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ABSTRACT

Mortality is a crucial dimension of wellbeing and inequality in a population, and mortality trends have been at the core of public debates in many Western countries. In this paper, we provide the first analysis of mortality inequality in Canada and compare its development to trends in the U.S. We find strong reductions in mortality rates across both genders and at all ages, with the exception of middle ages which only experienced moderate improvements. Inequality in mortality, measured across Canadian Census Divisions, decreased for infants and small children, while it increased slightly at higher ages. In comparison to the U.S., mortality levels in Canada improved at a similar rate despite lower initial levels. Inequality at younger ges, however, fell more strongly in the U.S., implying converging mortality gradients between the two countries.

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1 Introduction

Mortality rates are a closely watched indicator of the wellbeing of a population. In the U.S., a strong overall decline in mortality rates since 1990 has been accompanied by prominent studies of the extent to which the gains have, or have not been, equally distributed in the population (e.g. Cutler et al. 2011; Chetty et al. 2016; NRC 2015; Case and Deaton 2015). Most recently, overall U.S. life expectancy actually fell (Xu et al. 2016), an extraordinary development which would seem to bear out earlier studies warning that some U.S. groups were not benefitting from improvements in longevity to the same extent as others (Olshansky et al. 2012; Wang et al. 2013; Murray et al. 2006).

While economists and demographers have made great strides documenting these trends, little progress has been made in understanding the social factors underlying them. Aizer and Currie (2014) and Currie and Schwandt (2016a,b) show that inequality in mortality declined sharply for infants, children, and young adults between 1990 and 2010, while rising among older white adults. They argue that social investments in children, and in particular the extension of public health insurance to millions of low income children beginning in the late 1980s, may be responsible for at least some of the improvements in the relative health status of poor children.

Chetty et al. (2016) focus on older adults, and show that some characteristics of local areas (commuting zones) are associated with better outcomes for the poor. Specifically, they find that in the U.S. low income people "live longest in affluent cities with more educated people and higher local government expenditures…" and that declines in life expectancy are also concentrated in certain areas such as Nevada, Appalachia, and southern Ohio. These results suggest there may be characteristics of particular areas that affect everyone living in that location.

This paper contributes to this literature by examining inequality in mortality in Canada, and comparing it to the U.S. Since, for example, Canada has had universal public health insurance throughout the period we examine, if expansions in health insurance have been driving the relative improvements among poor young people in the U.S., then one would not expect to see similar patterns in Canada. More generally, to the extent that mortality rates are everywhere lower in Canada, one possible explanation is that Canadians have universal health insurance. Another possibility is that lower income inequality will be reflected in lower inequality in mortality in Canada than in the U.S.

While many studies in the literature on mortality trends examine life expectancy (e.g. Chetty et al. 2016; Pappas et al. 1993; Pijoan-Mas and Ríos-Rull 2014, we focus exclusively on age-specific mortality rates. Period life expectancy collapses all the mortality rates at different ages in a given year into a single number and this number is – in a context of changing mortality rates – not informative about the expected longevity of any past, current, or future cohort (see Currie and Schwandt (2016a,b) for a more detailed discussion).

In order to facilitate comparison, we treat Canadian and U.S. mortality in a parallel way, ranking areas by indicators of socioeconomic status and examining the gradient between these rankings and mortality in 1990/1991, 2000/2001, and 2010/2011 (U.S./Canada). To our knowledge, this is the first time that Canadian mortality data has been examined in this way. A conceptual contribution of our paper is that we compare different ways to rank CDs by socioeconomic status. The LICO (Low Income Cut Off) measure is the most frequently used indicator of hardship in Canada, although Statistics Canada is careful to note that that LICO is not intended to measure poverty. When we rank CDs by the share of the population below LICO we often find that mortality is lower in areas with higher shares of the population below LICO. In contrast, when we rank areas by the share of high school dropouts, we consistently find that area with more dropouts have higher mortality. The counter-intuitive relationship between LICO and mortality is driven by large cities, and is the consequence of city-specific income cutoffs that are set higher for bigger cities. We construct an alternative

LICO measure using a fixed cutoff for all locations and show that this measure shows a consistent relationship with mortality; That is, areas with more people below the fixed cutoff LICO have higher mortality.

Starting with an analysis of the Canadian data, we find strong reductions in mortality for both genders in all age groups. For children and teens, these reductions are broadly parallel for more advantaged and less advantaged areas, when areas are ranked by either the share of high school dropouts of the fixed cutoff LICO, implying relatively little change in mortality inequality among the young. What is more remarkable is an increase in inequality in mortality among Canadian adult women over 15. Among working age adult men, whether one observes an increase in inequality in mortality or a decrease across areas depends on how one ranks the CDs. Ranking by education suggests increases in mortality inequality in that mortality fell fastest in the places with the fewest high school dropouts. Areas with the highest numbers of high school dropouts often saw little decline in mortality among middle aged men at all. Ranking by income produces decreases in mortality inequality in some cases, in that mortality did not fall as much as expected in some higher income areas. That is, there are areas with high male mortality that have relatively low education but high income.

We next compare the evolution of mortality inequality in Canada between 1991 and 2011 with that in the U.S. between 1990 and 2010. The U.S. experienced similar reductions in mortality, but started at higher levels in 1990, and mortality rates remain above Canadian levels at all ages two decades later. Mortality inequality, on the other hand, fell strongly for infants, children and adolescents in the U.S., and the mortality gradient continued to flatten in middle ages, both for males and females. This implies a considerable catchup for the U.S.: Mortality inequality was much higher in the U.S. than in Canada in 1990, but in 2010 U.S. gradients are similar or even flatter than their Canadian counterparts in many age groups. At older ages, mortality inequality changed little in either country. There are strong overall reductions in mortality, but inequality in mortality remains higher in the U.S.

Finally, we make some initial exploration of the causes of death that drive these developments. The overall reductions in mortality are reflected in the leading causes of deaths at different ages, with particular decreases in accidental deaths at young ages and improvements in heart disease and cancer-related mortality at older ages. An exception is accidental death in middle age, a leading cause of death in that age range which decreased little in Canada and increased in the U.S. Underlying this development has been an exorbitant surge in accidental drug poisoning in the wake of the opioid epidemic. In Canada, deaths due to accidental drug poisoning increased by 60% and 220%, while they soared by 300% to 1,100%, depending on the age group, in the U.S.

2 Background

According to a recent National Academy report there are three ways to measure inequality in mortality: "One looks at differences in the mortality of populations of U.S. counties in relation to county-level economic measures. Another looks at mortality by educational attainment. A third approach looks at mortality by career earnings" (NRC, 2015).

Many studies divide the population by level of education (Pappas et al., 1993; Elo and Preston, 1996; Preston and Elo, 1995; Olshansky et al., 2012; Meara et al., 2008; Cutler et al., 2011; Montez and Zajacova, 2013; Montez and Berkman, 2014; Mackenbach et al., 2016) although the share of the population with high school or college has increased dramatically over time (Dowd and Hamoudi, 2014; Hendi, 2015; Bound et al., 2014; Goldring et al., 2016). If those who would have been expected to have less education in 1990 have moved into higher education categories by 2010, then it would not be surprising if the remaining high school drop outs proved less healthy in 2010.

Other studies focus on inequality in mortality by relative income (NRC, 2015; Pappas et al., 1993; Waldron, 2007, 2013; Bosworth and Burke, 2014; Pijoan-Mas and Ríos-Rull, 2014). These studies may be biased by reverse causality since low income could be caused by ill health rather than the reverse (Smith, 1999, 2005, 2007). Moreover, in Canada and the U.S., mortality data do not have information about the decedent's income. Research based on the longitudinal U.S. Health and Retirement Study finds increasing divergence in life expectancy at age 50 by income over time but these results are based on a relatively small sample and require extrapolations of life expectancy (NRC, 2015; Bosworth and Burke, 2014; Pijoan-Mas and Ríos-Rull, 2014).

Finally, one can pursue the strategy we use here, and examine inequality by geographical areas. Such analyses can be biased by selective migration if, for example, the healthiest people in a declining area leave, or if, in the Canadian case, a booming resource extraction sector attracts many people with relatively low levels of education to an area with well-paying jobs. Some previous studies have focused on mortality trends within small areas such as individual counties, an approach that is particularly prone to biases due to migration (for example, (Kulkarni et al., 2011; Wang et al., 2013; Murray et al., 2006). Singh and Siahpush (2006) divide U.S. counties based on a socioeconomic index for the population in 1980 and follow these same county groups up to 2000, in order to avoid these biases. We will follow a similar strategy here.

Previous Canadian research in this area also typically adopts a geographical approach at the provincial and/or CMA level (for example, Statistics-Canada (1999), Ross et al. (2000), Auger et al. (2012), Tjepkema et al. (2013)). While not necessarily based on data from a single year, much of this evidence does not explicitly consider changes in the relationship between mortality and measures of social inequality over time.

While the focus on county groups mitigates the concern about migration into and out of individual counties, there may still be net migration from county groups. Currie and Schwandt (2016a,b) address this concern by reordering counties in each Census year and then re-grouping counties so that they are always following county groups that represent a fixed share of the population. That is, they can examine the counties that together account for 5 percent of the population in each Census year, even if those are not always the same counties in each year. They show that in the U.S., the results are not affected by this re-ordering, suggesting that the ranking of counties by poverty rates is stable over time and that that in general, there have not been large population shifts away from the poorest counties. In what follows, we focus on areas ranked in 2001 and use a fixed ranking over the three Census years we consider.

3 Data and Methods

3.1 Canadian Data

Canadian death counts come from the administrative data set, Canadian Vital Statistics: Deaths Database (CVS:D). Vital statistics are collected in Canada at the provincial or territorial level. These data are then transferred to Statistics Canada who in turn maintain the CVS:D and produces associated summary statistics. While the information recorded on death certificates varies by province, the information we use in the analysis is collected in all provinces. Because the registration of death is a legal requirement in all provinces and territories, the report of deaths is virtually complete.[2]

We draw counts of deaths for the years 1990-1992, 2000-2002 and 2010-2012 from the CVS:D to construct 3-year mortality rates. These data are organized into five-year age groups, with the exception of the groupings of ages 5-14, 65-74 and 75+. The aggregation of ages 5-14 is to satisfy Statistics Canada's minimum sample size requirements for some of our calculations in 2011. The age groups 65-74 and 75+ were created to match the reporting of population counts by our chosen geographic area (see below) from the short form census

[2]The deaths of non residents of Canada are registered at the provincial level but excluded from the CVS:D.

in 1991. We restrict our sample to the provinces, thereby omitting the Yukon, the Northwest Territories, and Nunavut.

Our counts of population by age group are from the "short form" files of the censuses of population for 1991, 2001 and 2011. The short form records a set of basic characteristics of the Canadian population and participation in this part of the census is mandatory. We relate our estimates of death rates by our "five-year age groups" to economic and demographic characteristics of the geographic area of the decedent's place of usual residence. To construct these characteristics, we use information from the 1991 and 2001 "long form" censuses and the 2011 National Household Survey in 2011. The long form file contains information from a supplementary questionnaire administered to 20 percent of the population and completion of this survey is also mandatory. For the 2011 census, the federal government of the day replaced the mandatory long form census with the voluntary National Household Survey (NHS). The questionnaire for this survey was distributed to one-third of households. The response rate to the survey was just under 69 percent, which can be compared to response rates for the previous long form censuses in excess of 90 percent. As a result, the data from this source are viewed as having greater sampling error, particularly at small areas of geography. To minimize an impact of these issues with the NHS we use a "fixed ranking" of geographic areas based on economic and demographic characteristics calculated using the 2001 long form census for our main results. In some instances we also show some results using rankings based on characteristics taken from the 1991 long form census and the NHS for comparison.

We calculate the 3-year death rates at the geographic level of the Census Division (CD). CDs are secondary geographical areas, below the provinces and territories but larger than the tertiary census sub-divisions (e.g., municipalities). In five of 10 provinces, the CDs mostly correspond to county divisions.[3] However, the range in population size across CDs is large,

[3]They do not correspond primarily in provinces that do not have a county organization.

as, for example, the city of Toronto is a CD.

We relate 3-year death rates for a given five-year age group at the CD level to measures of educational attainment and the level of "poverty" in a CD. Our measure of educational attainment is the proportion of the adult population (age 19 and above) who did not complete a high school diploma. This is fairly comparable to the measure of educational attainment used for the US data.

Unlike the US, Canada does not have an official poverty measure. Instead, the Low-Income Cut-offs (LICOs) produced by Statistics Canada have come to serve this role, although Statistics Canada is emphatic that the LICO does not measure poverty.[4] The LICO is based on the expenditures of Canadian families on food and shelter as measured in expenditure surveys. LICOs are income thresholds below which a family would spend a greater proportion of their income than the proportion spent by the average family plus 20 percentage points on these two categories.[5] The last update to the average expenditure patterns on food and shelter was in 1992, and since then, the LICO income cutoffs have only been adjusted for price inflation.

