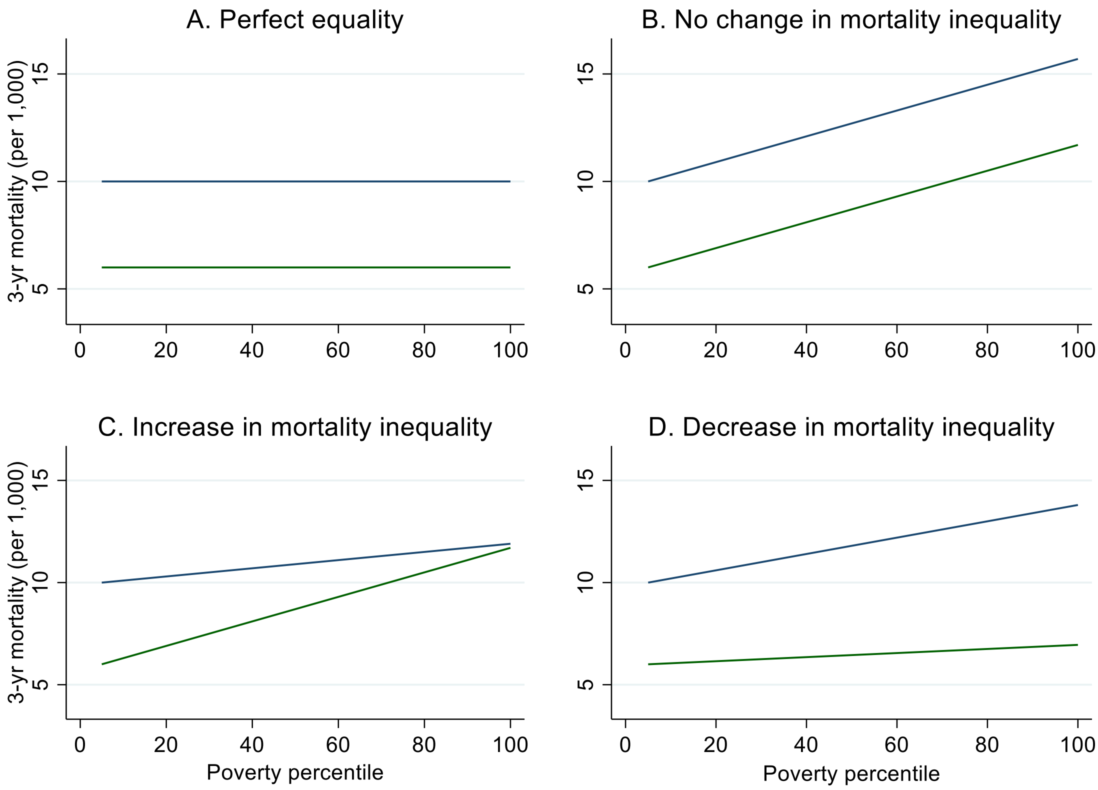
A horizontal line indicates no mortality inequality – that is, the mortality rate in a given SA3 group is independent of its SES rank. Thus, Panel A shows a situation of perfect equality across both the earlier and later period.

In contrast, an upward sloping line is indicative of mortality inequality – that is, high SES regions have lower mortality rates than low SES regions. For example, in Panel B in 2001 the predicted mortality rate for the richest SA3 group – with the lowest possible rank of 1 – is 10 deaths per 1,000, whereas for the poorest (highest ranked) SA3 group it is 15.7 deaths per 1,000. Furthermore, a parallel shift down of the regression line indicates that the mortality rate has decreased by the same amount for all SA3 groups. This is the case in Panel B. That is, mortality inequality exists in both periods, but the extent of the inequality is unchanged over time.

The bottom two panels show meaningful changes in mortality inequality across time. In Panel C mortality rates are falling more for rich regions than poor regions. This indicates *increasing* mortality inequality between 2001 and 2016 – an unfavourable outcome. In Panel D, mortality is falling more for poorer regions than richer regions, resulting in a convergence of death rates over time, or a *decrease* in mortality inequality.

do not rank individuals according to their income. But the effect might still be picked up by the estimate β, particularly when we use poverty rates to construct the rank variable.

Figure 2: Stylised Figures



Notes: These are stylised figures, with the blue and green line representing hypothetical fitted regression estimates of Equation (1) in 2001 and 2016. The horizontal axis is the percentile rank of SA3 group based on a poverty ranking. A percentile or rank of 1 corresponds to the lowest poverty ("richest") and 100 indicates the percentile with the highest poverty ranking.

There are three important issues to clarify about the methodology. First, when using mortality data for small geographic areas, measurement error caused by small death counts is a potential problem. For this reason, we calculate three-year, as opposed to one-year mortality rates. Furthermore, we analyse the mortality rates of *groups* of SA3s of equal population size, as opposed to individual SA3s. This is important since small SA3s will have small or zero death counts in certain age and gender groups, and cause of death categories. Aggregating SA3s into groups significantly increases the size of the cells, thus reducing measurement error. This is the same approach used by other studies in the literature (see Currie and Schwandt (2016a, b) and Baker et al (2019)).

A second problem when using geographical regions is selective migration, that is, net migration of "healthy" people out of poor regions and into regions with higher incomes. For example, healthy individuals may seek to match with higher paying jobs that are more readily available in richer regions. So, even without any change to individual health, it might *appear* that health inequalities are increasing, that is, the positive coefficient β would increase in magnitude over time. This is an important concern for studies that use characteristics of geographical regions to proxy for lifetime income (see Singh and Siahpush 2006, Wang et al 2013, Chetty et al 2016, Murray et al 2016, Currie and Schwandt 2016a, 2016b, González and González 2018, Baker et al 2019). The approach we use mitigates this problem by allowing $Rank$ to vary over time, following Currie and Schwandt (2016a, 2016b). Specifically, we rank and group SA3s into 5 percent groups of the population separately in each Census year, thus accounting for SA3s growing or shrinking in population or becoming richer or poorer over time. For example, if some healthy people migrated out of the poorest region as defined by the 2001 rankings, the model specification would account for this by creating a 'new' poorest five percent population group in 2006. In contrast, if we did not re-rank SA3s each census year, the estimates would produce an artificial increase in mortality for this ventile.

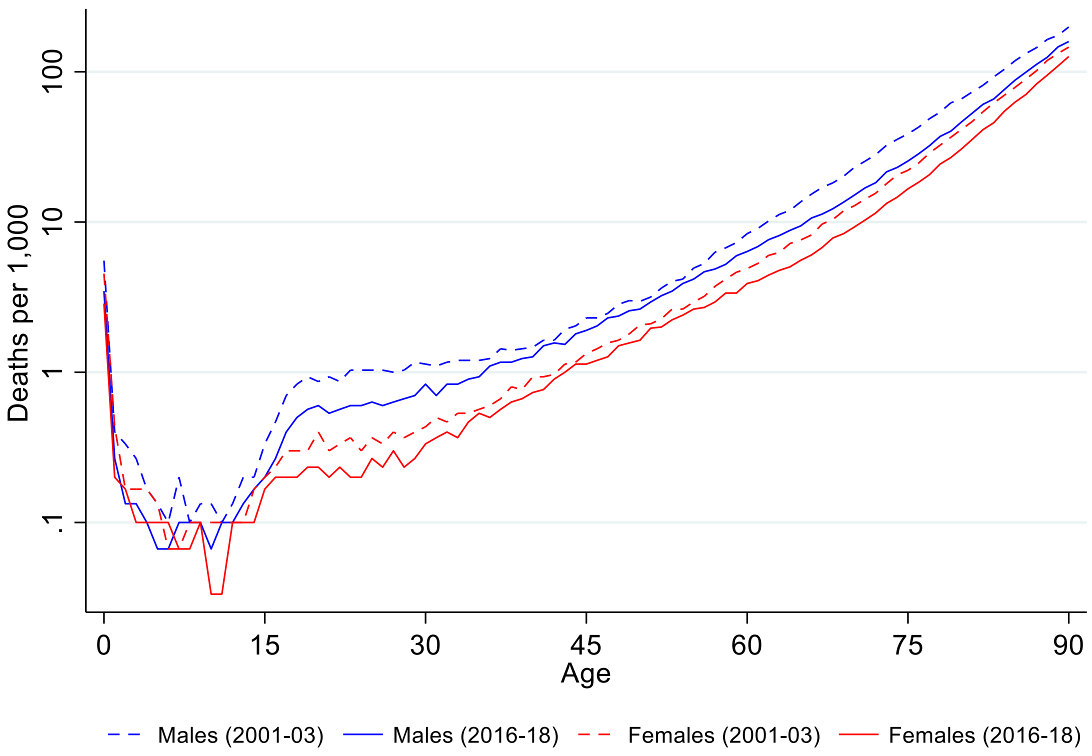
There may also be changes in the age structure within age groups. To account for changes in the age structure within age groups, we age-standardise mortality rates by the age group bands for all years using the population data from the first year included in our analysis (2001).

5. Results

5.1 Trends in nationwide mortality

We start by describing general trends in life-cycle mortality in Australia over the past 20 years. Figure 3 shows death rates per 1,000 people for every age from 0 to 90 and above, for both males and females. This figure provides us with several important insights. The first thing to note is that mortality rates by age follow a 'hockey stick' shaped pattern (Baker et al 2019). Infants have high death rates, however, this declines sharply after infancy, with children having the lowest mortality rates of all ages. In the early teenage years mortality rates increase and continue to rise with age. Strikingly, infants have similar mortality rates to people around the age of 60.

Figure 3: Age-Specific Death Rates in Australia



Notes: One year mortality rates 2001-03 (averaged), 2016-18 (averaged). This figure shows annual mortality rates by gender and single year of age. Rates are based on 3-year averages to reduce the variability in mortality rates at younger ages when mortality is a rare event.
Source: ABS 2019b.

The second insight relates to the stark gender gap in mortality. At virtually every age, men have higher mortality rates than women. This is the case in both 2001-03 and 2016-18. Furthermore, from young adulthood onwards, males in 2016-18 still have higher mortality than females in the initial period, 2001-03. The rise in death rates that occurs in early teen years is also more pronounced for males than females – with death rates increasing more rapidly for males than females from around 15 years old. Analysis of mortality rates in Canada and the US also confirms a large mortality gender gap for teens and young adults.

Finally, death rates are lower in 2016-18 than they were in 2001-03 at essentially every age, and for both males and females. This is a remarkable outcome considering this relatively short time period. In fact, for most ages, annual death rates (averaged over three years) have declined across each of the four time periods. Children and young people under 30 have experienced the largest percentage falls in the mortality rate. This indicates that well-documented, recent gains in life expectancy in Australia have not only been driven by increases in longevity occurring at older ages, but also by lower mortality at younger ages. It is important to investigate whether these declines in mortality have been equally shared across regions, or if there is a link between mortality outcomes and the socioeconomic characteristics of regions.

5.2 Trends in all-cause mortality inequality

Before examining the age-specific results, we present results aggregated across all age-groups. Figure 4 presents the fitted regression lines from the estimation of Equation (1), for males and females in the left and right panel, respectively. The four lines in each panel represent the four, 3-year periods, beginning in 2001, 2006, 2011 and 2016, respectively. In each period there are 20 points, one for each ventile[9]. This figure summarises the relationship between the 3-year mortality rate per 1,000 people and the ranking of SA3 groups by an indicator of SES. For clarity, we focus throughout the paper on our results using poverty rates. However, results using the IRSD and the education indicator are shown in the Appendix and are discussed in Section 5.2.2 Alternative Ranking Measures below.