Like the US poverty measure, LICO income cut-offs vary by family size. However, in contrast to the US poverty measure, LICO cut-offs also vary by city size, thereby capturing to a certain extent any geographical variation in the price of food and shelter. To account for this difference in the Canadian and US measures, we also construct a "fixed-cutoff LICO" by calculating the low-income rate using income cut-offs that vary by family size but not by city size. To implement this measure, we use the 2001 LICO income cut-offs for "small urban regions", which are urban areas of less than 30,000 people, to determine the low-income rate in all CDs. These income cut-offs by family size are approximately equal to the cutoffs for the US poverty measure in 2001, converted at current exchange rates.

[4]See, for example the Chief Statistician's statement in 1997, Ivan Fellegi "On poverty and low income" http://www.statcan.gc.ca/pub/13f0027x/13f0027x1999001-eng.htm (accessed on March 20, 2017).

[5]For more detail see the Statistics Canada publication "Low income cut-offs for 2008 and low income measures for 2007" http://www.statcan.gc.ca/pub/75f0002m/2009002/s2-eng.htm (accessed on March 21, 2017).

A 0/1 low-income indicator based on the actual LICO is calculated by Statistics Canada and included in the census and NHS files for each economic family and for individuals not in families. To calculate a corresponding low-income indicator using the fixed-cutoff LICOs, we compare the income of each economic family or individuals not in families to the LICOs for small urban regions as described above.

3.2 Ranking Canadian CDs by Socioeconomic Indicators

We explore alternative rankings of the CDs by the different socioeconomic indicators: the percent of the population with less than 12 years of education, the LICO, and the fixed-cutoff LICO. Appendix Figure A.1 shows the rankings of CDs by the share with less than 12 years of education in 1991, 2001, and 2011. This share ranges from about 15% in the most educated CDs to around 60% in the least educated. If both the shares and the rankings had remained exactly the same over time, the lines represented by the blue triangles and the green dots would lie on the black dashed line. The fact that the blue triangles (for 1991) lie above the dashed line, while the green dots (for 2011) lie below indicates that the share of the population with less than 12 years of education has been falling over time. However, for our purposes, the important point is that the lines are for the most part parallel and strictly increasing, suggesting that the ranking of CDs does not change quickly over time and is relatively constant.

Figures A.2 and A.3 show similar comparisons for the ranking of CDs by LICO and the fixed-cutoff LICO. In both figures, most of the CDs are close to the dashed 45-degree line, indicating that there has not been much of an overall trend in the level of these LICO measures and that the ranking of CDs remained fairly stable, whether or not one holds income cutoffs fixed. Since LICO is not a measure of poverty per se, but a measure of relative income deprivation, perhaps this result is not surprising. For our purposes here, it means that we can use CD rankings in 2001 for the analysis in 1991 and 2011 without doing violence to the data in the other years. Recall this allows us to avoid the concerns over the response rates in the Canadian NHS in 2011.

3.3 Comparing the Ranking of Canadian CDs by different Socioeconomic Indicators

One important difference that is apparent when comparing the rankings of the CDs by LICO and the fixed-cutoff LICO (figures A.2 and A.3) is the position of the biggest CDs (those with the largest marker size). They are at the top end of the distribution in the ranking by LICO but in the middle of the distribution for the ranking by the fixed-cutoff LICOs.

Figure A.4 illustrates how the rankings by education and alternative poverty measures compare by relating them directly to each other in one graph. The high school drop out rate in 2001 is on the x-axis, while the y-axis shows the 2001 LICO measures. The relationship between educational ranking and fixed-cutoff LICO is clearly positive, as shown by the upward sloping line fitted through the green circles. In other words, sorting CDs by education results in a similar ranking as the sorting by the fixed-cutoff LICO measure. In contrast the relationship of the ranking by education and the ranking by LICO measure is very different. The line fitted through the blue triangles is slightly downward sloping, meaning that there is actually a negative relationship between the LICO ranking and high school dropout share ranking. A closer look suggests that there might be a positive relationship between the two ranking for smaller CDs, but that this relationship is outweighed by large CDs which have a low high school drop out rate but relatively high shares of low income population as measured by the LICO. These graphs highlight the fact that Canadian cities tend to have higher shares of "low income" households because Statistics Canada defines the low income cutoff to be higher in larger cities.

3.4 U.S. Data

For the analysis of trends in the U.S. we use data from Vital Statistics Mortality and from the Census (in 1990 and 2000) and from the American Community Survey (ACS) in 2010 since the ACS replaced the long form of the Census. Population estimates for 1990 are based on NCHS bridged population estimates (NCHS, 2004), to account for reporting problems in the 1990 Census, which affected the population counts for age <1 in that year. Indicators of socioeconomic status, such as the share of the population that had less than 12 years of education and the poverty rate, are taken from the U.S. Census (in 1990 and 2000) and from the ACS in 2010.

3.5 Method

Following Currie and Schwandt (2016a,b), we first rank Canadian CDs (and U.S. counties) by an indicator of socioeconomic status.[6] We then group CDs (counties) into 20 bins, each representing about 5% of the Canadian (U.S.) population and calculate mortality rates for each age and gender group.[7]

Grouping CDs (counties) into equal shares of the population helps to address the problem of measurement error in mortality rates for small areas, in particular when analyzing age ranges with low mortality. We also focus on 3-year mortality rates to ameliorate potential

[6] In the U.S., most of the poorest counties that together make up 10 percent of the U.S. population in both 1990 and 2010 were located in the South and Southwest, together with some counties in the Midwest (in particular, in South Dakota), and in Alaska. Conversely, the counties with the lowest poverty rates that make up 10 percent of the population in both 1990 and 2010 are predominantly located in the North, with clusters in the Northeast. Thus, the geographic distribution of the counties with the highest and lowest poverty rates remained fairly stable between 1990 and 2010, and in fact, whether we readjust county groups to account for population changes or instead follow fixed sets of poor and rich counties over time, the results are similar.

[7] In order to smooth the size of the county groups in the U.S. we divide the five largest counties in our sample—Cook County, Illinois (which includes the city of Chicago), Los Angeles County, California, Riverside County, California, Harris County, Texas (including Houston), and Maricopa County (including Phoenix), Arizona into three smaller groups, each of identical size and with the identical mortality rates. dividing counties into groups that represent equal fractions of the population is not an exact procedure because counties at the margin will overlap the bins, making one group too large and the next group too small. In practice, however, this variation in county group size is relatively small.

problems due to small cell sizes. To be specific, in the Canadian data we calculate the 3-year mortality rate in 1991 as the ratio of of all deaths that occurred in a cohort between January 1, 1990, and December 31, 1992, divided by the 1991 Census population count. We use the decedent's CD of residence, rather than the CD where the death occurred. In the U.S. data we calculate the 3-year mortality rate in 1990 as the ratio of all deaths that occurred in a cohort between April 1, 1990, and March 31, 1993, divided by the 1990 Census population count. We again use the decedent's county of residence, rather than the county where the death occurred.[8]

3.6 Mortality by age in Canada and the U.S.

Figure 1, a graph of the age profile on one year mortality rates[9] in Canada and the US in 2009-2011, shows several important features of the Canadian and U.S. mortality data. First, one can clearly see the hockey-stick pattern in log mortality by age: mortality rates tend to be high for infants and then to fall precipitously in early childhood. They start to rise again in the teenage years and continue rising. Mortality rates do not begin to exceed those in very early childhood until after age 50. Second, one can see large gender differences: Death rates for males exceed those for females at all ages. The gap is especially pronounced during the teen age years and in young adulthood and starts to narrow starting around age 35 or 40. Although we will not present a detailed analyses of death rates by cause of death, it is worth bearing in mind that injuries (both intentional and unintentional) are the primary cause of death among teens and young adults by a wide margin, as shown in Tables A.2 and A.3. Males are much more likely to die of injuries than females, and a large part of the gap in death rates between the U.S. and Canada appears to be due to higher death rates from

[8]This difference in the calculation of the death rates between the two countries is necessitated by the fact that the Canadian vital statistics for the years 2013 and later are not yet available for research, and so we cannot use the method for the US data for the Canadian death rates in 2011.

[9]These mortality rates differ from the ones we use in our analysis because they are based on a single year of death counts.

injuries (both intentional and unintentional).

A third feature of this figure that is especially salient for our study is that the gender-specific mortality rates are higher in the U.S. than in Canada at all ages. That is, Canadian men are less likely than U.S. men to die at all ages, and the same is true when comparing women across countries. Canadian women have the lowest mortality rates of the four demographic groups we considered, followed by U.S. women. At some ages, Canadian men have mortality rates similar to U.S. women, but Canadian men have higher mortality than U.S. women in the teen and young adult age range, and again after age 50. It is important to keep these level differences in mind when examining trends in mortality. Because men and women have systematically different mortality rates, we mostly consider them separately in the analysis.

4 Results

4.1 Trends in Inequality in Mortality in Canada by Education

Figure 2 shows graphs of the relationships between mortality and the share of a CD's population with less than high school education in 2001 for males, by 5 year age categories, in 1991, 2011 and 2011. There are 20 points in each year. These points represent the ventiles of the distribution of the CDs' mortality rates ordered by the (increasing) share of high school dropouts. Generally and not surprisingly, the lines are upward sloping, indicating that areas with more high school dropouts tend to have higher mortality. The graphs for ages 0-4 through 20-24 show overall reductions in mortality across years, which were somewhat more pronounced in areas with higher rates of high school dropouts, indicating a slight decrease in mortality inequality over time among infants and children in Canada.

What is more remarkable is a pronounced increase in mortality inequality for males between the ages of 25 and 49 in Canada. This increase is evidenced in the graphs by the fact that the line drawn through the scatter of points (the inverse education gradient) is steeper in 2011 than in 1991; that is, mortality fell by a greater amount in places with fewer high school dropouts. Indeed, in some age groups (35-39 and 40-44), Canadian male mortality appears to have shown no improvement at all in the areas with the most dropouts. It is also worth noting that in 1991, there was little relationship between the share of high school dropouts in an area and mortality among 30 to 44 year olds, but this share had become much more predictive of mortality by 2011, largely because mortality fell in more educated areas. At older ages (age 50 and above) mortality decreased strongly for all education groups. But as in the middle ages, improvements were stronger in more educated areas, implying an increase in mortality inequality. Appendix Table A.1 summarizes the inequality development show in Figures 2 to 7.

Figure 3 shows that these increases in mortality inequality at middle and older ages are even more pronounced among females. It appears that in Canada, female mortality fell in the areas with the fewest dropouts for ages 15 though 49 and among those 75 and over, but showed little improvement in the areas with the most high school dropouts in these age ranges. The result is that inequality in mortality between more and less educated areas generally increased for women over 15.

4.2 Trends in Inequality in Mortality by LICO

The huge expansion of the natural resource extraction sector in Canada since 1990 means that in Canada, areas with low education are not necessarily those with low income. For example, Fort McMurray is one of the wealthiest areas in Canada but many of the jobs are blue collar and do not necessarily require high school or college education.[10] Hence it is interesting to also rank CDs by LICO, even though LICO is not intended as a poverty measure and income cutoffs change across areas, making interpretation of areas ranked by

[10] See: http://globalnews.ca/news/370804/income-by-postal-code/, accessed April 1 2017. See Foley and Green (2016) for evidence of the impact of the resource boom on returns to education in Canada.

LICO somewhat difficult.

Figures 4 and 5 show plots identical to Figures 2 and 3 except that CDs are now ranked by LICO in 2001 before being placed into 20 groups. A remarkable thing about these figures is that in many cases a regression line through the scatter of points slopes downwards, indicating that places that have more low income residents have lower mortality. This is a quite unprecedented finding in the literature where measures of socioeconomic disadvantage are almost always associated with higher mortality rates. One possible reason for this puzzling finding is that as discussed above, Statistics Canada uses higher income cutoffs in larger cities. Thus, places like Toronto are thought to have more low income residents, in part because Torontonians are deemed to require more income to live comfortably. Rankings by the share low income appear to be quite sensitive to the changes in these cutoffs by city size.

There has been spirited debate in the economics literature recently about how amenities in larger cities should be valued and set against their often higher costs (Moretti, 2013; Diamond, 2016). For example, a larger city may have better hospitals and trauma care as well as better public transportation enabling residents to live without a car. And while rent is likely to be higher, food costs may well be lower. While there is unlikely to be a simple solution to this problem, as discussed above, we have adopted the expedient of constructing a fixed-cutoff LICO measure, using a single set of income cutoff by family size to define low income across all CDs.

Figures 6 and 7 show figures similar to 2 and 3 except that CDs are ranked by fixed-cutoff LICO in 2001 before grouping the observations into 20 categories and plotting the mortality rates for 1991, 2001, and 2011. These lines are all upward sloping, indicating that places with higher shares of low income families have higher mortality when the low income cutoff is fixed across areas. This is the relationship that one would expect given past research on income and mortality gradients. However, examining the points themselves suggests that the relationship between even fixed-cutoff LICO and mortality is much less linear than the relationship between education rankings and mortality: especially among prime age adults, there appear to be groups of CDs near the middle of the fixed-cutoff LICO ranking that have high mortality.

Figure 6 suggests that male mortality has declined across the income distribution, and that for males 20-44 years old, the delinces were greater in the places with the most low income people, implying decreases in mortality inequality. However, figure 7 suggests that female mortality follows a similar pattern to that shown in Figure 3, with greater declines in mortality among women 15 and older in the places with the fewest low income people.

Taken as a whole, these results show increases in inequality in mortality among Canadian adult women. Among men, whether one observes an increase in inequality in mortality or a decrease across areas depends on how one ranks the CDs, especially among working age adult men. It seems that there are areas with relatively low education but high income that nevertheless have high mortality. These results may suggest that policies aimed at reducing inequality in mortality might work better if they are targeted to areas with less education rather than at areas with more low income people.

4.3 Comparing trends in the U.S. and Canada

Figures 8 and 9 compare the mortality trends across Canadian CDs ranked by their rate of high school dropouts (as shown in Figures 2 and 3) with the same trends for the U.S. To avoid clutter, we do not plot the mortality rates in individual ventiles but only show lines fitted through these rates. The thin and thick solid blue lines refer to U.S. rates in 1990 and 2010, respectively. The thin and thick dashed red lines show rates for Canada in 1991 and 2011.

Let us first focus on the developments among male infants, children, and young adults up to age 24 as shown in first four panels of Figure 8. Comparing the thin lines in 1990/1991 shows that mortality was generally higher in the U.S. than in Canada. Moreover, at ages 0-4 and 15-20, the U.S. gradients are also steeper than in Canada, reflecting higher inequality in mortality across areas ranked by the rate of high school dropouts. This pattern changes considerably over the following two decades due to differential trends in both countries.

Between 1991 and 2011, male mortality rates in Canada decreased relatively uniformly across areas for children, as reflected by the parallel downward shifts of the dashed red lines (also discussed in Figure 2). In the U.S., on the other hand, mortality among children declined more strongly in areas with higher dropout rates, leading to a considerable flattening of the blue solid lines. As a consequence, despite the steeper slope of the US line in 1990/1991, the gradients are similar for both countries in 2010/2011 or even flatter for the U.S. In other words, while mortality levels remain lower in Canada in 2010/2011, among children the U.S. has caught up in terms of inequality reduction or even taken the lead. This is of course the age group that experienced the tremendous increase in public health insurance coverage in the US.

Turning to young adult and early middle age, in Canada male mortality improvements between age 25 and 50 are concentrated in more advantaged areas, with little or no improvement in the areas with the highest dropout rates, implying a considerable increase in mortality inequality. The opposite development occurs in the U.S. Disadvantaged areas with high dropout rates experienced strong male mortality reductions, while mortality rates in areas with low dropout rates were largely stagnating. Even more so than at younger ages, these opposing developments imply that even though inequality in the age range 20-50 was much larger in the U.S. in 1990/1991, it had equalized or become lower than in Canada by 2010/2011.

At older ages, there are strong reductions in male mortality in both countries that were relatively uniform across areas, with only a slight increase in mortality inequality. Canada has been particularly successful in reducing mortality. Even though it started at a lower rate than the U.S. in 1990/1991, the improvements are stronger in most cases.

Figure 9 shows that this differential mortality development in Canada and the U.S. occurred in a similar or even more pronounced way for females. Mortality inequality increased among Canadian females from age 15 onwards, while it decreased in the U.S. up to age 40. Above age 45, inequality in female mortality increased in both countries strongly, compared to a slight increase in mortality inequality for males.

Figures A.5 and A.6 show the same comparison of mortality trends in Canada and the U.S., but instead of the high school dropout rate we use fixed-cutoff LICOs and poverty rates to rank CDs and counties, respectively. In line with the results in Figures 6 and 7, there is less of an increase in mortality inequality for males in Canada when this alternative ranking is used. The mortality inequality trends in the U.S., on the other hand, are very similar regardless of the socio-economic indicator used to rank counties (in line with the results in Currie and Schwandt, 2016a,b).

Summing up the comparison between the two countries, in terms of levels, both countries have experienced large mortality improvements, with the U.S. starting at a higher level in 1990 and remaining above Canada in 2010. In terms of mortality inequality, the U.S. experienced a strong decrease in mortality inequality among infants and children, with gradients by socioeconomic status becoming similar to those in Canada by 2010. In contrast, in Canada mortality among infants and children fell similarly across areas regardless of the share high school dropout. Third, among men 20-49, inequality in mortality increased in Canada and decreased in the US when areas are ranked by the share of high school dropouts. Among women 20-39 inequality in mortality decreased in the U.S. but increased in Canada; for women 55 plus, inequality in mortality increased in both countries. For men over 50, inequality in mortality was constant or decreasing in the U.S. but increasing in Canada. Thus, although mortality levels remain higher in the U.S. in 2010, the U.S. has shown considerable improvement relative to Canada both in terms of levels, and in terms of the distribution of inequality in mortality. These relative improvements have been especially strong for children 0-4, where Canadian and U.S. mortality rates are now quite close. Among older children, the mortality rates are the same in the areas with the largest shares of high school dropouts, and U.S. rates are higher because of greater death rates in areas with higher socioeconomic status.

4.4 Trends by Causes of Death in the U.S. and Canada

Which causes of death are driving the strong overall mortality reductions that we observe in Canada and the U.S.? Appendix Tables A.2 and A.3 show the five leading causes of death for different age groups in Canada and the U.S. in 2011, as well as their growth rates over the past two decades. Among infants in both countries, the leading case of death in 2011 is congenital anomalies. At the same time, there have been substantial improvements in that category, potentially due to prenatal detection and selective abortions, implying that the most severe cases which would die within the first year of life are not born.

Deaths due to short gestation, low birth weight, and pregnancy complications, on the other hand are leading causes that increased over the past two decades, in particular in Canada. These increases might be driven by better pre-birth treatments of complicated pregnancies leading to higher survival rates of fetuses until birth. Another factor might be increases in maternal age and raising rates of in-vitro fertilization which are often associated with lower gestation length and birth rate. Substantial improvements have been made in both countries in sudden infant deaths, in line with existing research (Moon et al., 2007).

Among children and adolescents, the leading cause of death in 2011 is accidents (unintentional injuries), and the rate of fatal accidents is about 1.5 times larger in the U.S. than in Canada. However, improvements over the past twenty years were also strongest in that category, with mortality reductions of about 50 to 60% in both countries. Deaths due to assaults show a similar pattern, with both higher U.S. levels, and stronger improvements in the U.S., but assaults play a quantitatively less important role than accidents.

In young adulthood and middle age up to age 64, accidents remain a leading cause of death and they become an even more relevant source of cross-country disparity, with U.S. rates amounting to 2 to 2.5 times the Canadian rates. Moreover, in those age groups there has been less improvement in accidental deaths over the past two decades than at younger ages. In fact, in the U.S. the rate of fatal accidents in middle age increased strongly, by up to 80%. This increase is mainly due to an exorbitant surge in deaths due to accidental drug poisoning (which are broken out in the tables). In the U.S. this death rate increased by 300% to 1,100%, a development mainly driven by the opioid epidemic. Canada experienced milder but nevertheless significant increases in accidental drug poisoning, ranging between 60% and 220%. Another cause of death that has increased somewhat, in particular in the U.S., is suicide. But intentional self harm is often difficult to distinguish from accidental drug poisoning, so both increases might represent the same phenomenon. Overall, these negative developments in middle age are outweighed by strong improvements that occurred with respect to cancer and heart disease deaths.

At age 65 and above, mortality in both countries has strongly declined for all leading causes, with the exception of female deaths due to chronic lower respiratory diseases. This mortality cause is mostly driven by smoking and increases in this subgroup could reflect the rising rates of female tobacco addiction that occurred in these cohorts (see Currie and Schwandt (2016b) for a more detailed discussion). At the same time, smoking has strongly declined in more recent cohorts, suggesting that the increases in this cause of death might be reversed in future.

To sum up, there have been strong improvements in most of the leading causes of death across all ages. At younger ages, reductions in mortality due to accidents have been particularly relevant, while cancer and heart disease mortality played an important role at older ages. An exception to this positive trend are increasing mortality rates due to accidental drug poisoning and suicides at middle ages which slowed down the otherwise positive development in that age group. The results from the previous section suggest, that the early life reductions in accidental deaths have been particularly pronounced in poorer and less educated areas in the U.S., while the improvements at older ages were more pronounced in more advantaged areas both in the U.S. and in Canada.

4.5 Discussion

While our analysis is mainly descriptive, it does provide supporting evidence consistent with several hypotheses about the factors underlying different levels and trends in U.S. mortality rates for different ages. With respect to children, we observe that mortality rates fell in both countries, consistent with broad based technological changes (everything from medical technologies to safer cars and seatbelts) that have improved health. However, trends in inequality in mortality are quite different in the two countries. In Canada, child mortality levels are fairly similar in high and low SES areas, whereas in the U.S., child mortality rates are higher in low SES areas, but have also shown more dramatic declines in these areas than in high SES areas. This pattern is consistent with the idea that declines in inequality in child mortality in the U.S. may have been driven by the remarkable expansion of public health insurance for low income pregnant women and children that took place beginning the late 1980s and continuing through the early 2000s. As Currie et al. (2008) showed, these expansions resulted in large increases in eligibility: The fraction of children 0-3 eligible for Medicaid rose from approximately 20 to over 50 percent, and the fraction of children 13-17 rose from 15 to over 40 percent by 2000 (also see Appendix Figure A.7 for evidence from the NHIS). At the margin, the available evidence suggests that providers who know that essentially all children are covered by insurance will be more likely to provide costly and potentially life saving services (Currie and Gruber, 1996a,b). As Finkelstein (2007) showed for the introduction of Medicare (public health insurance for all elderly in 1965), and as Card et al. (2009) show for the case of elderly people with life-threatening conditions, it is hard to understate the effects of eligibility for insurance on the practice of medical care.

Several recent papers follow the cohorts who became eligible for public health insurance as a result of the Medicaid expansions. Brown et al. (2015) use U.S. Internal Revenue data from tax returns which allows them to examine disability and employment as well as income. Wherry and Meyer (2015) examine effects on mortality using Vital Statistics data while Wherry et al. (2015) look at hospitalizations and Emergency Room visits using hospital discharge data. All of these studies find positive long-term effects of having been eligible for health insurance coverage in childhood on young adult health, suggesting that the the Medicaid expansions could potentially explain at least some of the declines in inequality in mortality among Americans up to age 30.

It seems unlikely, however, that expansions of public health insurance can explain the large reductions in mortality for adult males 20-44 in the U.S. relative to Canada, since in this age category, injuries (intentional and unintentional) are the leading cause of death. Improvements in automobile safety, for example, ought to affect both Canadians and Americans, and so they cannot explain the reduction in mortality in the U.S. relative to Canada, or the large reduction in inequality in mortality in the U.S. among men in this age group. It doesn't seem like homicide is a large enough cause of death for the decline in crime to be solely responsible, though it is likely to be a factor. Another possibility is that better trauma care is responsible for improved survival and that this has had a differential effect in the U.S. where low SES males are most likely to be the victim of both intentional and unintentional injuries.

For older males, we see reductions in mortality among males relative to females in both Canada and the U.S. This could reflect better care for things like heart disease (especially in the 65+ population where all Americans have health care). Again, since males were more likely to suffer from heart disease to begin with, improvements in medical care could have a differentially beneficial effect on them.

Our results also provide an interesting perspective on the choice of how to measure social disadvantage. In both Canada and the US, ranking the areas by the proportion of high school dropouts leads to positively (or at least non negatively) sloped gradients of mortality with disadvantage. As noted above the US inference is not particularly sensitive to instead ranking the areas by the official US poverty rate. For Canada, however, we observe some negatively sloped gradients when we rank areas by the LICO, a difference that is mostly reconciled when we instead rank the areas by the fixed cutoff LICO. Because life expectancy is a basic building block of well being, we might want to choose a ranking measure, such as education, which results in positive mortality/disadvantage gradients. However, mortality is just one "block", and rankings such as LICO or the US Supplementary Poverty Measure[11] attempt to account for the smaller consumption bundles that might result from higher prices in larger cities for a given income. Implicit here, therefore, is a question of how to trade off consumption and mortality, or other components of well being.

All told, our results comparing Canada and the U.S. may be interpreted like a glass that is either half empty or half full. Canadians have systematically lower mortality in most age and SES categories. On the other hand, inequality in mortality is actually increasing among middle aged adults in Canada, suggesting little cause for complacency. Finally, the increase in deaths due to accidental poisonings, attributable largely to the opioid epidemic, is a disturbing development that merits further policy response in both countries.

[11] See https://www.census.gov/hhes/povmeas/methodology/supplemental/overview.html accessed April 25, 2017.