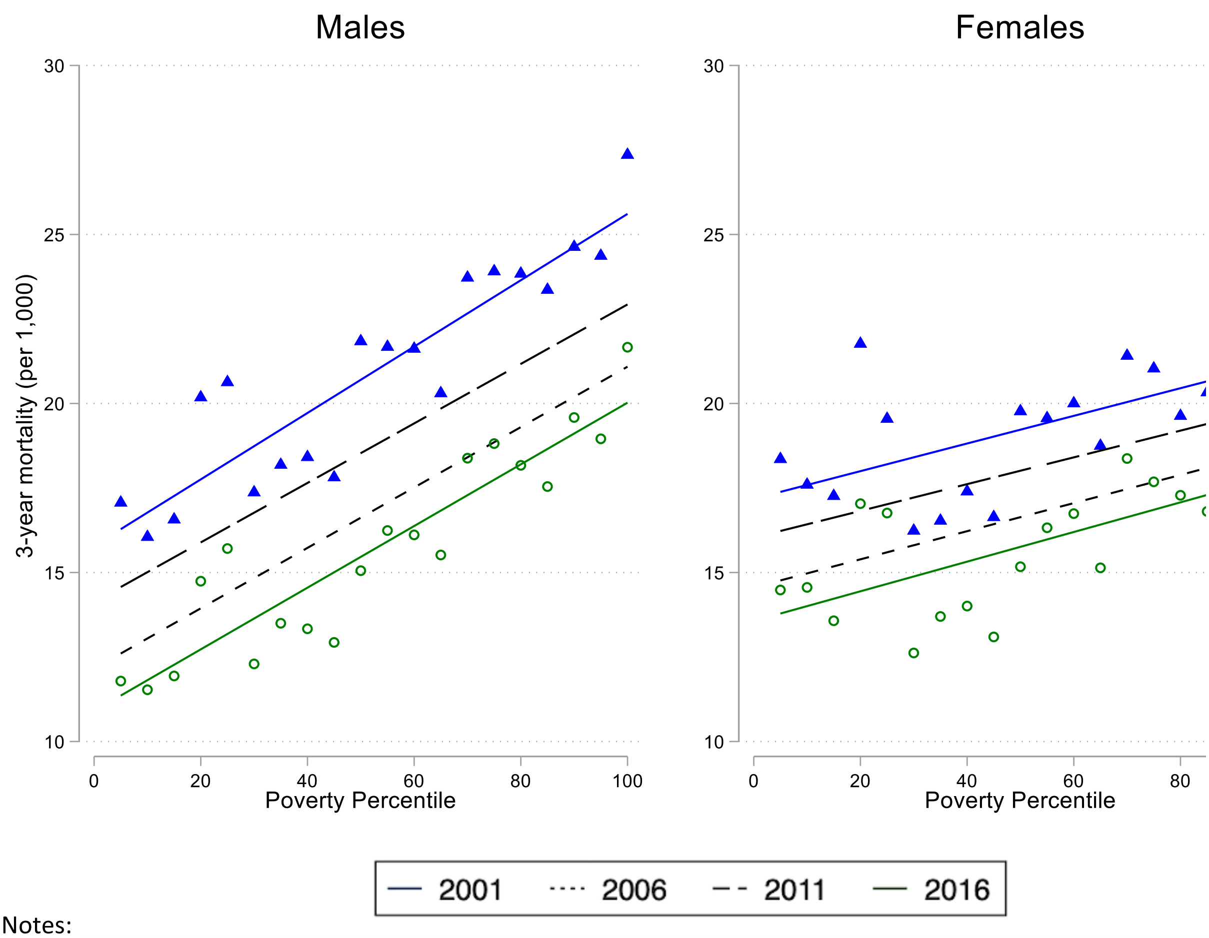
From this figure, we can clearly see that the fitted lines are positively sloped in all years, for both males and females, indicating substantial mortality inequality. The lines move down in each time period, signifying falling death rates over time. However, it appears that in aggregate, there is very little change in the slopes of these lines, that is, there is no clear change in mortality inequality. This figure might conceal important age heterogeneity and we examine this below in Section 0.

5.2.1 All-cause mortality: results by age

Figure 5 and Figure 6 reproduce the results in Figure 4, but now by age as well as by gender. We observe substantial mortality inequality in Australia for both males and females, and across virtually all age groups. This implies that death rates are higher in SA3 groups which have a higher proportion of households in poverty (low SES, poorer regions), than in SA3 groups with relatively fewer households in poverty (high SES, richer regions).

[9] For visual clarity, we omit the points themselves in 2006 and 2011.

Figure 4: Mortality inequality by poverty ranks for all ages



Notes:
groups of SA3 grouped by their poverty rate, from lowest poverty (at the 1st percentile) to highest poverty (at the 99th percentile). Each bin represents a ventile, that is, a group of SA3s accounting for about 5% of the national population in the respective year.

Columns (1)-(2) of Table 1 show the slope of the fitted regression lines, β, from Equation (1) for each age and gender sub-group in 2001-03 and 2016-18. These fitted lines are also plotted in Figure 5 and 6, in blue for 2001-03 and green for 2016-18. These two columns reveal that the mortality inequality is statistically significant for all age-gender groups in both years, with the exception of females aged 5-14 in 2001-03 and females aged 75+ in both periods.

Turning to the change over time, as we noted for Australia as a whole, the data show a fall in the mortality rate between 2001-03 and 2016-18: the green line is always below the blue line in all panels of Figure 5 and 6. Furthermore, for the most part, the death rates have been falling across each of the intervening time periods. For brevity, we focus on mortality changes between 2001-03 and 2016-18, only pointing out important inconsistencies occurring in intervening years.

Overall, there has not been any distinct change in mortality inequality over the period. Looking at **Table 1** Columns (3)-(4), across most age and gender subgroups there is not a significant increase or decrease in the slope of the fitted regression line. However, two age groups are exceptions and we now discuss those in detail.

First, in a concerning development, there has been a significant increase in mortality inequality for middle aged people – specifically, for males aged 45-54 and for females aged 55-64. For males, between 2001-03 and 2016-18, death rates fell in richer SA3 groups, but stagnated in poorer groups, and even *increased* in the very poorest ventile, generating the higher mortality inequality observed.[10] The slope of the fitted line in Figure 5 increases by 0.018 deaths per 1,000 and this change is significant at the 10 per cent level (Table 1, Columns (3)-(4)).

For females aged 55-64 – one age-group older than males – increasing mortality inequality is also observed. In this case, death rates fell across all groups, even in very poor regions. Thus, the increase in mortality is generated by greater falls in richer SA3s than poorer SA3s. The magnitude of the increase in slope is the same as for males aged 45-54, that is, 0.018 deaths per 1,000, also significant at the 10 per cent level *(Table 1*, Columns (3)-(4)).

The second important change in mortality inequality is declining mortality inequality for teenagers and young adults aged 15-24. Death rates are falling for young people across all SA3 groups, with this convergence between the rich and the poor being driven by larger falls in mortality rates in poor regions than in rich regions. The size of the decrease in the slope of the fitted line is 0.006 deaths per 1,000 for males, and 0.004 deaths per 1,000 for females – both of which are significant at the 5 per cent level (Table 1, Columns (3)-(4)). This is a positive

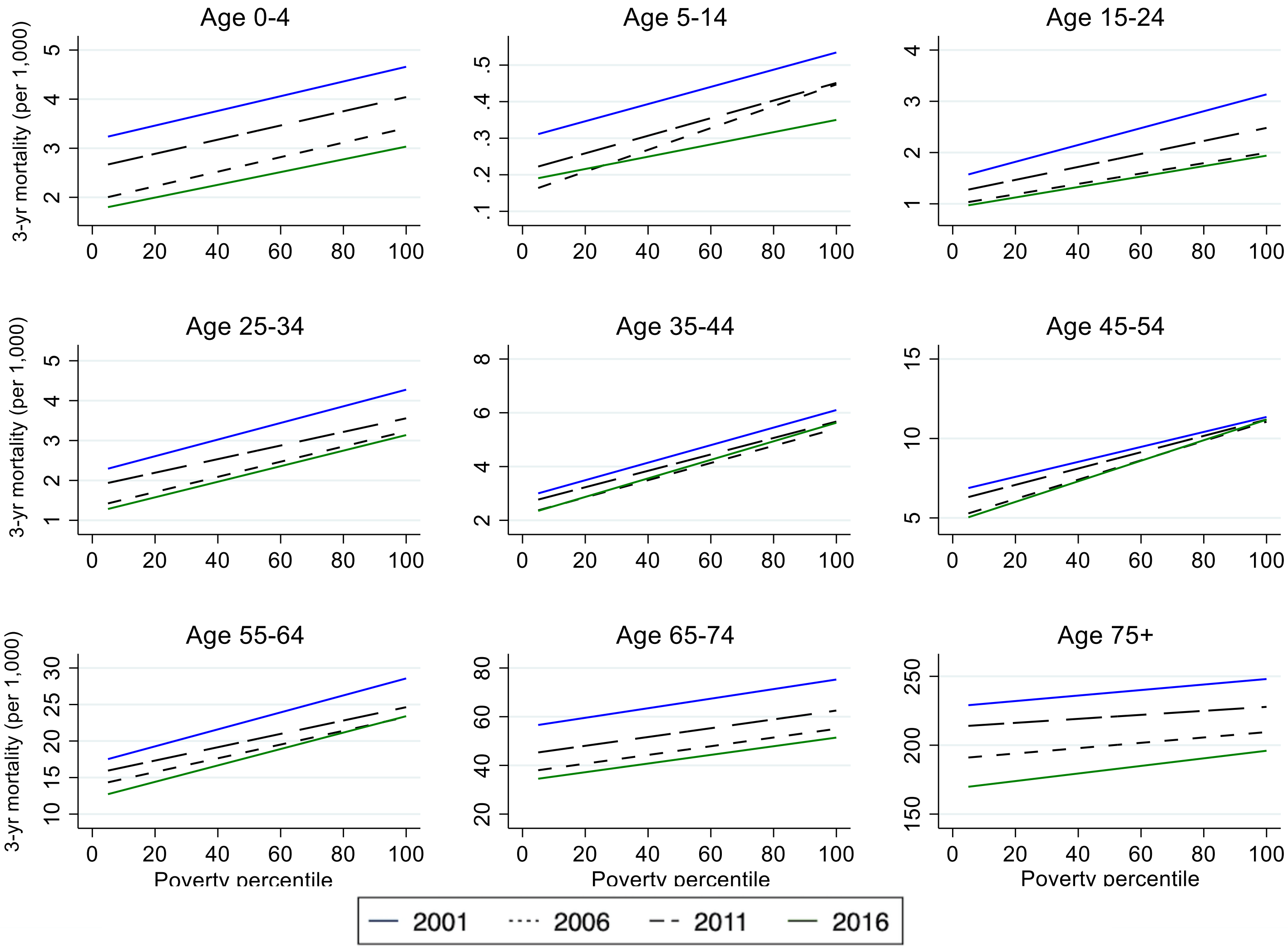
[10] Specifically, in the poorest SA3 group the death rate increased from 11.507 deaths per 1,000 to 13.669 deaths per 1,000. In contrast, the richest region saw mortality fall from 5.987 to 5.526 deaths per 1,000.

outcome, indicating that that more disadvantaged youth are ‘catching up’ in terms of death rates. Nevertheless, in 2016-18 substantial mortality inequality remains. For example, looking at males aged 15-24 in Figure 5, as indicated by the green line, in 2016 a person in the poorest SA3 group is twice as likely to die as one in the richest SA3 group. There is still room for progress in equalising mortality rates across regions.

Table 1: All-cause Mortality Inequality by poverty ranks, by age and gender Slope of fitted regression line				
	2001-03	**2016-18**	**Difference**	**p-value o differenc**
Gender/Age	(1)	(2)	(3)	(4)
Males				
0-4	0.015***	0.013***	-0.002	0.505
5-14	0.002***	0.002**	-0.001	0.326
15-24	0.016***	0.010***	-0.006	0.027**
25-34	0.021***	0.020***	-0.001	0.811
35-44	0.033***	0.034***	0.002	0.792
45-54	0.047***	0.065***	0.018	0.088*
55-64	0.116***	0.112***	-0.004	0.815
65-74	0.197***	0.178***	-0.019	0.640
75+	0.200*	0.275***	0.075	0.432
Females				
0-4	0.014***	0.010***	-0.004	0.191
5-14	0.0008	0.001*	0.001	0.485
15-24	0.009***	0.005***	-0.004	0.025**
25-34	0.009***	0.008***	-0.001	0.569
35-44	0.014***	0.016***	0.002	0.562
45-54	0.024***	0.033***	0.009	0.144
55-64	0.040***	0.058***	0.018	0.063*
65-74	0.096***	0.115***	0.019	0.368
75+	0.016	0.092	0.076	0.360

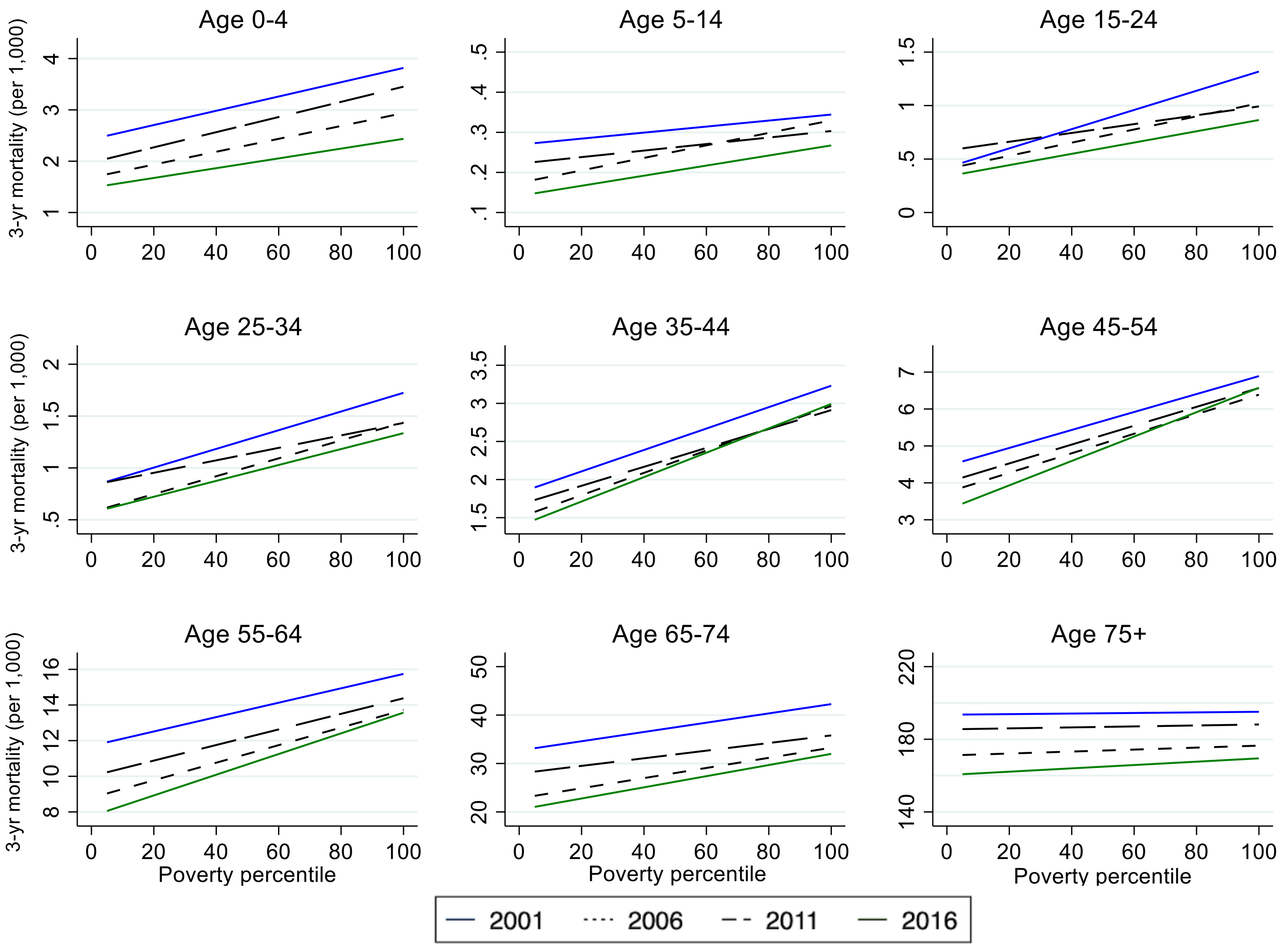
Notes: Each cell in Columns (1) and (2) gives the estimated coefficient on rank from Specification (1) for the indicate gender and year. Column (3) gives the difference, equal to (2) – (1). Column (4) shows the p-value for the test significance of the difference in (3). p-values calculated using robust standard errors: *** p<0.01, ** p<0.05, * p<0

Figure 5: All-cause Mortality inequality by poverty rank for males



Notes: Three-year mortality rates for males in nine age groups. Fitted regression lines estimating Equation (1), by poverty percentile ranking with lowest poverty at the 1st percentile and highest poverty (at the 99th percentile). lowest poverty (at the 1st percentile) to highest poverty (at the 99th percentile).

Figure 6: All-cause Mortality inequality by poverty rank for females



Notes: Three-year mortality rates for females in nine age groups. Fitted regression lines estimating Equation (1), by poverty percentile ranking with lowest poverty at the 1st percentile and highest poverty (at the 99th percentile).

5.2.2 Alternative Ranking Measures

To check the robustness of our findings, as an alternative to constructing ventiles using poverty rates we construct ventiles to form the $rank$ variable using the proportion of high school dropouts ('education') and the Index of Relative Socioeconomic Disadvantage (IRSD). We then re-estimate Equation (1) using these alternative indicators in turn. The results using IRSD and education to rank ventiles are presented in Appendix Figures A4-A7 and Tables A2-A3. Overall, the results are qualitatively consistent with our main findings using poverty rates to rank SA3s. One difference of note is that when using IRSD the decrease in mortality inequality for men and women aged 15-24 is smaller in magnitude and no longer significant.

5.3 Trends in inequality in mortality by cause

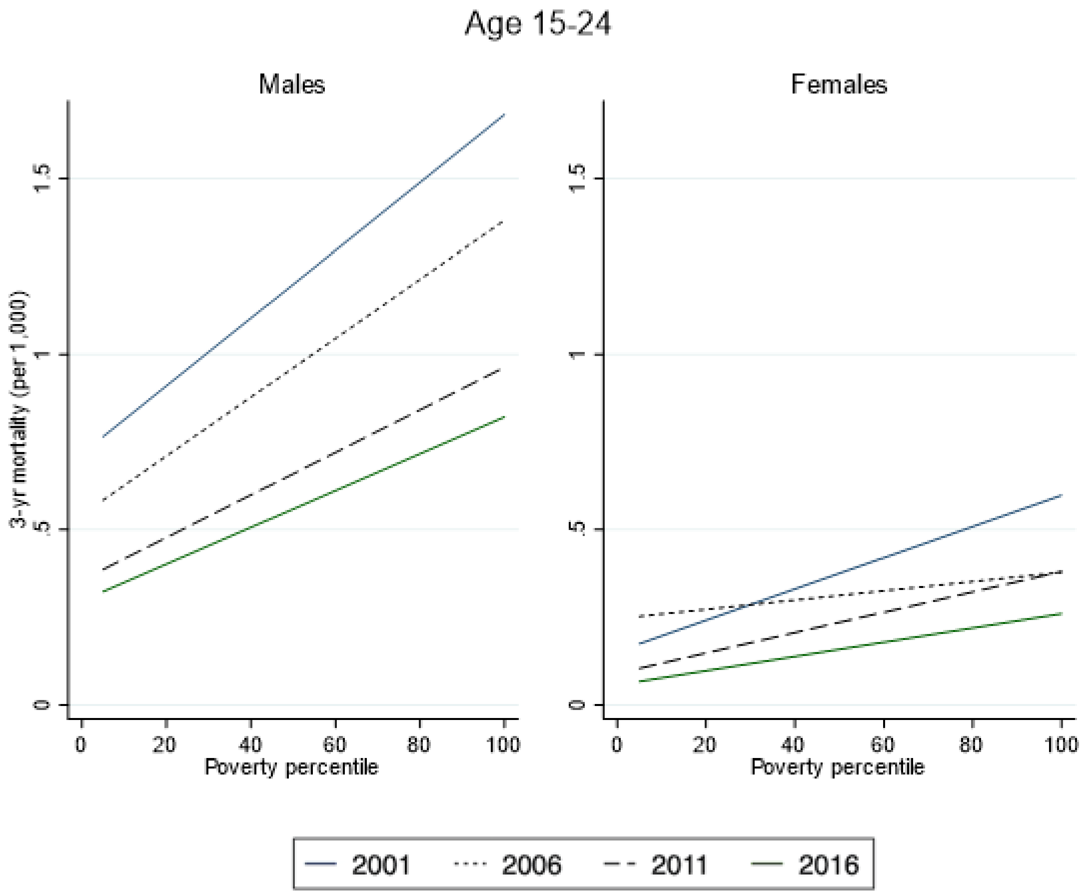
To shed light on the mechanisms underlying the age-specific trends, we analyse trends in causes of death across all age groups. Appendix Table A1 lists the categorization of causes respective ICD codes. Here we focus our discussion on the leading causes of death for each age group. As above, we use poverty rates as our socioeconomic indicator to rank the SA3s. Figures of results by age and cause of death, similar to Figure 4 and 5, are provided in Appendix C (Figures B1 to B12).

For both males and females aged 15-24 the leading cause of death in 2016-18 was suicide, followed by land transport accidents and accidental poisonings (Table A4). Deaths from "all external causes of morbidity and mortality, excluding suicides" (hereby "death by external cause") have been declining over the past 20 years.[11] For males aged 15-24, deaths by external cause fell by around 0.648 deaths per 1,000 between 2001-03 and 2016-18, and for females the decline was smaller at 0.219 deaths per 1,000.

Furthermore, our results show a significant decline in mortality inequality for death by external cause, which is key in explaining the decline in all-cause mortality inequality for male and female teenagers and young people (Figure 7). That is, death due to external cause has declined more in low socioeconomic areas than in high socioeconomic areas. From Figure 7, the striking gender mortality-gap with respect to these deaths is also evident. Moreover, the decline in death rates and fall in the socioeconomic gradient is greater for males, paving the way for a gradual convergence of mortality rates for deaths by external cause between men and women.

[11] Deaths by external cause (V01–Y98, excl. X60–X84, Y87.0) includes (among other things) transport accidents, accidental injury (e.g. falls), assaults/homicide, events of undetermined intent and complications of medical and surgical care. Specifically, it includes poisonings of undetermined intent and accidental *but not* intentional poisonings.

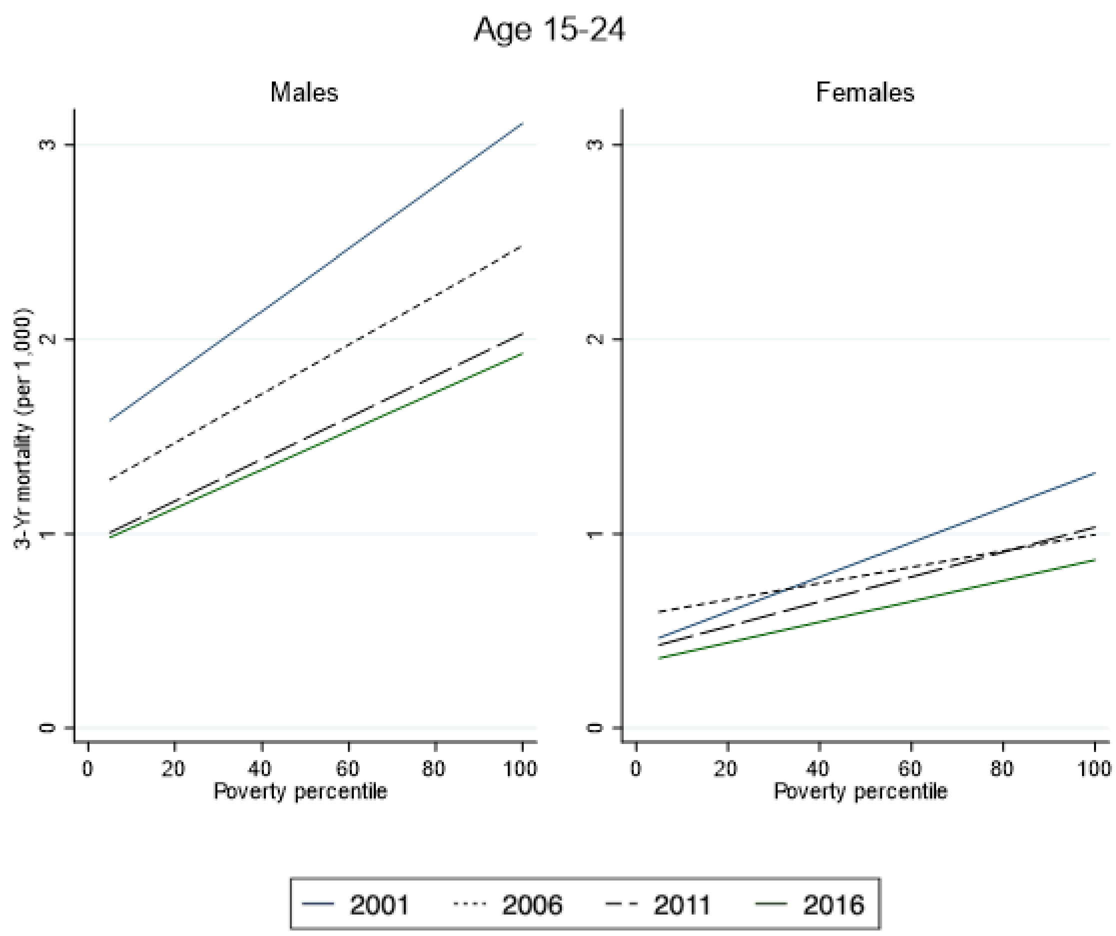
Figure 7: Mortality inequality – death by external cause



Notes: Fitted regression lines estimating Equation (1) for death by external cause, by poverty percentile for males and females aged 15-24.

The fall in mortality inequality for death by external cause has largely been driven by land transport accidents (Figure 8). This decline coincides with substantial efforts by national and state governments to reduce the road toll, for example the 2001-2010 National Road Safety Strategy. This strategy focuses on factors such as road improvements, vehicular safety, speed limits as well as behavioural initiatives focused on drink driving, seatbelt usage and speeding (Public Health Association Australia 2018). It is plausible that these measures have differential effects across groups, for example, these measures may be particularly beneficial for males or people from more disadvantaged backgrounds since they were initially more likely succumb to fatal transport accidents.