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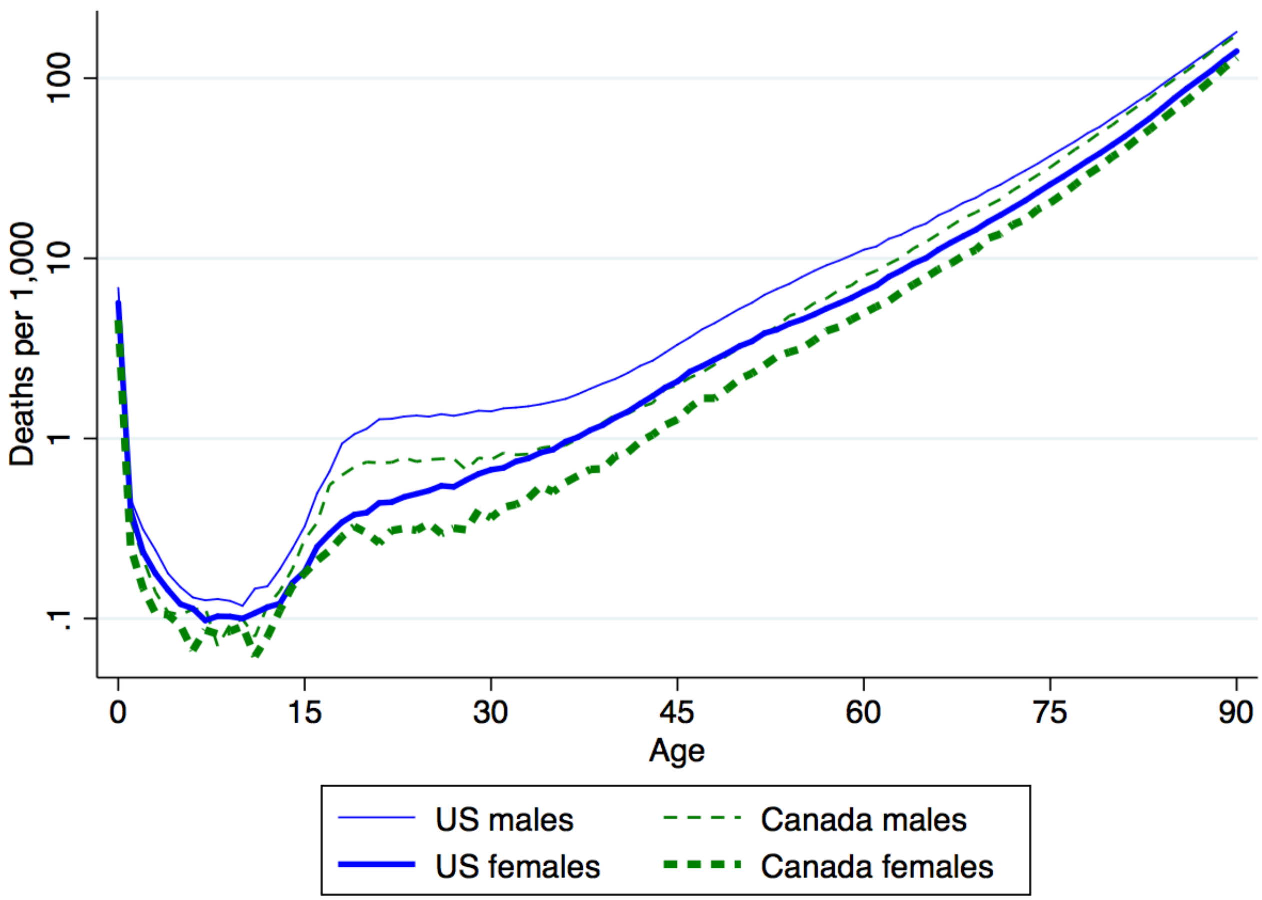
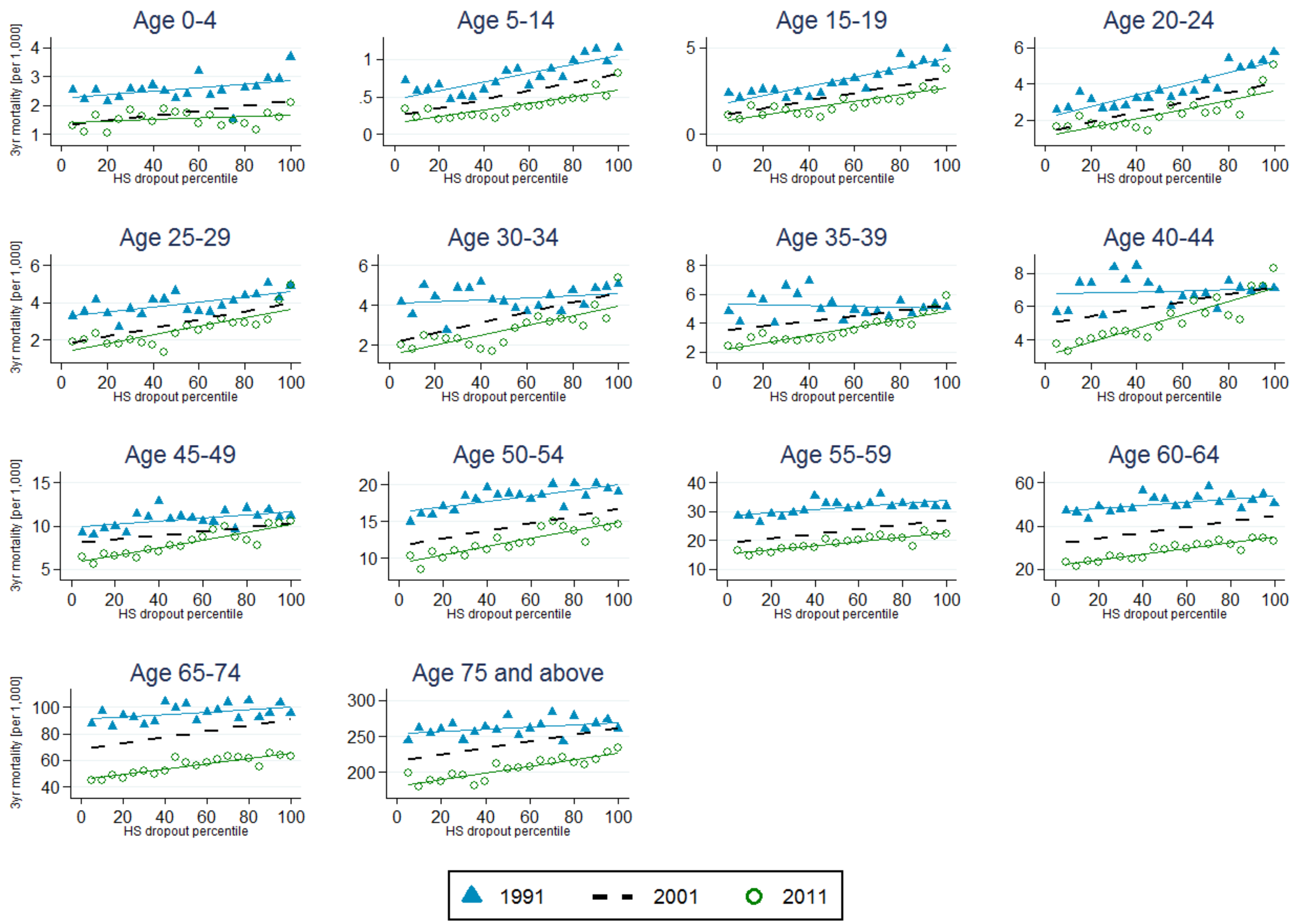
Figure 1: 1-year mortality rates in Canada and the US, 2009-2011 (averaged)



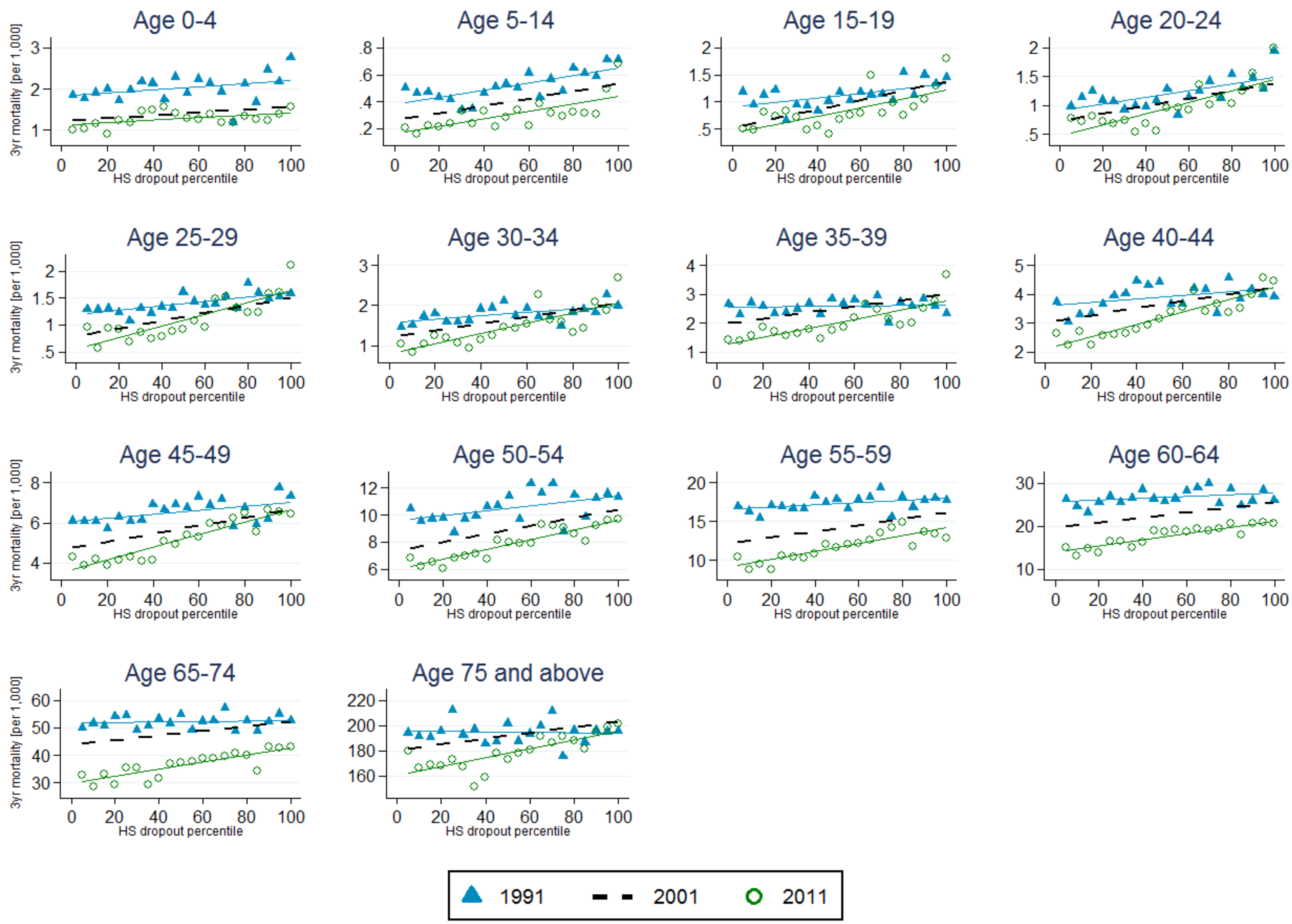
Notes: This figure shows annual mortality rates by gender and single year of age for Canada and the U.S. Rates are based on three year averages in both countries, in order to reduce variability in mortality rates at younger ages when mortality is a rare event.

Figure 2: 3-yr mortality rates by high school dropout percentile across age, males



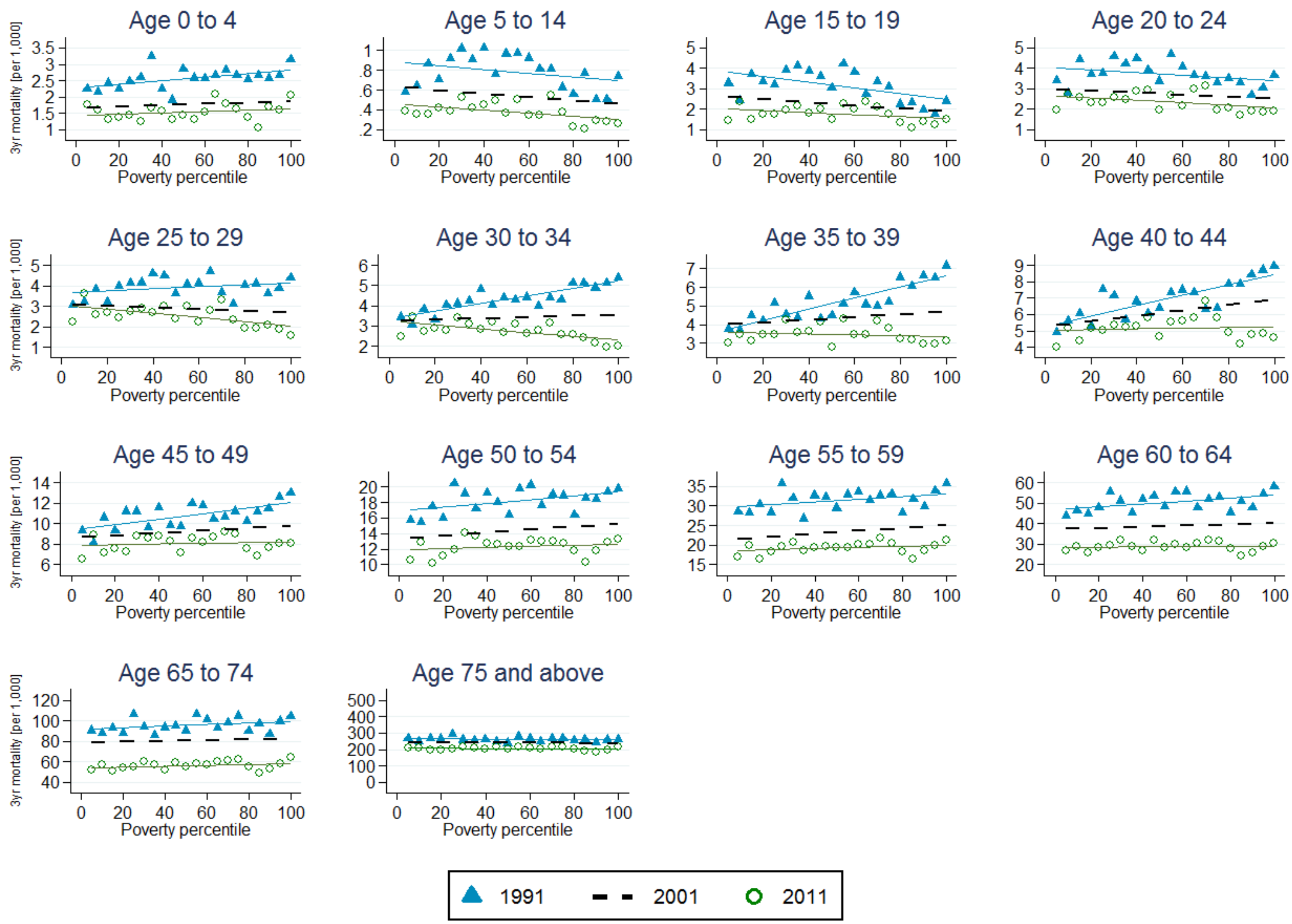
Notes: Average male 3-year mortality rates are plotted across groups of CDs divided by their rate of high school dropouts. Each bin represents a group of CDs with about 5% of the overall population in the respective year. Straight lines provide linear fits.