Figure 8: Mortality inequality - land transport accidents

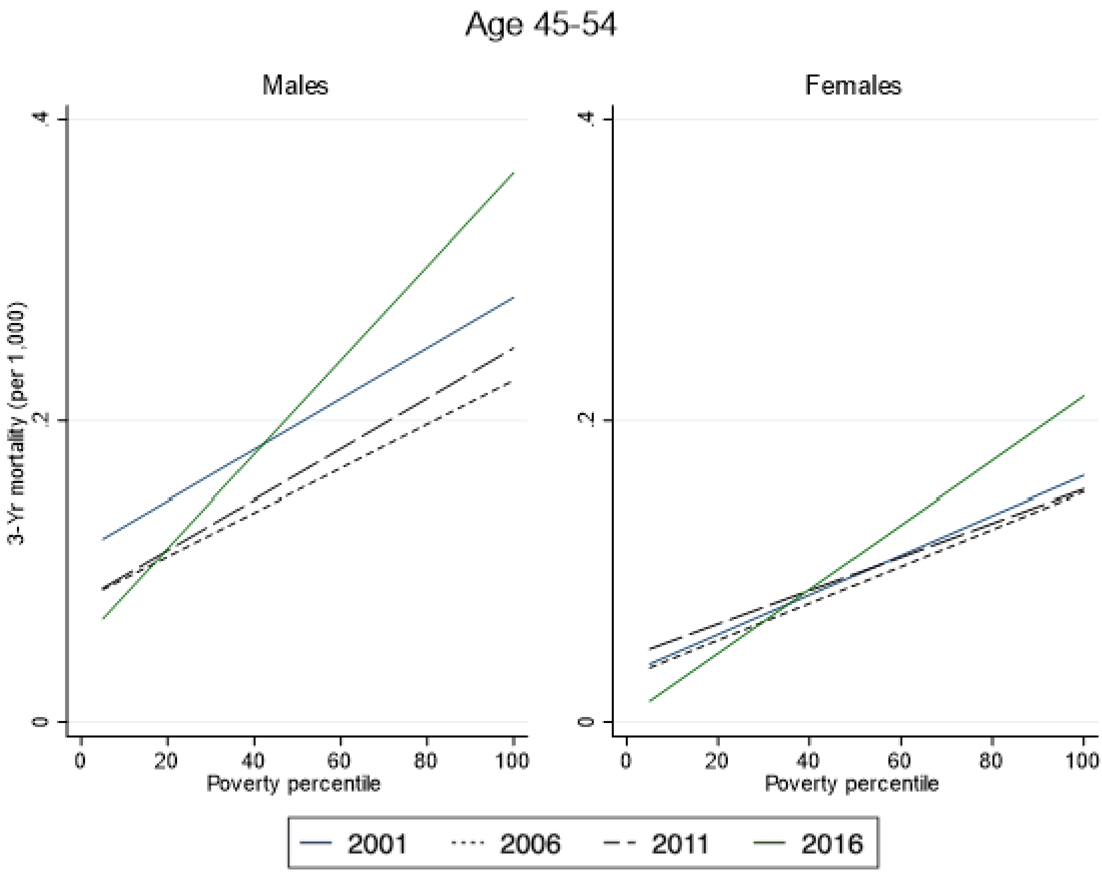


Notes: Fitted regression lines estimating Equation (1) for land transport accidents, by poverty percentile for males and females aged 15-24. See Appendix C, Figure B9 for other age groups.

Suicide is the top cause of death for males and females aged 15-44, and as such, it is particularly important to identify whether those with low lifetime income are disproportionately burdened by high suicide rates (AIHW 2020a). Figure 9 shows suicide mortality is higher for males than females. Moreover, for males the socioeconomic gradient of suicide is larger than for females – indeed, for females in some age groups, there is no socioeconomic gradient at all. For example, for females aged 35-44 in all years except 2011-13, suicide rates do not significantly differ across the ventiles. This finding is robust to using education to rank SA3 groups. Furthermore, for both males and females, there is no consistent trend in suicide death rates or suicide mortality inequality over the past 20 years.

Suicide remains the top cause of death for both males and females until around age 45 where coronary heart disease and breast cancer take over as the leading causes of death for males and females, respectively (AIHW 2020a). As discussed above, we found increasing mortality inequality for middle-aged men and women. From the specific-cause data, it appears that for men aged 45-54, this is being driven by higher mortality inequality due to diabetes. As demonstrated in Figure 10, between 2001 and 2016 – and especially after 2011 – there is a very distinct increase in the slope of the socioeconomic gradient. Death rates due to diabetes fall for the richest SA3 groups but increase for the poorest groups. The increase in the slope between 2001 and 2016 is significant at the 5 percent level. This supports recent research conducted by the AIHW that shows that not only does diabetes have a large socioeconomic gradient, but that diabetes mortality inequality in Australia is increasing (AIHW 2019a). Our findings extend on the AIHW findings for all age groups, showing that this increase in inequality over time is driven by the middle-aged. Although the exact mechanisms through which poverty relate to diabetes is unresolved, Williams et al (2010) found that in Australia, smoking and physical activity partially mediate (explain 27%) of the relationship between low education and type 2 diabetes.

Figure 7: Mortality inequality - diabetes



Notes: Fitted regression lines estimating Equation (1) for diabetes, by poverty percentile for males and females aged 45-54. See Appendix C, Figure B2 for other age groups.

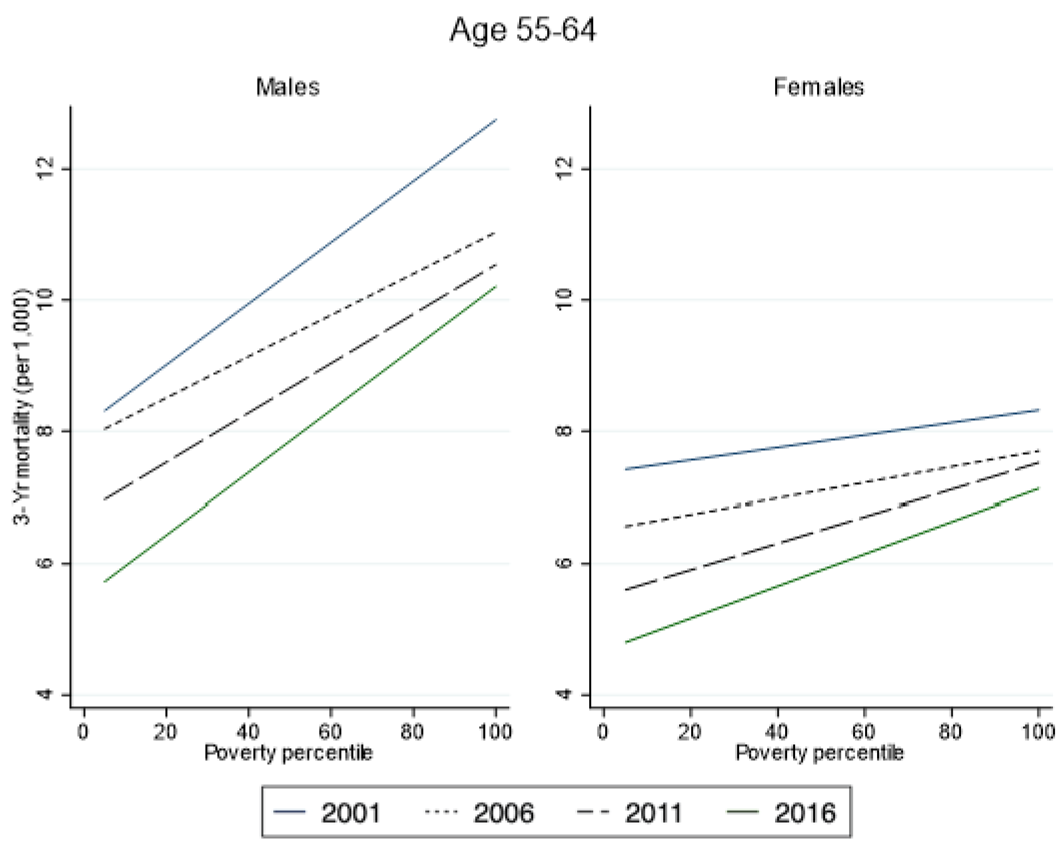
In contrast, from the specific-cause data, it appears that for middle-aged women higher mortality inequality is being driven by cancer deaths. In fact, for women, there is increasing cancer mortality inequality for all age groups 45 and above. As evident in Figure 8, cancer death rates are falling for women aged 55-64 across all SA3 groups, but the drop in death rates is significantly larger for those in richer regions than poorer regions. The magnitude of the increase in the slope of the regression line is 0.015 deaths per 1,000 people, which is significantly different from 0 at the 1 per cent level.

Breast cancer is the most commonly diagnosed cancer for females, and for women aged 35-60, it is the most common cause of cancer deaths (AIHW 2019b).[12] Mortality due to breast cancer, like all cancers, is

[12] At age 60, lung cancer overtakes breast cancer as the most common cause of cancer deaths for women.

affected by exposure to risk factors, the stage at which the cancer is diagnosed and effectiveness of available cancer treatments (AIHW 2019b). The fall in cancer death rates, which strongly favours the rich, coincides with an increase in breast cancer survivability, as measured by the 5-year relative survival rate, from 85.5% to 91.1% from 1997-2001 to 2012-16 (AIHW 2020b). Higher survivability encompasses both earlier and/or more accurate detection of cancer and increased effectiveness of treatments. Our finding of higher mortality inequality due to cancer may indicate that better detection and/or treatment of breast cancer is disproportionately favouring the rich. To investigate this more closely, finer cause of death data which indicates different cancer cites/types is required. This remains an interesting avenue for future research.

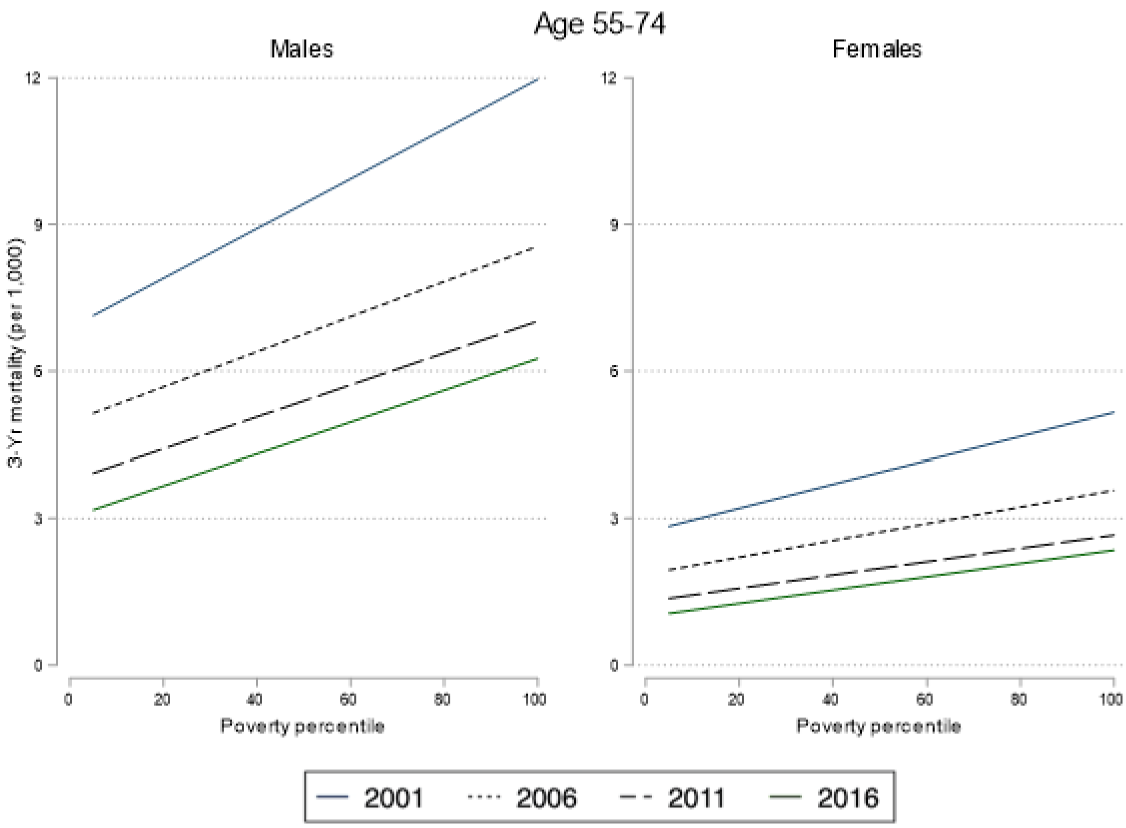
Figure 8: Mortality inequality - cancer



Notes: Fitted regression lines estimating Equation (1) for cancer, by poverty percentile for males and females aged 45-54. See Appendix C, Figure B1 for other age groups.