Figure 3: 3-yr mortality rates by high school dropout percentile across age, females



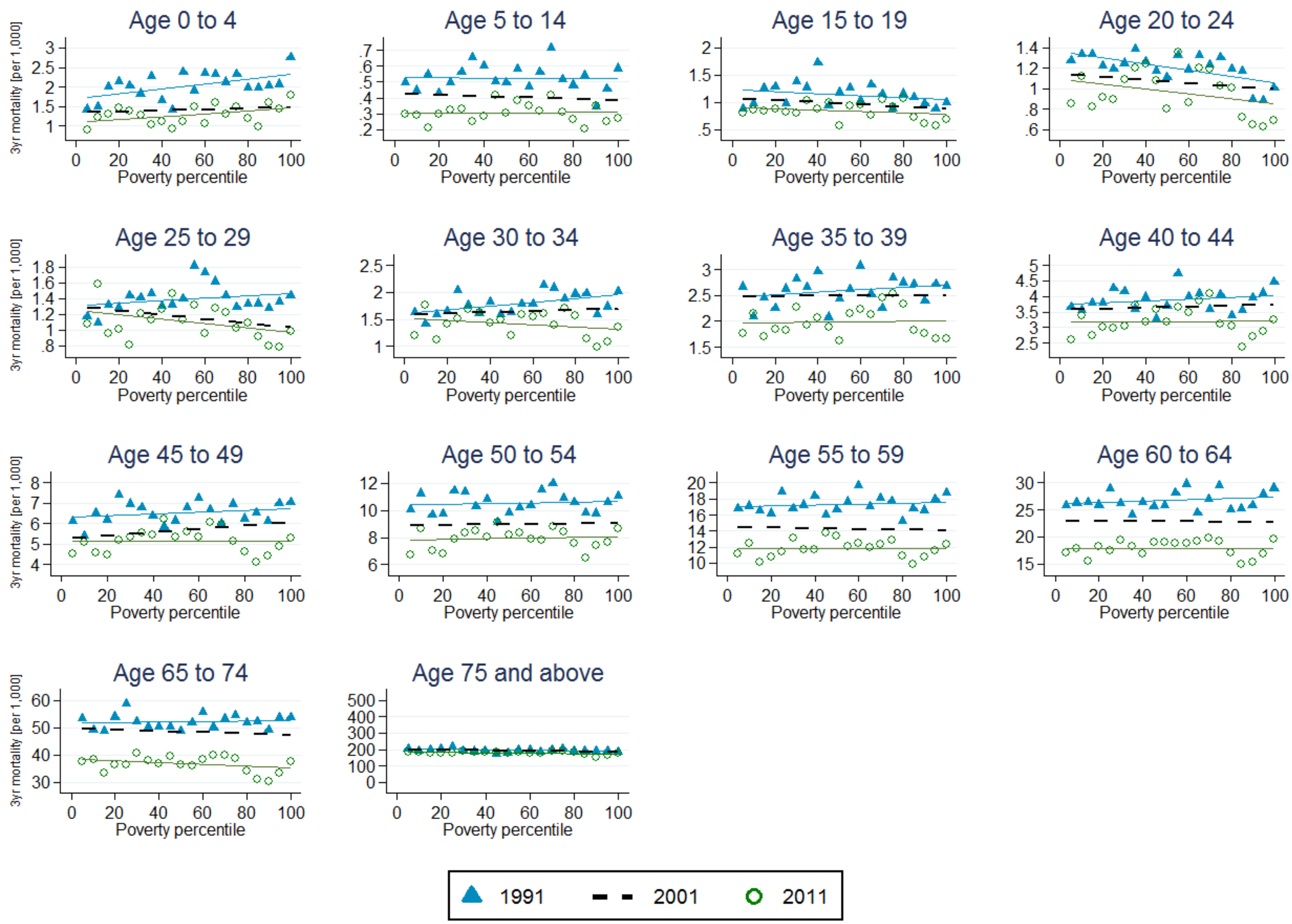
Notes: Average female 3-year mortality rates are plotted across groups of CDs divided by their rate of high school dropouts. Each bin represents a group of CDs with about 5% of the overall population in the respective year. Straight lines provide linear fits.

Figure 4: 3-year mortality rates by 2001 LICO percentile across age, males



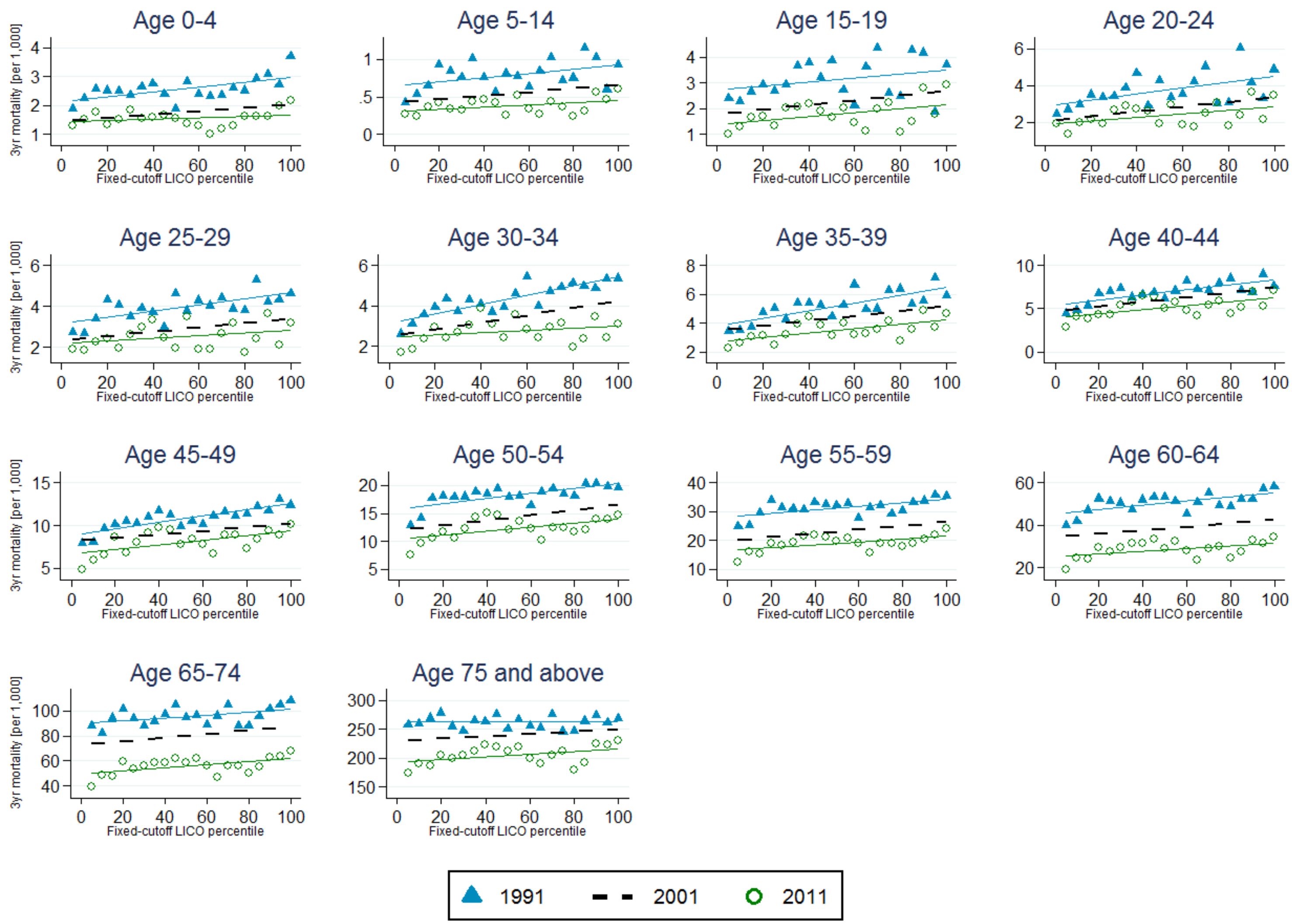
Notes: Average male 3-year mortality rates are plotted across groups of CDs divided by their LICO rate. Each bin represents a group of CDs with about 5% of the overall population in the respective year. Straight lines provide linear fits.

Figure 5: 3-year mortality rates by 2001 LICO percentile across age, females



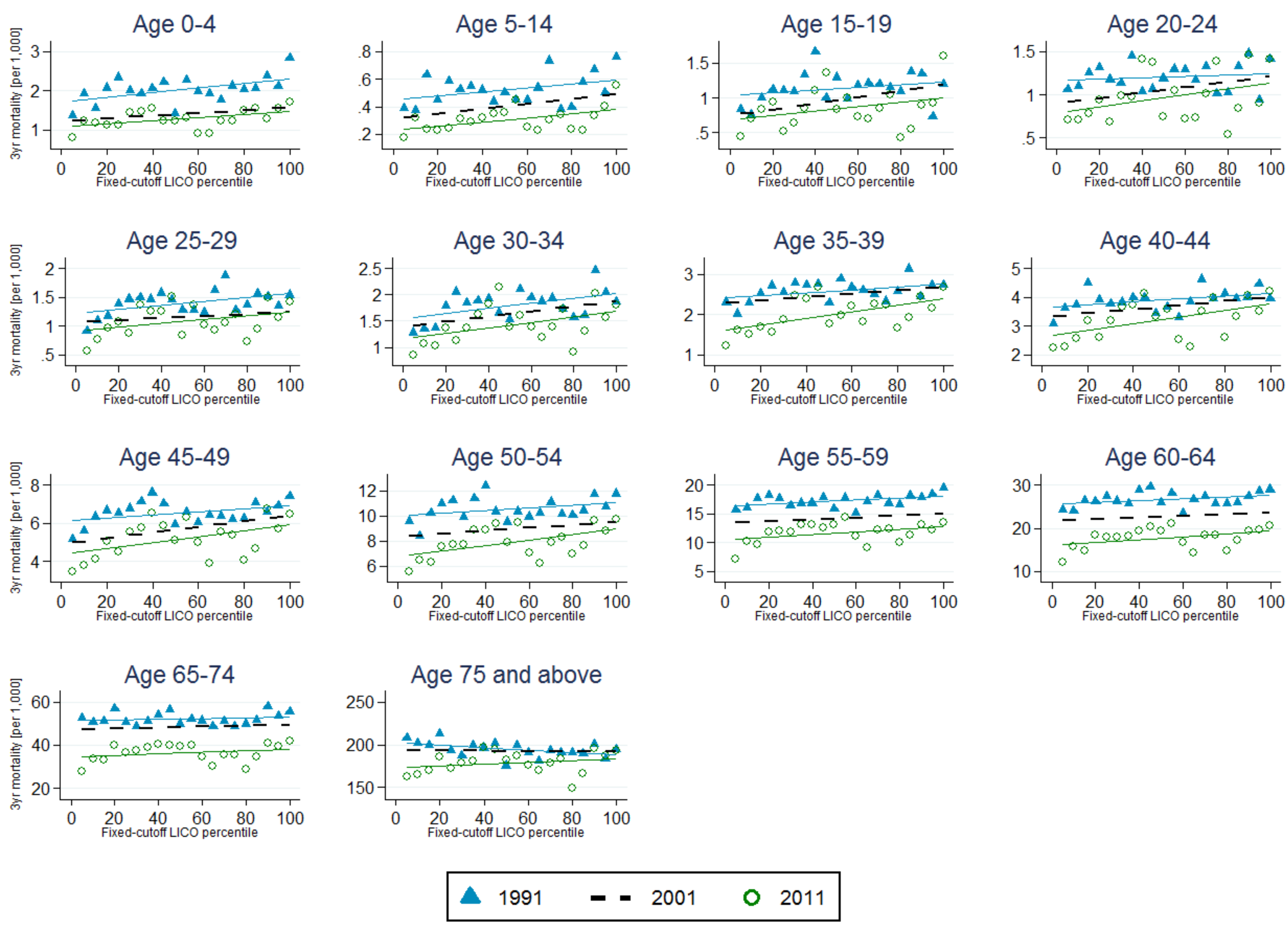
Notes: Average female 3-year mortality rates are plotted across groups of CDs divided by their LICO rate. Each bin represents a group of CDs with about 5% of the overall population in the respective year. Straight lines provide linear fits.