Another interesting trend emerges for older men and women aged 55-74. For this age group coronary heart disease (or ischaemic heart disease) is the top cause of death for men, and the fourth ranked cause of death for women. The two main clinical manifestations of coronary heart disease are heart attack and angina (AIHW 2017). Since the late 1960s, there has been significant falls in mortality due to coronary heart disease, driven by both prevention and treatment. However, since around 2000, the rate of decline has slowed for those under 75, as key risk factors for developing cardiovascular diseases have become more prevalent at earlier ages (AIHW 2017). These risk factors include obesity, smoking, poor nutrition and a sedentary lifestyle. Interestingly, mortality inequality with respect to coronary heart disease *fell* for males and females aged 55-74 (Figure 9). That is, poorer SA3 groups have experienced greater falls in mortality due to coronary heart disease than richer groups. These declines appear to be concentrated early in the 2000s, for example, between 2001-2006, perhaps indicating that longevity improvements associated with coronary heart disease are slowing down. This decrease in mortality inequality coincided with a large increase in the prescriptions of lipid modifying agents (statins) to treat high cholesterol between 1998-2007 (AIHW 2011). Thus, the widespread availability of effective medication to treat cholesterol may have contributed to this convergence in death rates for coronary heart disease.

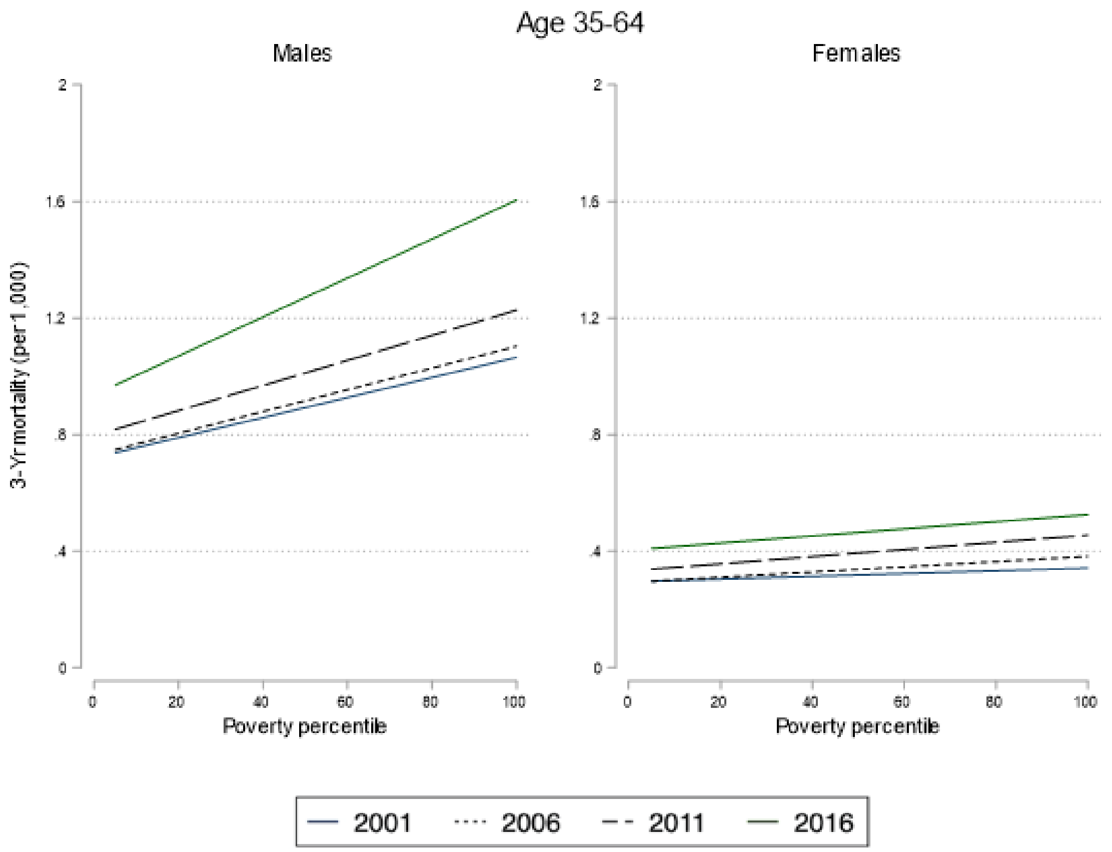
Figure 9: Mortality inequality - coronary heart disease



Notes: Fitted regression lines estimating Equation (1) for coronary heart disease, by poverty percentile for males and females aged 55-74. See Appendix C, Figure B4 for other age groups.

Finally, in the age categories from 35 to 64, there is a clear decrease in mortality rates for all main causes of death with the important exception of deaths of despair (homicides, assaults, alcohol, suicides, accidental drug poisoning). In Figure 10 (and Figure B11) we observe that 2016-18 mortality rates are both higher and exhibit larger socioeconomic gradients than the 2001-3 mortality rates. That is, in 2016-18 deaths of despair are more common among the middle aged (35-64) living in poorer areas than in 2001-3. In contrast, we note that for the age group 25-34 there is no increase in the level of or in the inequality in mortality over this period (see Figure B11). These findings suggest that provision of mental health support across the lifecycle and in particular for the disadvantaged remains an important policy goal. Policy initiatives will need to focus not only on younger adults but will also need to be effective at reducing these deaths among the poor at any age.

Figure 10: Mortality inequality – deaths of despair



Notes: Fitted regression lines estimating Equation (1) for deaths of despair, by poverty percentile for males and females aged 35-64. See Appendix C, Figure B11 for other age groups.

5.4 Geographic Remoteness and Mortality Inequality

A further way to spatially decompose the Australian population is across different levels of population density. Well-established health differentials exist not only between the rich and the poor in Australia, but also between urban and rural and remote areas. For example, those in rural and remote areas have a greater disease burden and shorter life expectancies than those in major cities (AIHW 2019c). One important factor underlying these differences could be difficulties in accessing healthcare resources, particularly GPs and specialists. Other possible reasons include higher incidences of disease risk factors, for example smoking and obesity, greater occupational risks and lower levels of income, education and employment (AIHW 2019c). Another important way in which rural and urban populations differ is their proportion of Aboriginal and Torres Strait Islander populations.[13]

Here we present the results from heterogeneity analysis designed to identify the role of urban and rural mortality differences in shaping the mortality inequality trends we have presented above. For young people where mortality inequality declined, we seek to identify whether this decrease is driven by larger falls in death rates in poorer regional Australia than in more affluent major cities. For middle-aged men and women, we ask: is the increase in mortality inequality driven by bigger falls in death rates in richer urban SA3s than those in poorer rural SA3s?

There are 328 spatial SA3s in our dataset. SA3s form part of a hierarchical structure as defined by the ASGS, in which SA1s are the smallest unit of geography, containing an average population of 400 people. Whole SA1s are aggregated to form SA2s, and whole SA2s are aggregated to form SA3s (ABS 2010).

This is important since the ABS categorises SA1s into one of five categories or Remoteness Areas (RAs)[14], based on an index of relative access to services (ABS 2018b). Using this, we allocate each SA3 in our sample to a RA based on the most common RA of the SA1s in each SA3. We then analyse the extent of mortality

[13] Indigenous people represent a greater share of the population in rural, and particularly remote Australia, than they do in major cities. This is of critical importance given the very significant health and mortality differences between Indigenous and non-Indigenous Australians. Aboriginal and Torres Strait Islander people have substantially higher death rates for all age groups than non-Indigenous Australians (Gracey and King 2009, AIHW 2015). As such, differences between urban and country Australia will perhaps reflect trends in Indigenous death rates. However, comparing mortality trends across remoteness areas is not sufficient to comment on trends in Indigenous mortality, since 61 per cent of Indigenous Australians live in major cities and inner regional areas (ABS 2018b). This work is much better done using individual level data, for example, with the 2016 Death Registrations to Census project (ABS 2018c).

[14] We use the ABS 2011 Remoteness Structures.

inequality using the same methodology but sequentially restricting our sample by first eliminating SA3s classified as Very Remote, Remote or in Outer Regional Australia, and then we further eliminate SA3s in Inner Regional Australia to consider only the Major Cities.

The decrease in mortality inequality we find for males and females aged 15-24 is robust to using Major Cities and Inner Regional Australia only. That is, looking at Columns (3) and (4) from Table 2, there is still a statistically significant difference in the slope of the regression lines between 2001-03 and 2016-18, albeit slightly smaller in magnitude. This suggests that the fall in mortality inequality cannot be solely explained by death rates declining more in poorer parts of outer regional and remote Australia than in cities and bigger regional areas. When we further exclude Inner Regional Australia, we find that while there is still a decrease in mortality inequality, it is no longer statistically significant. This suggests there are meaningful mortality rate declines in poorer Inner Regional areas which are, to some extent, contributing to the convergence of mortality rates between the rich and the poor in the 15-24 age group.

Turning to the increase in mortality inequality for middle aged males between 2001 and 2016 we find that this increase in inequality is driven largely by death rates falling by less in poor SA3s *outside* of Major Cities, than they are inside Major Cities. Specifically, in Figure 14 Panel A, we observe that, unlike for teenagers and young adults, that the increase in inequality is not robust to sample restrictions. For example, when we restrict the sample to Major Cities and Inner Regional Australia only, as in Figure 14 Panel B, the magnitude of the increase drops and is no longer significant (***Table 2***, Column (3)). Further, when using only Major Cities, there is no longer an increase in the slope of the regression line between 2001 and 2016 (***Table 2***, Column (3)). That is, looking at Figure 14 Panel C, the blue and green lines are parallel. This suggests that the divergence in mortality outcomes for poor and rich SA3s is driven by death rates falling by less in poor SA3s in non-urban areas. This is an important finding as it suggests policymakers must direct efforts to improve health inequalities amongst middle-aged males towards rural and regional areas.

Interestingly, for women aged 55-64 the same is not true. This suggests that we cannot attribute the increasing mortality inequality for females aged 55-64 to higher death rates in Outer Regional and Remote Australia.

6. Discussion

6.1 Access to healthcare

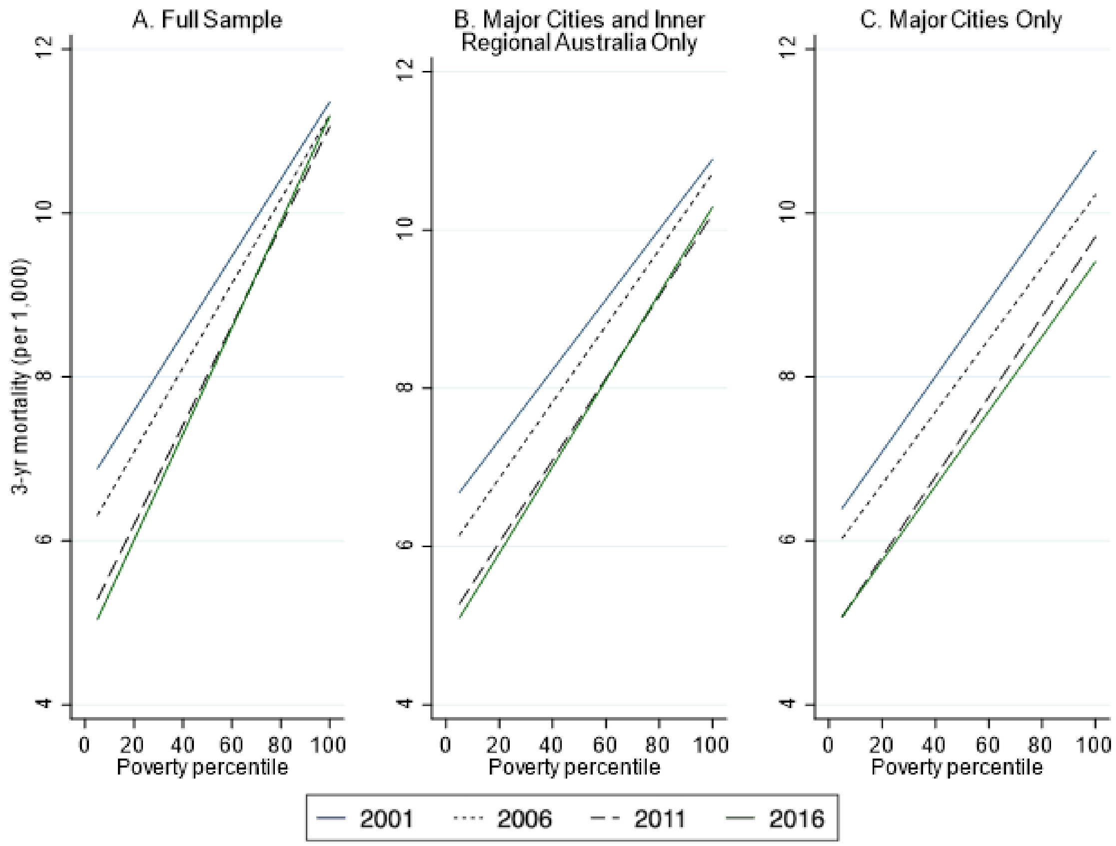
Our results show that, on average, richer people have lower mortality rates than poorer people, and for some, the mortality inequality we observe is getting worse. There are many channels through which higher lifetime income (or related indicators such as higher education levels) can lead to better health outcomes, and specifically, greater longevity. One important factor is access to healthcare, which includes the quality of doctors, nurses and other health professionals, as well as any possible delay in accessing these services and any relevant prohibitive costs. For example, Baker et al (2019) find that in the US, mortality inequality for children fell between 1990-2010. They propose that the reason for this was the large expansion of eligibility for public health insurance for low-income children and expecting mothers between the late 1980s to early 2000s, making healthcare more accessible (see Baker et al 2019, p.348).