Figure 6: 3-year mortality rates by 2001 fixed-cutoff LICO percentile across age, males



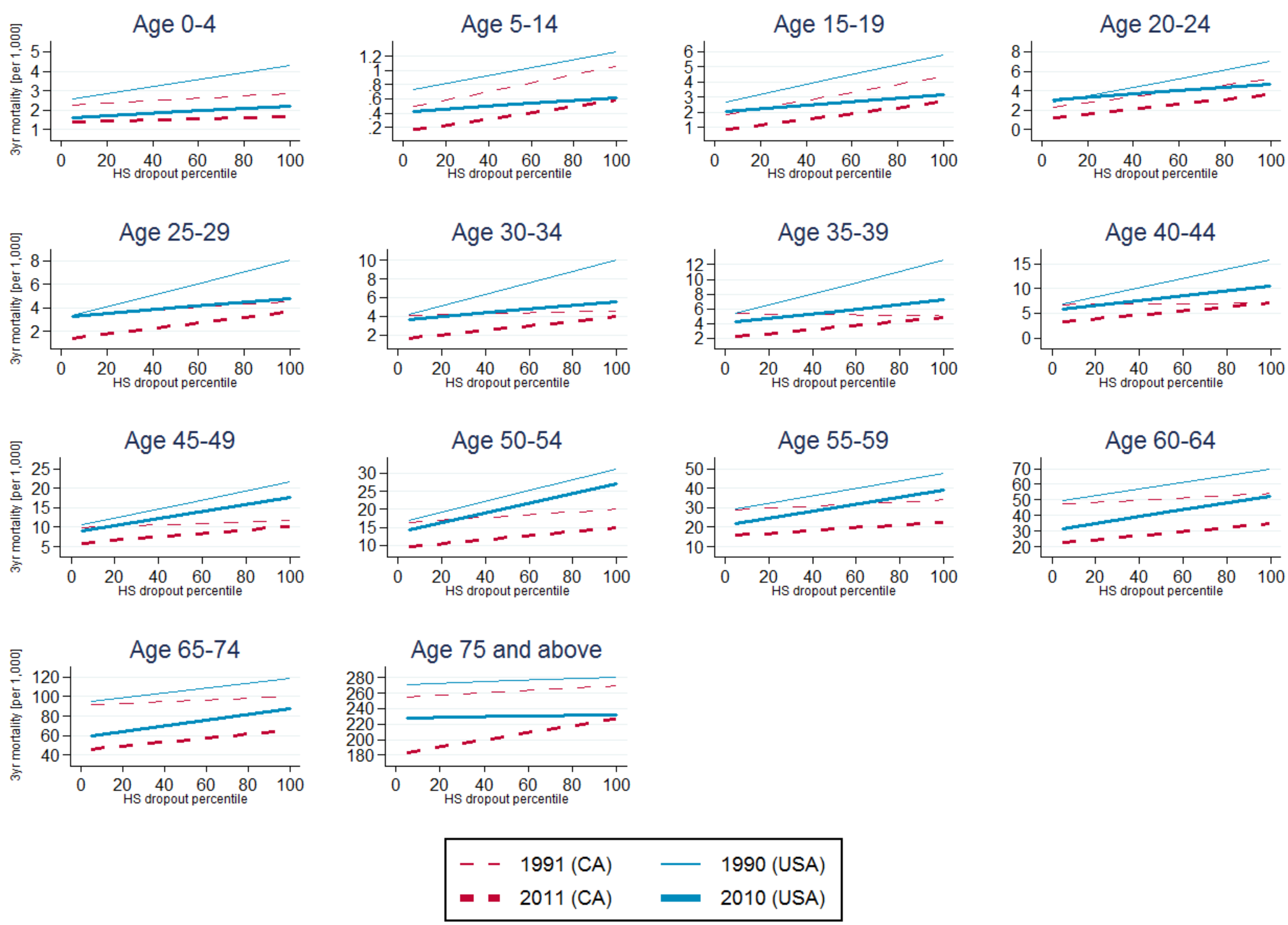
Notes: Average male 3-year mortality rates are plotted across groups of CDs divided by their fixed-cutoff LICO rate. Each bin represents a group of CDs with about 5% of the overall population in the respective year. Straight lines provide linear fits.

Figure 7: 3-year mortality rates by 2001 fixed-cutoff LICO percentile across age, females



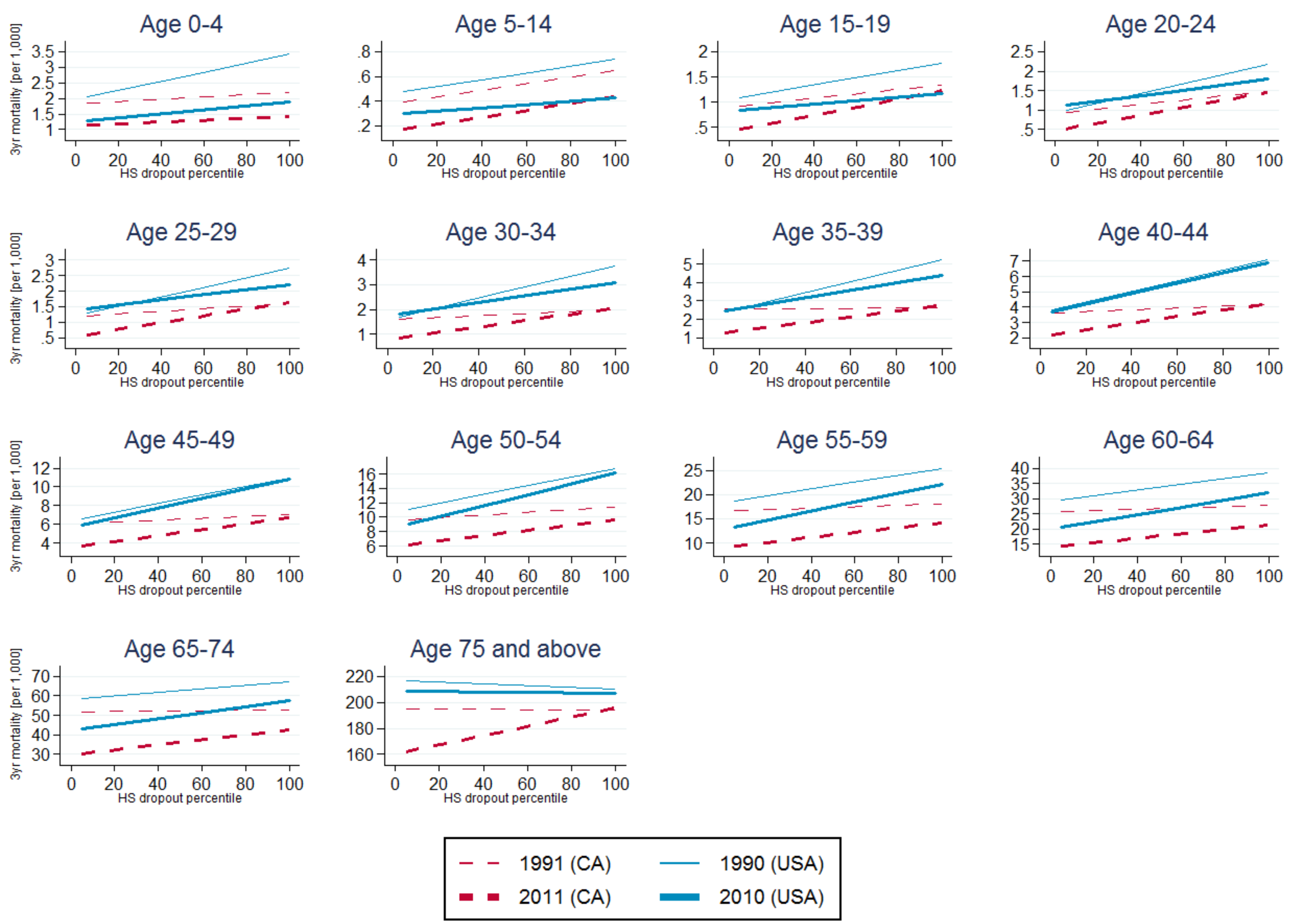
Notes: Average female 3-year mortality rates are plotted across groups of CDs divided by their fixed-cutoff LICO rate. Each bin represents a group of CDs with about 5% of the overall population in the respective year. Straight lines provide linear fits.

Figure 8: Canada vs USA mortality rates in 1990/91 and 2010/11 by base year high school (HS) dropout rate, males



Notes: This figure compares the gradients in male mortality rates across CDs in Canada with those across counties in the U.S. CDs and counties are ranked by their share of high school dropouts in both countries.

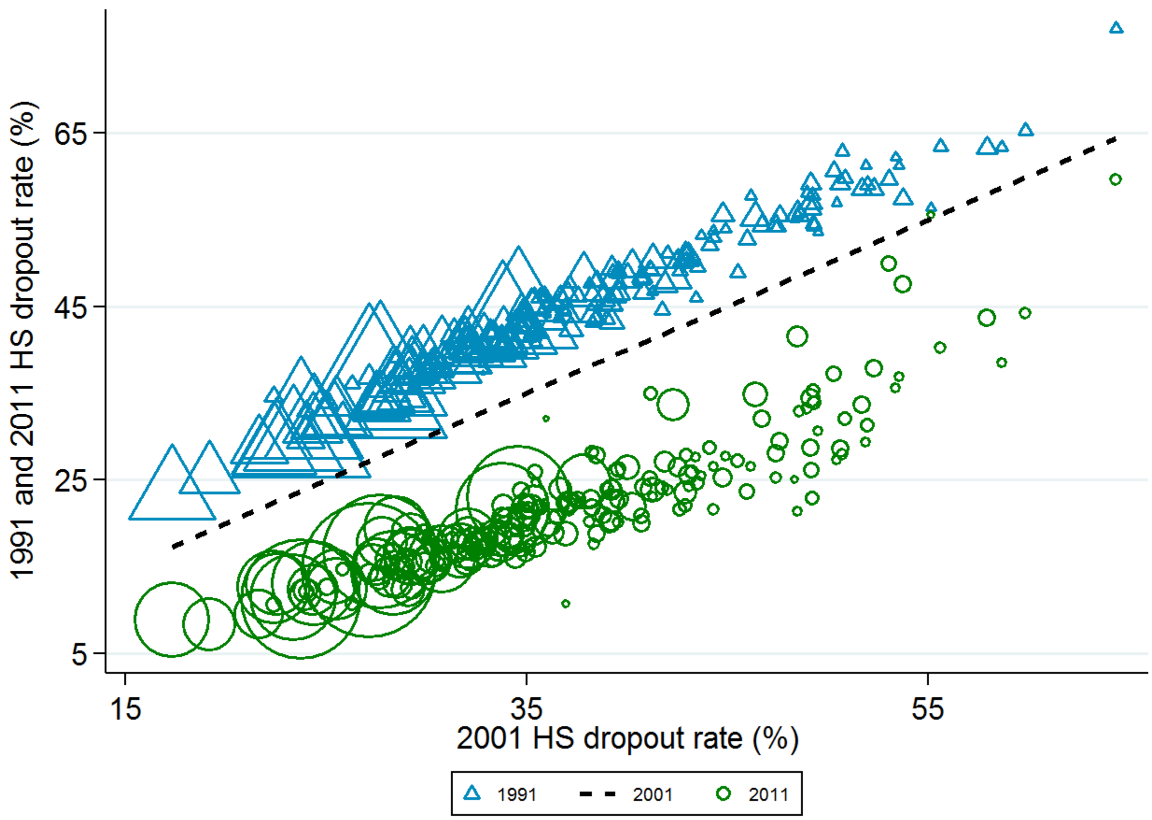
Figure 9: Canada vs USA mortality rates in 1990/91 and 2010/11 by base year high school (HS) dropout rate, females



Notes: This figure compares the gradients in female mortality rates across CDs in Canada with those across counties in the U.S. CDs and counties are ranked by their share of high school dropouts in both countries.