Table 2: Heterogeneity analysis by remoteness
All-cause mortality by poverty ranking for select remoteness areas and age groups
Slope of fitted regression line

Gender/Age	Remoteness Area	2001-03 (1)	2016-18 (2)	Difference (3)	p-value of difference (4)
Males					
15-24	All	0.016***	0.010***	-0.006	0.027**
	Major Cities and Inner Regional Australia Only	0.012***	0.008***	-0.004	0.039**
	Major Cities only	0.007***	0.005***	-0.002	0.290
45-54	All	0.047***	0.065***	0.018	0.088*
	Major Cities and Inner Regional Australia Only	0.044***	0.055***	0.010	0.156
	Major Cities only	0.046***	0.046***	0.000	0.962
Females					
15-24	All	0.009***	0.005***	-0.004	0.025**
	Major Cities and Inner Regional Australia Only	0.007***	0.004***	-0.003	0.014**
	Major Cities only	0.005***	0.002**	-0.002	0.109
55-64	All	0.040***	0.058***	0.018	0.063*
	Major Cities and Inner Regional Australia Only	0.035***	0.054***	0.020	0.013**
	Major Cities only	0.038***	0.046***	0.009	0.410

Notes: Each cell in Columns (1) and (2) gives the estimated coefficient on rank from Specification (1) for the indicated age, gender and year. Column (3) gives the difference, equal to (2) – (1). Column (4) shows the p-value for the test of the significance of the difference in (3). P-values calculated using robust standard errors: *** p<0.01, ** p<0.05, * p<0.1.

Figure 11: All-cause Mortality inequality for males 45-54 across different remoteness areas



Notes: Fitted regression lines estimating Equation (1), by poverty percentile for males aged 45-54 across different remoteness areas.

Despite Australia having universal public healthcare, this does not mean there is equal access to healthcare across different regions. We investigate this using the number of doctors per 1,000 people in each SA3 group as a proxy for access to healthcare. It is not hard to see that if there are more doctors per person, then people will find it easier to get an appointment with a GP or specialist, and there will be more doctors on duty in the local emergency departments. It also may make it easier for patients to seek a second opinion and find a doctor they are comfortable communicating with.

We model healthcare access by comparing the number of doctors per capita across the same poverty ranked SA3 groups we use in our earlier analysis. We pool the data for the four separate time periods and regress the number of doctors per 1,000 people in each SA3 group on the poverty rank of the SA3 group, year dummies and year-rank interaction terms. Specifically, we estimate Equation (2):

$$
\begin{aligned}
Per\ capita\ doctors_{vt} = \quad & \alpha + \beta Rank_{vt} + \delta_1 Year2006_t + \delta_2 Year2011_t + \delta_3 Year2016_t \\
& + \gamma_1 Year2006_t * Rank_{vt} \\
& + \gamma_2 Year2011_t * Rank_{vt} \\
& + \gamma_3 Year2016_t * Rank_{vt} + \epsilon_{vt} \qquad \textbf{(2)}
\end{aligned}
$$

Table 3, Column (1) shows the regression without the interaction terms, and Column (2) shows the full specification. Looking at Column (2), in 2001, as the poverty rank increases by 1 (moving from richer ventiles to poorer ventiles), the number of doctors drops by an average of 0.0810 doctors per 1,000 people. This coefficient is significant at the 5 per cent level. The story is the same across the other periods; there is a significant, negative relationship between poverty rank and per capita doctors. This negative correlation between poverty and access to doctors is evidently problematic, and although we cannot on face value conclude that fewer doctors in poorer SA3s is causing inferior health outcomes and higher death rates, it certainly warrants the attention of policymakers.

What is happening to inequality in access to healthcare over time? Firstly, between 2001 and 2016, and particularly from 2011 onwards, the average number of per capita doctors in each ventile or group of SA3s is increasing. This is evident from the positive coefficients on the year dummies in Columns (1) and (2) (which are statistically significant in 2011 and 2016). Now moving to the interaction terms in Column (2), in 2011 and 2016 the coefficients are negative (and in 2011 it is different from zero at the one per cent significance level). A negative coefficient implies that inequality in access to doctors between rich and poor SA3s is getting worse.[15] Hence, we can conclude that there is no significant *convergence* in the number of per capita doctors in rich and poor SA3s between 2001-18.[16]

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[15] One potential caveat here is that in 2010 there was a change in the survey methodology for collecting data on the number of doctors and this affected response rates in 2010-2012. Full details of the change are provided in the Data Appendix. The year dummies will partially control for this issue.

[16] To investigate this further, we use a discrete specification of the rank variable, which allows for possible non-linearities in the relationship between poverty rank and the number of doctors. That is, we again estimate Equation (2), except instead of modelling rank as a continuous variable, we include 19 indicator variables for ventiles 2-20, with the first ventile (rank 1) being the base level dummy. The results are presented in Table A5. This specification

Table 3: Number of Doctors and Poverty rank of SA3

	Dependent Variable: Number of doctors per 1,000 people	
Independent Variables	(1)	(2)
Poverty Rank	**-0.152*** **	**-0.0810** **
	(0.0392)	(0.0382)
Year 2006	**0.412**	**0.163**
	(0.320)	(0.719)
Year 2011	**2.130*** **	**3.753*** **
	(0.423)	(0.957)
Year 2016	**3.014*** **	**4.772** **
	(0.724)	(2.220)
Poverty Rank * Year 2006		**0.0254**
		(0.0430)
Poverty Rank * Year 2011		**-0.145*** **
		(0.0548)
Poverty Rank * Year 2016		**-0.158**
		(0.146)
Constant	**3.251*** **	**2.455*** **
	(0.547)	(0.650)
Observations	1,309	1,309
R-squared	0.041	0.045

Notes: Column (1) reports the regression specification with poverty rank and year dummy variables only. Column (2) also includes poverty rank and year interaction terms and thus displays estimates for Equation (2). 2001 is the base year. Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1.

This persistent inequality in access to healthcare could be a factor contributing to the increasing mortality inequality for middle aged people. Over the past 20 years there have been substantial technological advances in medicine. However, access to new medications and treatments is often only available following consultations with primary physicians and even specialists. Thus, inequality in access to

supports what we found using the continuous rank variable, that is, no evidence of significant convergence in the number per capita doctors in poor and rich regions over time.

healthcare is likely to lead to a differential benefit from medical advancements between the rich and the poor.

Recent research from the Baker Heart and Diabetes Institute provides a troubling example of this. Morton et al (2020) conduct a study of 1.2 million people with type 2 diabetes in Australia over 2007-15 and find that those in low socioeconomic and remote areas are significantly less likely to be prescribed a newer and superior diabetes drug than those in high socioeconomic and urban areas. In an interview with ABC News (Dalzell, 2020), co-author Jonathan Shaw posited that one reason for this may be an undersupply of doctors in more disadvantaged areas, which forces doctors to prioritise cases requiring urgent care instead of updating themselves on new medications which are continuously being made available. Our results, in particular our finding of higher mortality in diabetes deaths for middle-aged men and the greater degree of inequality in more regional areas, are consistent with and support this conjecture.

6.2 International comparison

We compare our findings with Baker et al (2019) and Currie and Schwandt (2016a, 2016b), which investigate trends in mortality inequality in Canada and the US between 1990 and 2010.

What did they find? Baker et al (2019) which conducts a cross country comparison, finds that Canada has lower age specific mortality rates than the US at all ages and for both men and women. Further, between 1990 and 2010 mortality rates fell across time for both Canada and the US. With respect to mortality inequality, Baker et al (2019) found that for children and young adults in Canada mortality inequality held steady but increased significantly for males over 24 and females over 14. In the US, mortality inequality decreased for children and young people, and either remained unchanged or increased marginally for older people (Baker et al 2019, Currie and Schwandt 2016a, 2016b).[17]

We compare Australia to the US, using data from 2011-13 and 2010-12, respectively.[18] Across all age and gender groups, Australia has lower age specific death rates than the US.[19] For both males and females, at ages 25 and above mortality inequality is greater in the US than it is in Australia (Table A6). This is because

[17] See Table A7, which is the same as ***Table 1*** except shows results for the US between 1990-92 and 2010-12.
[18] Data are not available for Canada, so we cannot directly compare Australia and Canada in the same way as we do for Australia and the US.
[19] We cannot directly compare death rates between Australia and the US for ages 0-4 due to inconsistent definitions of infant mortality.

for ages 25 and above, absolute death rates in Australia (and Canada) are much lower than those in the US. This will, to some extent, inflate the socioeconomic gradients in the US relative to Australia, and is not necessarily picking up meaningful differences in mortality inequality between the countries.

For ages 5-24, mortality inequality is either the same or slightly higher in Australia than in the US (Table A6). In fact, at these ages, the US also has lower mortality inequality than Canada (Baker et al 2019). It is important to note that Australia and Canada have very low absolute death rates for these age groups. Both countries have universal healthcare which plays a protective role. This contrasts with the US which has a largely private health system (for a description of the healthcare systems in Canada and the US, see Ridic et al 2012). However since the late 1980s to early 2000s, in the US there was a widespread expansion of public health insurance to poor children and pregnant women, perhaps explaining why mortality inequality for US children and young people has converged to, and even in some cases fallen slightly below, that in Australia and Canada (Currie et al 2008).[20] For example, by 2001 all children under age 19 who lived in households with incomes below the poverty line were covered by the federal and state government health insurance program Medicaid (Currie et al 2008). This means that by 2010/2011, the healthcare system in the US as it applies to children is similar (albeit certainly not identical) to the system in Australia and Canada of free universal healthcare. In addition, by 2010 the healthcare reform in the US had been going on for well over a decade, so young adults who grew up in low-income households are likely to be beneficiaries of these changes.[21]

7. Conclusion

There have been striking falls in average death rates across the Australian population in the last 50, and even 20 years, as there has been across most other countries in the world. However, for Australia there is a gap in the literature regarding whether and how these longevity gains are distributed across the population. Are there people who are being left behind? This paper investigates the differences in death rates across people with different levels of lifetime income using a geographical approach. We find that

[20] Recall from Section 6.1, Baker et al (2019) suggest this as a possible reason for the decrease in mortality inequality in the US between 1990 and 2010.

[21] In fact, Currie et al (2008) find that Medicaid eligibility in early childhood may have a greater positive effect on the trajectory of future health than on current health.

there is significant mortality inequality in Australia, across virtually all age, and gender groups – that is, richer people tend to live longer than poor people.

Our findings about all-cause mortality inequality over the period 2001-18 are three-fold. First, for many subgroups of the population, there is no significant change in the level of mortality inequality. While a zero result, it should certainly not be considered a negative result. For many age groups among both males and females, mortality inequality has not increased. Second, for middle-aged Australians mortality inequality is increasing. For men, this can largely be explained by differences in mortality rates across urban and rural populations, however this is not the case for women. Third, for teenagers and young people, there is a convergence in death rates between the rich and the poor.

Looking at specific causes provides further insight into these trends. For middle aged males, it appears that diabetes is the major cause generating higher mortality inequality, and for women the major cause is cancer. For young people, the greater equality is driven largely by mortality due to death by external cause, including accidents. There has also been a welcome convergence between male and female death rates as a result of accidents, particularly motor vehicle accidents. This specific cause data also identifies trends that are not picked up by the all-cause results. One example is the positive development of decreasing mortality inequality for coronary heart disease, which is a leading cause of death for adults over 45, and particularly men.

Examining data on the number of doctors per capita in different regions suggests that there are inequalities in access to healthcare across different regions in Australia, and there has been no significant improvement on this front between 2001 and 2018. This problem may contribute to the persistent and growing diabetes mortality inequality that exists for males aged 45-54. Improving access to doctors in poor regions is certainly an avenue policymakers should target when seeking out ways to reduce mortality inequalities.