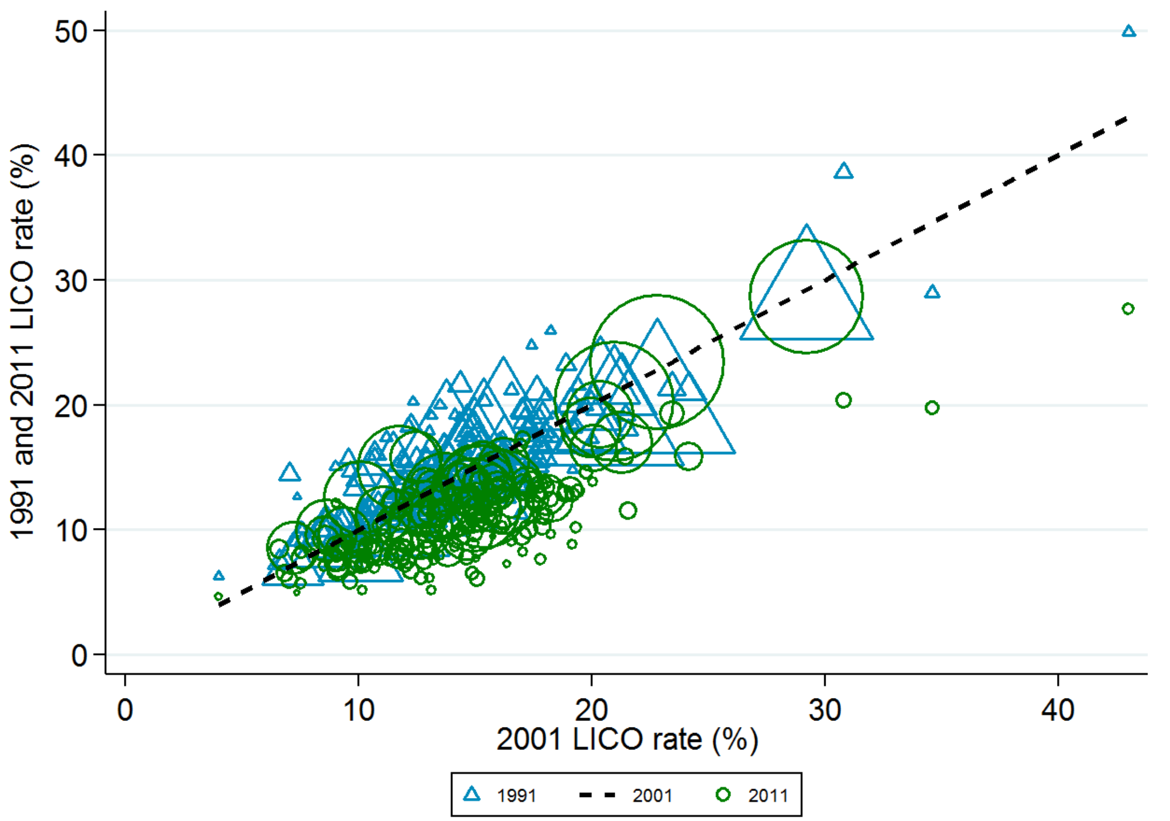
Appendix

Figure A.1: Canadian CDs ranked by high school drop out rate in 2001, vs. 1991 and 2011



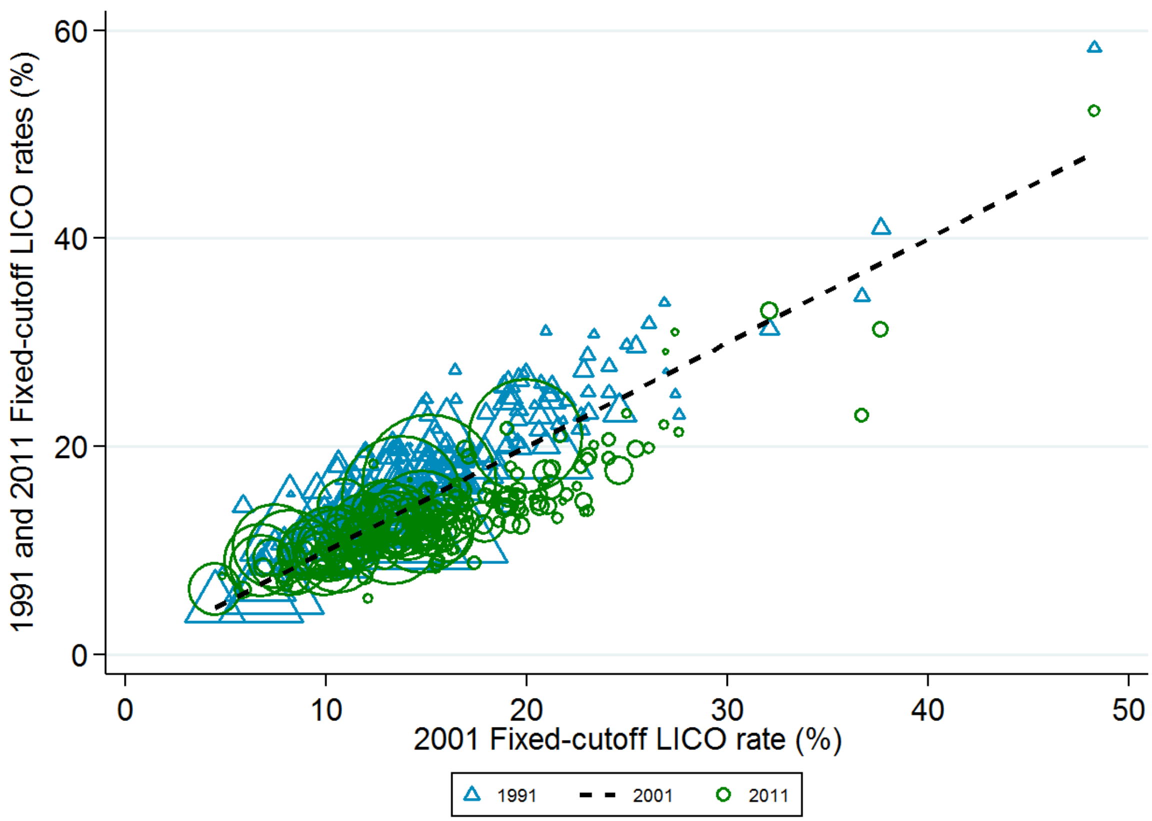
Notes: This figure compares high school dropout rates of individual CDs in 1991 and 2011 to their rate in 2001. Each marker represents one CD and the marker size is proportional to its population.

Figure A.2: Canadian CDs ranked by LICO in 2001, vs. 1991 and 2011.



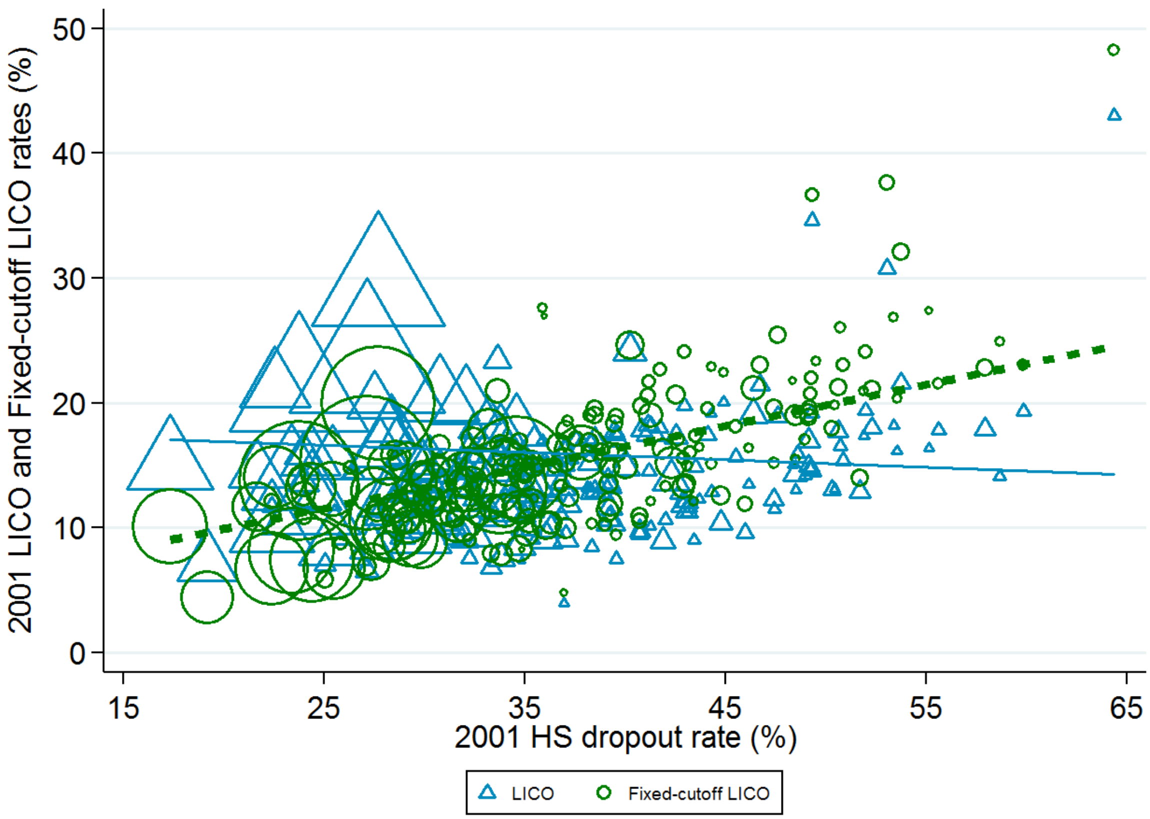
Notes: This figure compares LICO rates of individual CDs in 1991 and 2011 to their rate in 2001. Each marker represents one CD and the marker size is proportional to its population.

Figure A.3: Canadian CDs ranked by fixed-cutoff LICO in 2001, vs. 1991 and 2011.



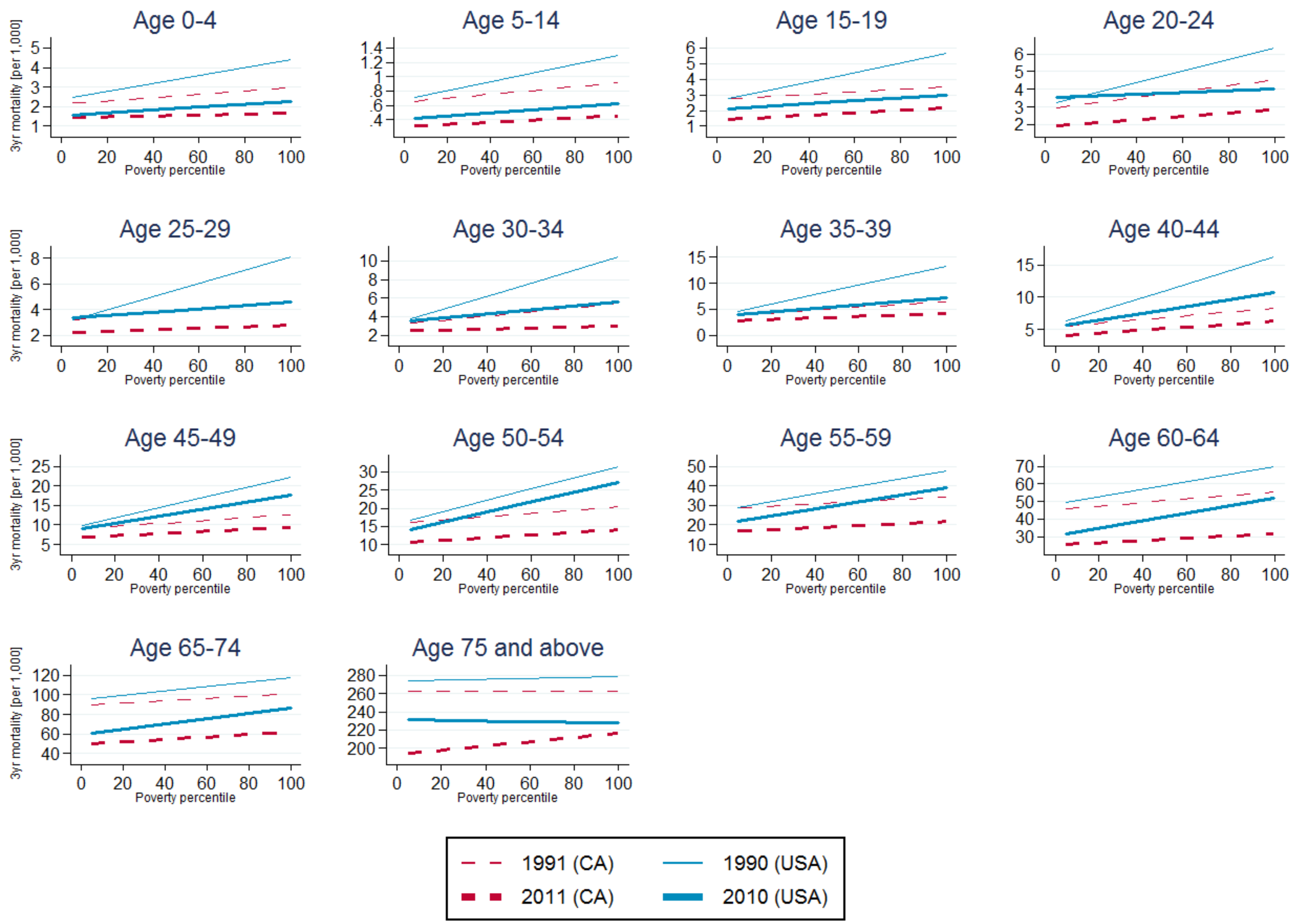
Notes: This figure compares fixed-cutoff LICO rates of individual CDs in 1991 and 2011 to their rate in 2001. Each marker represents one CD and the marker size is proportional to its population.