We also conduct two simulations to assess the burden of mortality inequality in Australia (results are shown in the Appendix B). These simulations allow us to determine the size of the mortality inequality burden or what is known as 'excess mortality' (Turrell and Mathers 2001). The results show that in the period between 2016 and 2018, just over 31,100 deaths could have been avoided if the spatial inequality in mortality were eliminated. This highlights how mortality inequality is a significant burden on society – even without including the loss of productive members of society. Since we know that the very low death rates enjoyed by the rich are feasible, policymakers should not shy away from the challenge of reducing Australia-wide mortality rates to this level.

To conclude, this paper shows that there are substantial health differentials between the rich and the poor that must be carefully monitored and ultimately addressed. In an ideal world, policymakers could eliminate poverty. However, while they struggle with this difficult task, there are actions that can be taken to improve health outcomes for the poor, and thus reduce health disparities. Our analysis indicates that one way to do this is improving access to healthcare, particularly in regional and remote areas of Australia. Further, since diabetes and suicide death rates for the poor have stagnated (and in some cases increased) over recent years, policies which target the treatment of and contributing factors for diabetes and mental health may also prove promising in reducing mortality inequalities.

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Appendix

A. Data Appendix (health workforce data)

In Australia, health workforce data is collected using survey data. Up to 2009 this was collected by the AIHW using Labour Force Surveys (AIHW 2018). In 2010 the Australian Health Practitioner Regulation Agency (AHPRA) was introduced, under which the AIHW was to remain custodian of the newly named National Health Workforce Dataset (NHWDS) (Department of Health 2019). The Health Department assumed the role of collecting health workforce data from the AIHW in 2016 and has since revised health workforce data releases from 2013 onwards (Department of Health 2019). As such, there is some discrepancy in survey methodology over the period 2001-18, particularly between the 2001-12 and 2013-18. Furthermore, between 2010-12 there was a drop in response rates for most jurisdictions. It is useful to keep this in mind when interpreting the results.

B. Simulations: Excess mortality

Our results show the evolution of mortality inequality from 2001-18. However, we have not quantified the burden of the mortality inequality, and the changes in mortality inequality, that have been identified. We conduct two simulations to assess the impact of hypothetical changes in mortality inequality in Australia. These simulations allow us to determine the size of the mortality inequality burden or what is known as 'excess mortality' (Turrell and Mathers 2001).

The first is to calculate excess mortality using the 'Regression-based population attributable risk (PAR)' which was first suggested in Kunst's (1997) seminal paper 'Cross-national comparisons of socio-economic differences in mortality'. The regression-based PAR is the absolute number (or percentage) of deaths for each age and gender subgroup that could be avoided if there was no socioeconomic inequality – that is, everyone has the same mortality rates as the *predicted* mortality rates of the most advantaged group (Kunst 1997).[22]

Across all four periods, there is a substantial burden of excess mortality as calculated by the regression-based PAR. In 2016-18, excess mortality for all age- and gender- subgroups under age 75 is 31,118 people (28 per cent of total deaths), over 20,000 of which are attributable to males (Table B1). In absolute terms, as we expect, the burden is increasing in age, corresponding to the increase in death rates across the life-cycle. However, we can compare mortality inequality across age and gender groups by looking at the regression-based PAR as a percentage of total deaths. For females, the greatest burden of excess mortality in 2016-18 is at ages 15-24, where 39 per cent of total deaths for females aged 15-24 would have been avoided between 2016-18 if all ventiles had the same death rates as the predicted death rate of the richest ventile (Table B2). This is despite the decrease in mortality inequality since 2001-03, with the regression-based PAR in this earlier period being 47 per cent of total deaths. For males, those aged 25-44 are burdened most by mortality inequality, with excess mortality equal to around 40 per cent of all deaths.

From Table B1 we can also identify that the absolute burden of mortality inequality is larger for males than females. That is, excess mortality for males has remained close to 20,000 deaths per three-years across 2001-2018. In contrast for females, despite total excess mortality being around half the value it is for males, it has increased over time. This is a concerning development that needs to be monitored carefully over the coming years.

[22] This approach is particularly beneficial when comparing groups of different population size. For example, Kunst (1997) gave the example of comparing mortality rates between different occupational classes. Of course, I compare groups which are, by construction, equal in population. However, this approach is still useful to assess the absolute numbers of deaths in each age- and gender-group which are over and above those which would prevail if mortality were to be equal to that in the first ventile.

Table B1. Regression-based Population Attributable Risk (PAR)				
Absolute number of deaths				
	2001		2016	
Age	**Females**	**Males**	**Females**	**Males**
0-4	413	467	282	404
5-14	48	159	80	113
15-24	531	1023	310	632
25-34	573	1321	493	1237
35-44	976	2250	1112	2367
45-54	1512	2947	2059	4070
55-64	1859	5467	2697	5349
65-74	3296	6447	3995	5918
Total	9,210	20,079	11,029	20,090

Note: Regression based PAR is the absolute number of deaths that would be avoided if all ventiles had the same death rate as the predicted death rate of the richest ventile. Age group 75+ is omitted.

Table B2: Regression-based Population Attributable Risk (PAR)				
Percentage of deaths				
	2001		2016	
Age	Females	Males	Females	Males
0-4	21.09	18.13	22.95	25.62
5-14	11.85	26.94	29.30	30.10
15-24	46.52	32.37	39.42	32.37
25-34	31.54	28.83	36.15	40.41
35-44	25.65	33.74	33.61	40.60
45-54	19.81	24.38	30.95	37.81
55-64	14.16	24.39	26.13	30.29
65-74	12.72	15.06	21.77	21.05

Note: Regression based PAR is the percentage of deaths that would be avoided if all ventiles had the same death rate as the predicted death rate of the richest ventile. Age group 75+ is omitted.

The second simulation assesses the excess mortality in the most recent period, 2016-18, with regard to the mortality inequality that existed in 2001-03. That is, how many lives have been lost (saved) on account of the increase (decrease) in mortality inequality between 2001 and 2016. This differs from the first method in that for some age and gender subgroups for which mortality inequality decreased over the period 2001 to 2016, excess mortality will be negative. That is, there will be lives saved on account of the convergence in death rates between the rich and the poor. As such, we can interpret this measure to indicate Australia's *progress towards* (negative values) or *movement away from* (positive values) the goal of perfect equality in mortality outcomes.

In a positive sign, for all Australians under 35 (except for females 5-14), excess mortality is negative (Table B3). This means that the slope of the regression line is become flatter over time. As we discussed, this flattening of the slope is statistically significant for those aged 15-24. Thus in 2016-18, 252 female lives and 442 male lives were saved on account of the decrease in mortality inequality since 2001-03. In contrast, at older ages, excess mortality values are positive (except males 55-74). In absolute terms, excess mortality relative to 2001 reaches a peak of 902 deaths for females aged 55-64 and 1229 deaths for males aged 45-54. Again, it was in these age groups where mortality inequality significantly increased between 2001 and 2016. When aggregating across all ages, the different trends for younger and older people counteract one another, and so total excess mortality relative to 2001-03 is 1,906 women and -213 men. This supports the finding from the PAR calculation that for females the overall burden of mortality inequality is growing over time.

Table B3. Excess mortality in 2016-18 due to change in mortality inequality since 2001-03

Absolute number of deaths

Age	Females	Males
0-4	-144	-70
5-14	36	-49
15-24	-252	-442
25-34	-99	-111
35-44	151	133
45-54	598	1229
55-64	902	-181
65-74	713	-722
Total	1906	-213

Note: Excess mortality indicates the absolute number of lives lost (saved) on account of the increase (decrease) in mortality inequality between 2001 and 2016. Positive numbers indicate lives lost. Negative numbers indicate lives saved. Age group 75+ is omitted.

Table B4: Excess mortality in 2016-18 due to change in mortality inequality since 2001-03

Percentage of total deaths

Age	Females	Males
0-4	-11.71	-4.46
5-14	13.10	-13.06
15-24	-31.96	-22.63
25-34	-7.30	-3.62
35-44	4.58	2.29
45-54	8.99	11.42
55-64	8.74	-1.02
65-74	3.89	-2.57

Note: Excess mortality indicates the number of lives lost (saved) as a percentage of total deaths, on account of the increase (decrease) in mortality inequality between 2001 and 2016. Positive numbers indicate lives lost. Negative numbers indicate lives saved. Age group 75+ is omitted.

C. Appendix Figures

Figure A1: Australia-wide SA3 rankings based on rankings 2001
Figure A2: Australia-wide SA3 rankings based on rankings 2016
Figure A3: Sydney-wide SA3 rankings based on low-income 2001 to 2016
Figure A4: Mortality inequality by education rank for males
Figure A5: Mortality inequality by education rank for females
Figure A6: Mortality inequality by IRSD rank for males
Figure A7: Mortality inequality by IRSD rank for females

Causes (see Table A1 for definitions)

Figures B1: Mortality inequality by Poverty Rank: Cancer
Figures B2: Mortality inequality by Poverty Rank: Diabetes
Figures B3: Mortality inequality by Poverty Rank: Dementia
Figures B4: Mortality inequality by Poverty Rank: Heart
Figures B5: Mortality inequality by Poverty Rank: Cerebrovascular
Figures B6: Mortality inequality by Poverty Rank: Liver
Figures B7: Mortality inequality by Poverty Rank: Perinatal
Figures B8: Mortality inequality by Poverty Rank: Non-Transport Accidents
Figures B9: Mortality inequality by Poverty Rank: Transport Accidents
Figures B10: Mortality inequality by Poverty Rank: Suicide
Figures B11: Mortality inequality by Poverty Rank: Deaths of Despair
Figures B12: Mortality inequality by Poverty Rank: All Other Causes

Link: https://www.dropbox.com/s/fmmephmxocfxayk/AppendixFigures.pdf?dl=0

D. Appendix Tables

Table A1: Causes of Death

Causes of Death	**ICD-Codes**
Cancer (neoplasms)	C00–D48
Diabetes	E10–E14
Dementia, including Alzheimer disease	F01, F03, G30
Disease of the heart	I05-I09, I11, I 13, I20-I25, I26-I 52
Cerebrovascular diseases	I60–I69
Cirrhosis and other diseases of liver (liver diseases)	K70–K76
Conditions in the perinatal period	P00–P96
Non-transport accidents	W00–X59
Transport accidents	V01–V99
Suicide (intentional self-harm)	X60–X84, Y87.0
Deaths of Despair (Homicides/assualts + Suicide + Alcohol + Accidental drug poisoning)	X85-Y09, X60–X84, Y87.0, X40–X45, Y15
All other causes (all deaths excluding above)	All other ICD-10 codes (excluding above)

Table A1: Slope of fitted regression line using education to rank ventiles

Gender/Age	2001-03 (1)	2016-18 (2)	Difference (3)	p-value of difference (4)
Males				
0-4	0.017***	0.011***	-0.006	0.334
5-14	0.003***	0.002***	-0.001	0.170
15-24	0.020***	0.015***	-0.004	0.107
25-34	0.024***	0.027***	0.003	0.520
35-44	0.026***	0.039***	0.013	0.054*
45-54	0.041***	0.062***	0.022	0.028**
55-64	0.112***	0.114***	0.002	0.891
65-74	0.210***	0.200***	-0.010	0.717
75+	0.248**	0.381***	0.132	0.209
Females				
0-4	0.014***	0.007**	-0.007	0.077*
5-14	0.001	0.001**	0.001	0.408
15-24	0.010***	0.007***	-0.002	0.072*
25-34	0.009***	0.010***	0.001	0.719
35-44	0.015***	0.019***	0.003	0.196
45-54	0.024***	0.039***	0.016	0.003***
55-64	0.054***	0.067***	0.013	0.024**
65-74	0.120***	0.134***	0.015	0.349
75+	0.066	0.197**	0.131	0.243

Notes: Each cell in Columns (1) and (2) gives the estimated coefficient on rank from Specification (1) for the indicate age, gender and year. Column (3) gives the difference, equal to (2) – (1). Column (4) shows the p-value for the test of the significance of the difference in (3). P-values calculated using robust standard errors: *** p<0.01, ** p<0.05, * p<0.1

Source: Author calculations using mortality data from 2001-2018 and Census data from 2001, 2006, 2011 and 2016 (see Sections 4.2.2 – 4.2.3 for definitions).