Figure A.4: Canadian CDs ranked by HS dropout rate vs. LICO and fixed-cutoff LICO, in 2001



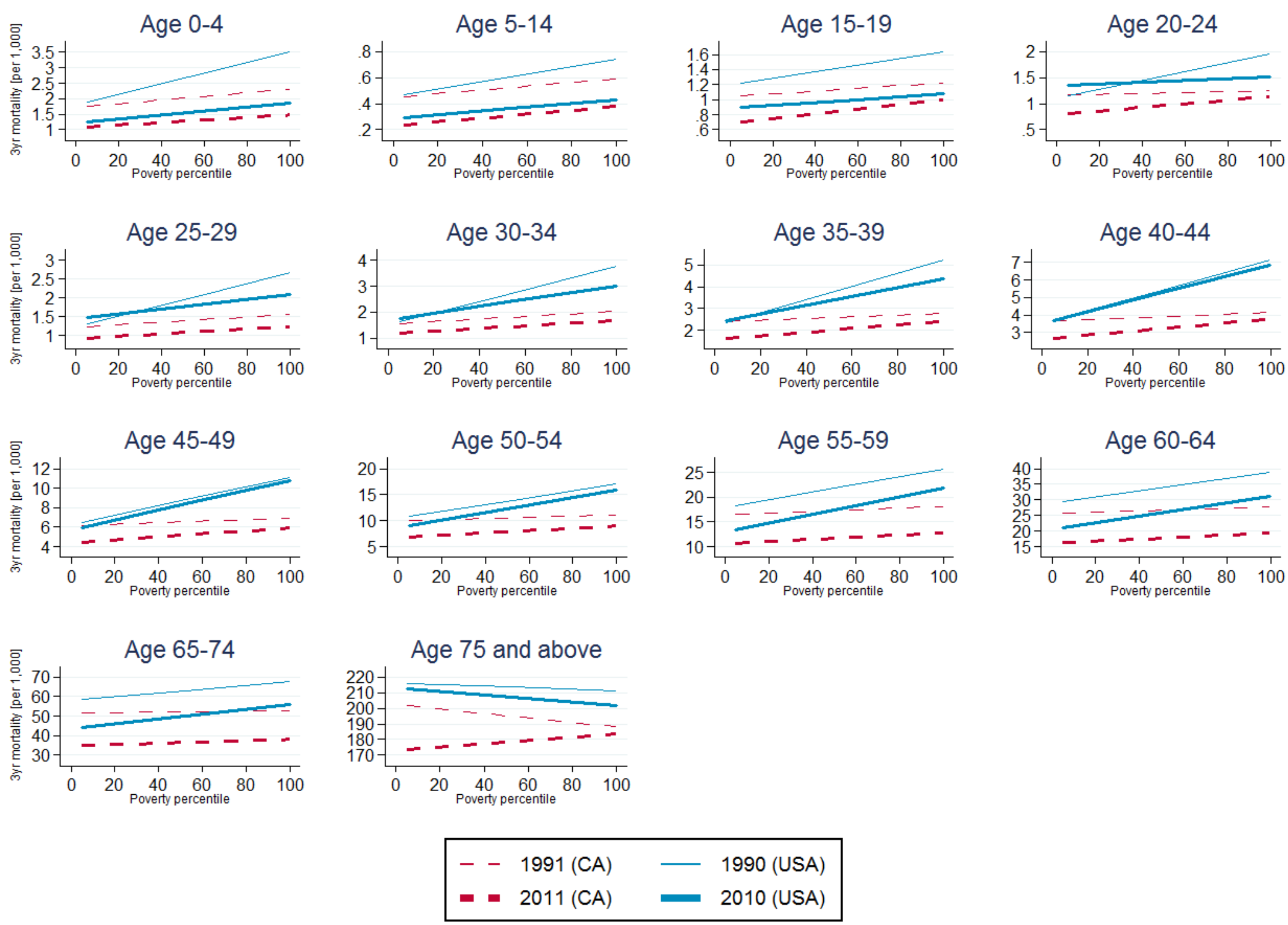
Notes: This figure compares high school dropout rates of individual CDs in 2011 with their LICO and fixed-cutoff LICO rates in the same year. Each marker represents one CD and the marker size is proportional to its population.

Figure A.5: Canada vs USA mortality rates in 1990/91 and 2010/11 by base year fixed-cutoff LICO/poverty, males



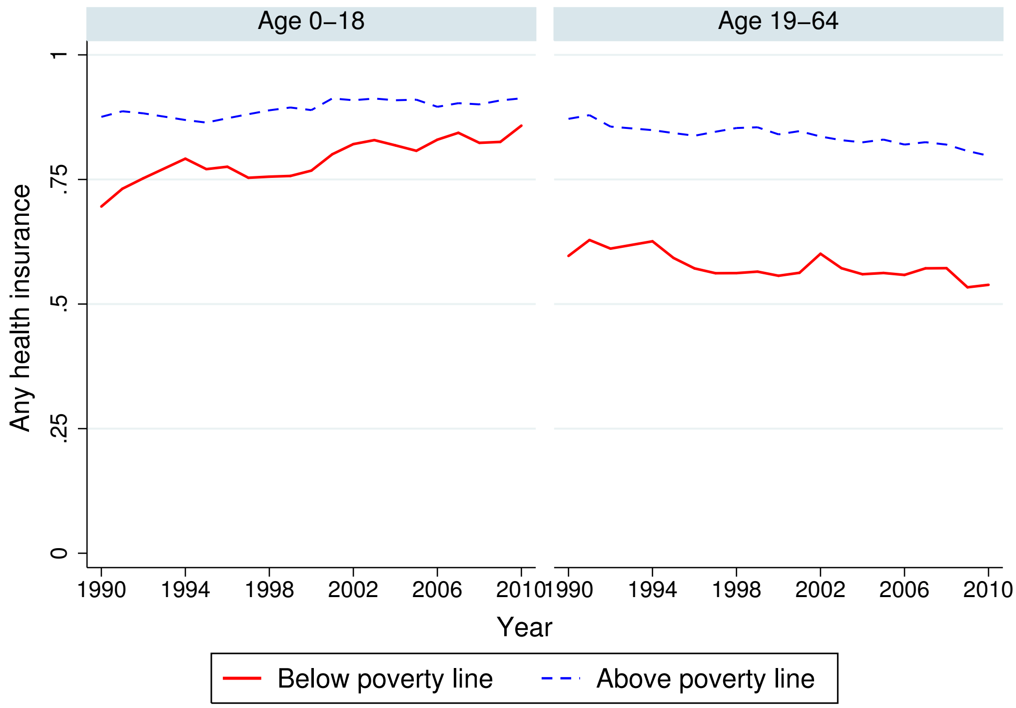
Notes: This figure compares the gradients in male mortality rates across CDs in Canada with those across counties in the U.S. CDs and counties are ranked by fixed-cutoff LICO rate in Canada and by their poverty rate in the U.S., respectively.

Figure A.6: Canada vs USA mortality rates in 1990/91 and 2010/11 by base year fixed-cutoff LICO/poverty, females



Notes: This figure compares the gradients in female mortality rates across CDs in Canada with those across counties in the U.S. CDs and counties are ranked by fixed-cutoff LICO rate in Canada and by their poverty rate in the U.S., respectively.

Figure A.7: Fraction with any health insurance coverage, U.S. 1990 to 2010



Notes: This figure shows the fractions of the U.S. population with any health insurance over time and by age group. Separate graphs are shown for the population with income below and above the poverty line. Data source is the National Health Interview Survey (NHIS).

Table A.1: Changes in mortality inequality in Canada, by age and CD ranking

	CD ranking by		
Age range	High school dropout rate	LICO	fixed-cutoff LICO
0-4	M ⬇, F ⬇	M ⬇, F ⬇	M ⬇, F ⬇
5-24	M ⬇, F ⬇	M ⬇, F -	M ⬇, F ⬆
25-49	M ⬆⬆, F ⬆⬆	M ⬇⬇, F ⬇	M ⬇, F ⬆
50-74	M ⬆, F ⬆	M ⬇, F ⬇	M -, F ⬆

Notes: Arrows indicate whether mortality inequality for males (M) and females (F) increased or decreased at different ages and according to different CD rankings.

Table A.2: Mortality rates by cause in Canada and the U.S., age 0 to 34

	2011 deaths per 100,000				Change, 1991-2011			
	Canada		U.S.		Canada		U.S.	
	Male	Female	Male	Female	Male	Female	Male	Female
(A) Age <1								
All Causes	537.7	439.0	658.4	552.4	-22%	-25%	-34%	-30%
Congenital anomalies	112.6	100.0	129.9	123.5	-45%	-47%	-35%	-29%
Short gestation/low birth weight	82.1	62.5	112.3	95.0	80%	39%	4%	2%
Pregnancy complications	46.5	46.7	44.7	35.6	65%	83%	12%	3%
Placenta, cord, membranes problems	36.7	22.8	27.1	23.6	52%	-16%	3%	15%
Sudden infant death	21.2	16.8	54.7	41.6	-80%	-76%	-65%	-59%
Undetermined	31.0	18.5	31.9	23.7	42%	-14%	30%	18%
(B) Age 1-19								
All Causes	24.3	15.3	32.7	18.3	-47%	-38%	-44%	-41%
Accidents	8.9	3.3	12.2	5.4	-59%	-55%	-52%	-50%
Accidental Drug Poisoning	0.4	0.4	1.3	0.5	385%	50%	440%	301%
Cancer	2.7	2.0	2.6	2.1	-33%	-33%	-34%	-30%
Suicide	4.0	2.1	4.1	1.2	-38%	65%	-17%	5%
Assault	1.2	0.7	4.6	1.3	34%	-51%	-52%	-48%
Undetermined	1.0	0.3	0.8	0.6	-48%	-74%	-35%	-31%
(C) Age 20-34								
All Causes	75.7	35.7	137.2	58.4	-42%	-25%	-28%	-14%
Accidents	28.1	8.3	54.3	19.0	-45%	-34%	-1%	17%
Accidental Drug Poisoning	7.4	2.8	21.7	8.7	58%	147%	351%	570%
Suicide	18.4	6.2	22.8	5.5	-40%	-4%	-9%	11%
Cancer	6.0	6.1	7.1	6.9	-38%	-40%	-31%	-32%
Assault	4.3	1.4	18.6	3.4	-12%	-39%	-44%	-56%
Undetermined	2.5	1.5	2.5	1.4	-57%	-40%	-46%	-28%

Notes: For comments see notes under the next table.

Table A.3: Mortality rates by cause in Canada and the U.S., age 35 and above

	2011 deaths per 100,000				Change, 1991-2011			
	Canada		U.S.		Canada		U.S.	
	Male	Female	Male	Female	Male	Female	Male	Female
(D) Age 35-49								
All Causes	164.0	105.3	278.2	173.5	-31%	-20%	-23%	0%
Accidents	28.6	10.1	55.4	25.5	-24%	-19%	22%	80%
Accidental Drug Poisoning	10.4	5.0	23.8	15.2	176%	123%	282%	697%
Cancer	35.6	45.5	41.2	49.1	-32%	-31%	-29%	-25%
Heart Diseases	24.9	8.0	54.5	22.7	-42%	-22%	-23%	-1%
Suicide	22.5	7.5	26.5	8.3	-17%	-4%	14%	20%
Undetermined	4.4	2.2	3.8	2.5	-52%	-43%	-47%	-20%
(E) Age 50-64								
All Causes	611.2	388.1	900.0	545.1	-40%	-31%	-27%	-24%
Cancer	239.7	213.8	268.7	210.8	-40%	-28%	-35%	-33%
Heart Diseases	127.2	111.8	219.1	141.1	-59%	-38%	-47%	-37%
Accidents	32.7	12.7	59.6	26.4	-22%	-24%	36%	57%
Accidental Drug Poisoning	6.6	4.3	18.2	12.1	220%	175%	1071%	1066%
Suicide	23.4	8.5	28.7	8.5	-8%	30%	15%	28%
Undetermined	7.3	3.9	8.2	4.8	-60%	-46%	-11%	0%
(F) Age 65 and above								
All Causes	2965.4	2078.1	3408.0	2521.0	-36%	-24%	-29%	-18%
Cancer	1105.6	770.0	1013.3	705.5	-23%	-5%	-26%	-13%
Heart Diseases	611.1	346.6	848.1	525.8	-59%	-60%	-52%	-51%
Chronic Lower Respiratory	161.0	127.2	250.7	212.1	-47%	17%	-16%	32%
Cerebrovascular	141.0	121.5	158.1	152.0	-53%	-50%	-44%	-38%
Undetermined	21.2	14.1	29.6	28.3	-63%	-60%	12%	60%

Notes: Population-weighted average 5yr age group death rates are shown, based on Statistics Canada and U.S. Centers for Disease Control data. Displayed causes are Canada's leading causes within each age group in 2011. Accidental drug poisoning displayed as subset of accidents, except for age 1-19, as accidental drug poisoning was not recorded for that age.