Table A2: Slope of fitted regression line using IRSD to rank ventiles				
	2001-03	**2016-18**	**Difference**	**p-value of difference**
Gender/Age	(1)	(2)	(3)	(4)
Males				
0-4	0.019***	0.016***	-0.003	0.546
5-14	0.003***	0.002***	-0.001	0.016**
15-24	0.014***	0.012***	-0.003	0.416
25-34	0.020***	0.019***	-0.000	0.994
35-44	0.028***	0.034***	0.007	0.148
45-54	0.051***	0.070***	0.018	0.013**
55-64	0.122***	0.128***	0.006	0.660
65-74	0.221***	0.232***	0.012	0.711
75+	0.225***	0.360***	0.135	0.065
Females				
0-4	0.018***	0.012***	-0.006	0.161
5-14	0.001	0.001**	0.001	0.421
15-24	0.007***	0.006***	-0.001	0.146
25-34	0.008***	0.008***	-0.000^	0.990
35-44	0.014***	0.017***	0.003	0.266
45-54	0.025***	0.039***	0.014	0.018**
55-64	0.056***	0.069***	0.013	0.080*
65-74	0.139***	0.145***	0.007	0.732
75+	0.013	0.121***	0.107	0.103

Notes: Each cell in columns (1) and (2) gives the estimated coefficient on rank from Specification (1) for the indicate age, gender and year. Column (3) gives the difference, equal to (2) – (1). Column (4) shows the p-value for the test of the significance of the difference in (3). P-values calculated using robust standard errors: *** p<0.01, ** p<0.05, * p<0.1

Source: Author calculations using mortality data from 2001-2018 and Census data from 2001, 2006, 2011 and 2016 (see Sections 4.2.2 – 4.2.3 for definitions).

Table A3: Three leading causes of death by age and gender, 2016-18		
Age	**Males**	**Females**
Under 1	1. Conditions originating in perinatal period 2. Other ill-defined causes 3. Sudden infant death syndrome	1. Conditions originating in perinatal period 2. Other ill-defined causes 3 Sudden infant death syndrome
1-14	1. Land transport accidents 2. Brain cancer 3. Conditions originating in perinatal period	1. Conditions originating in perinatal period 2. Brain cancer 3. Land transport accidents
15-24	1. Suicide 2. Land transport accidents 3. Accidental poisoning	1. Suicide 2. Land transport accidents 3. Accidental poisoning
25-44	1. Suicide 2. Accidental poisoning 3. Land transport accidents	1. Suicide 2. Breast cancer 3. Accidental poisoning
45-64	1. Coronary heart disease 2. Lung cancer 3. Suicide	1. Breast cancer 2. Lung cancer 3. Colorectal cancer
65-74	1. Coronary heart disease 2. Lung cancer 3. Chronic obstructive pulmonary disease	1. Lung cancer 2. Chronic obstructive pulmonary disease 3. Breast cancer
75-84	1. Coronary heart disease 2. Lung cancer 3. Dementia including Alzheimer disease	1. Dementia including Alzheimer disease 2. Coronary heart disease 3. Cerebrovascular disease
85+	1. Coronary heart disease 2. Dementia including Alzheimer disease 3. Cerebrovascular disease	1. Dementia including Alzheimer disease 2. Coronary heart disease 3. Cerebrovascular disease

Note: Leading cause of death by age group, 2016-18.

Source: AIHW 2020

Table A4: OLS Regression of Number of Doctors on Poverty Rank using discrete specification of rank

Dependent Variable: Number of doctors per 1,000 people

Independent Variables	(A)	Independent Variables	(B)	Independent Variables	(C)
Year 2006	1.208**	Rank 17	-0.178	Rank 16 * Year 2006	-0.320
	(0.613)		(0.264)		(0.841)
Year 2011	6.118***	Rank 18	0.0368	Rank 17 * Year 2006	0.0576
	(1.710)		(0.304)		(1.203)
Year 2016	11.83	Rank 19	-0.105	Rank 18 * Year 2006	-0.825
	(7.898)		(0.266)		(0.681)
Rank 2	1.228	Rank 20	-0.253	Rank 19 * Year 2006	-0.796
	(0.758)		(0.246)		(0.643)
Rank 3	1.171*	Rank 2 * Year 2006	-1.431	Rank 20 * Year 2006	-0.936
	(0.641)		(1.074)		(0.625)
Rank 4	0.512	Rank 3 * Year 2006	-0.842	Rank 2 * Year 2011	-4.699**
	(0.416)		(1.000)		(2.084)
Rank 5	4.644	Rank 4 * Year 2006	-0.691	Rank 3 * Year 2011	-0.891
	(4.344)		(0.849)		(2.557)
Rank 6	0.263	Rank 5 * Year 2006	-4.580	Rank 4 * Year 2011	-2.225
	(0.361)		(4.421)		(2.167)
Rank 7	0.668	Rank 6 * Year 2006	1.354	Rank 5 * Year 2011	-8.815*
	(0.555)		(1.615)		(4.705)
Rank 8	0.557	Rank 7 * Year 2006	-1.439	Rank 6 * Year 2011	-3.541*
	(0.514)		(0.900)		(2.032)
Rank 9	1.859	Rank 8 * Year 2006	-1.538*	Rank 7 * Year 2011	-3.914*
	(1.665)		(0.797)		(2.311)
Rank 10	-0.0634	Rank 9 * Year 2006	-2.325	Rank 8 * Year 2011	-3.956**
	(0.278)		(1.782)		(1.911)
Rank 11	0.454	Rank 10 * Year 2006	0.107	Rank 9 * Year 2011	-5.805**
	(0.592)		(0.956)		(2.740)
Rank 12	-0.182	Rank 11 * Year 2006	3.008	Rank 10 * Year 2011	2.916
	(0.262)		(2.979)		(6.558)
Rank 13	0.0573	Rank 12 * Year 2006	-0.442	Rank 11 * Year 2011	-2.402
	(0.308)		(0.648)		(2.819)
Rank 14	2.086	Rank 13 * Year 2006	-0.346	Rank 12 * Year 2011	-4.318**
	(1.640)		(0.703)		(1.763)
Rank 15	0.386	Rank 14 * Year 2006	-2.616	Rank 13 * Year 2011	-4.226**
	(0.554)		(1.751)		(1.777)
Rank 16	-0.161	Rank 15 * Year 2006	-1.208	Rank 14 * Year 2011	-6.391***
	(0.248)		(0.822)		(2.394)

Table A5 Continued: OLS Regression of Number of Doctors on Poverty Rank using discrete specification of rank

Dependent Variable: Number of doctors per 1,000 people

Independent Variables	(D)	Independent Variables	(E)	Independent Variables	(F)
Rank 15 * Year 2011	-4.575**	Rank 14 * Year 2016	-11.76	Rank 13 * Year 2016	-9.908
	(1.847)	Rank 15 * Year 2011	-4.575**		(7.907)
Rank 16 * Year 2011	-4.788***		(1.847)	Rank 14 * Year 2016	-11.76
	(1.748)	Rank 16 * Year 2011	-4.788***		(8.085)
Rank 17 * Year 2011	-5.267***		(1.748)	Rank 15 * Year 2016	-2.156
	(1.722)	Rank 17 * Year 2011	-5.267***		(9.483)
Rank 18 * Year 2011	-5.205***		(1.722)	Rank 16 * Year 2016	-9.396
	(1.738)	Rank 18 * Year 2011	-5.205***		(7.988)
Rank 19 * Year 2011	-4.953***		(1.738)	Rank 17 * Year 2016	-10.27
	(1.735)	Rank 19 * Year 2011	-4.953***		(7.904)
Rank 20 * Year 2011	-5.166***		(1.735)	Rank 18 * Year 2016	-10.62
	(1.719)	Rank 20 * Year 2011	-5.166***		(7.909)
Rank 2 * Year 2016	-11.26		(1.719)	Rank 19 * Year 2016	-10.80
	(7.962)	Rank 2 * Year 2016	-11.26		(7.903)
Rank 3 * Year 2016	-9.021		(7.962)	Rank 20 * Year 2016	-8.909
	(8.051)	Rank 3 * Year 2016	-9.021		(7.953)
Rank 4 * Year 2016	-7.519		(8.051)	Constant	0.965***
	(8.057)	Rank 4 * Year 2016	-7.519		(0.236)
Rank 5 * Year 2016	-13.63		(8.057)		
	(9.071)	Rank 5 * Year 2016	-13.63		
Rank 6 * Year 2016	-2.484		(9.071)		
	(10.76)	Rank 6 * Year 2016	-2.484		
Rank 7 * Year 2016	-9.114		(10.76)		
	(8.160)	Rank 7 * Year 2016	-9.114		
Rank 8 * Year 2016	-10.15		(8.160)		
	(7.937)	Rank 8 * Year 2016	-10.15		
Rank 9 * Year 2016	-11.87		(7.937)		
	(8.093)	Rank 9 * Year 2016	-11.87		
Rank 10 * Year 2016	-9.518		(8.093)		
	(7.927)	Rank 10 * Year 2016	-9.518		
Rank 11 * Year 2016	-10.39		(7.927)		
	(7.933)	Rank 11 * Year 2016	-10.39		
Rank 12 * Year 2016	-10.11		(7.933)		
	(7.905)	Rank 12 * Year 2016	-10.11	**Observations**	1,309
Rank 13 * Year 2016	-9.908		(7.905)	**R-squared**	0.098

	(7.907)

Notes: Table A5 presents estimates from Specification (2), except instead of modelling $rank$ as a continuous variable, I include 19 indicator variables for ventiles 2-20, with the first ventile (rank 1) being the base level dummy. 2001 is the base year. Robust standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1.
Source: Author calculations using healthcare data from 2001, 2006, 2011 and 2016, mortality data from 2001-2018 and Census data from 2001, 2006, 2011 and 2016 (see section 4.2.2-4.2.4 for definitions).

Table A5: Comparing the slope of the fitted line in US and Australia

Gender/Age	**US** **2010-12** **(1)**	**Australia** **2011-13** **(2)**
Males		
5-14	0.003***	0.003***
15-24	0.007***	**0.010*** **
25-34	**0.022*** **	0.019***
35-44	**0.046*** **	0.032***
45-54	**0.117*** **	0.061***
55-64	**0.207*** **	0.094***
65-74	**0.282*** **	0.179***
75+	**0.259*** **	0.194***
Females		
5-14	0.002***	0.002***
15-24	0.002***	**0.006*** **
25-34	**0.012*** **	0.009***
35-44	**0.031*** **	0.015***
45-54	**0.071*** **	0.026***
55-64	**0.112*** **	0.049***
65-74	**0.155*** **	0.105***
75+	**0.105** **	0.054

Notes: Each cell in Columns (1) and (2) gives the estimated coefficient on rank from Specification (1) for the indicate age, gender and year. The rank variable is constructed using poverty rates. P-values calculated using robust standard errors: *** p<0.01, ** p<0.05, * p<0.1. Ages 0-4 are omitted due to incomparable definitions of infant mortality. Bolded cells indicate that for the relevant age and gender group, Australia or US has larger mortality inequality.

Source: For US data, author calculations using Currie and Schwandt (2016) online data appendix. For Australian data, author calculations using mortality data from 2001-2018 and Census data from 2001, 2006, 2011 and 2016 (see Sections 4.2.2 – 4.2.3 for definitions).

Table A6: Slope of fitted regression line in US

Gender/Age	1990-92 (1)	2010-12 (2)	Difference (3)	P-value of difference (4)
Males				
0-4	0.020***	0.009***	-0.012	0.000***
5-14	0.007***	0.003***	-0.004	0.000***
15-24	0.032***	0.007***	-0.025	0.000***
25-34	0.057***	0.022***	-0.035	0.000***
35-44	0.086***	0.046***	-0.040	0.000***
45-54	0.136***	0.117***	-0.019	0.136
55-64	0.209***	0.207***	-0.003	0.897
65-74	0.238***	0.282***	0.045	0.191
75+	0.106**	0.259***	0.154	0.019**
Females				
0-4	0.017***	0.008***	-0.009	0.000***
5-14	0.003***	0.002***	-0.001	0.006***
15-24	0.007***	0.002***	-0.006	0.000***
25-34	0.018***	0.012***	-0.005	0.037**
35-44	0.031***	0.031***	0.000	0.966
45-54	0.055***	0.071***	0.017	0.014**
55-64	0.088***	0.112***	0.024	0.030**
65-74	0.096***	0.155***	0.059	0.012**
75+	-0.053	0.105**	0.157	0.012**

Notes: Each cell in Columns (1) and (2) gives the estimated coefficient on rank from Specification (1) for the indicate age, gender and year. The rank variable is constructed using poverty rates. Column (3) gives the difference, equal to (2) – (1). Column (4) shows the p-value for the test of the significance of the difference in (3). P-values calculated using robust standard errors: *** p<0.01, ** p<0.05, * p<0.1.

Source: For US data, author calculations using Currie and Schwandt (2016) online data appendix. For Australian data, author calculations using mortality data from 2001-2018 and Census data from 2001, 2006, 2011 and 2016 (see Sections 4.2.2 – 4.2.3 for definitions).

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