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Descriptive Findings

US regional and national cause-specific mortality and trends in income inequality: descriptive findings

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Max Planck Institute for Demographic Research

International Union for the Scientific Study of Population

Table of Contents

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Abstract

We examined the concordance of income inequality trends with 30-year US regional trends in cause-specific mortality and 100-year trends in heart disease and infant mortality. The evidence suggests that any links between income inequality and population health trends is likely to be complex. The descriptive findings here imply that income inequality would have to be linked and de-linked across different time periods, with different exposures to generate the observed heterogeneous regional and national levels and trends in different causes of death.

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1. Introduction

Over the last 10 years, there are few issues that have captured the imagination of public health researchers and advocates more than whether the extent of income inequality drives levels of population health within and between wealthy countries. This research theme has coincided with a heightened awareness and concern over the extent of income inequality between the rich and poor within countries, and the gaping chasm of inequality between rich and poor nations. In addition, there has been increased interest in understanding the capacity of environmental characteristics not conceptualized or measurable as characteristics of individuals - but rather as characteristics of places or aggregates of people - to affect the health of individuals (Diez-Roux 1998). Many so-called "contextual" health effects have been proposed (Pickett and Pearl 2001), including social capital and the extent of income inequality.

The idea that the unequal distribution of income in addition to the absolute amount of income might affect health has attracted contributions from scholars motivated by the humanitarian potential of showing how health could be improved through greater equity and social justice (Wilkinson 1996). It is also an important idea because of its relevance for wage and redistributive fiscal and tax policies. If one accepts the notion that income inequality is a determinant of population health then places that deliberately even out the life chances of individuals by having a more egalitarian income distribution will produce better overall health for their inhabitants. This is an appealing, intuitive, and policy relevant idea. Nevertheless, recent negative studies (Muller 2002; Shibuya, Hashimoto, and Yano 2002; Osler et al. 2002; Mellor and Milyo 2001; 2002; 2003; Deaton and Lubotsky 2003; McLeod et al. 2003; Messias 2003) have lead to questions over the strength of the evidence (Lynch and Davey Smith 2002). Johan Mackenbach commented that "… evidence for a correlation between income inequality and the health of the population is slowly dissipating" (Mackenbach 2002, p. 2).

2. The state of evidence linking income inequality to health

Where do we stand in the research program on income inequality and health? First, the original international evidence is clearly questionable (Wilkinson 1992) and seems likely to be an artifact of available data, but the association may be of importance for international differences in some infant and child health outcomes (Lynch et al. 2001). Second, while the aggregate level cross-sectional association between income inequality and health in the US seems solid, questions remain about both aggregate and cross-level confounding (Lynch, Harper, and Davey Smith in press). These issues have been examined in multilevel analyses (Subramanian, Blakely, and Kawachi 2003) and center around whether income inequality is a marker for other contextual characteristics of regions, states or cities in the US (Mellor and Milyo 2003; Muller 2002; Deaton and Lubotsky 2003), and/or whether it is confounded by compositional characteristics of these areas such as race/ethnicity and individual income (Deaton 2001; Subramanian and Kawachi in press). Third, the evidence suggests that the effects of income inequality on health differ within wealthy countries. There appear to be cross-sectional effects on health within the US, some inconsistent effects in the UK (Weich, Lewis, and Jenkins 2002), but no effects have so far been seen within Canada, Australia, Denmark, Sweden, Japan, or New Zealand (Ross et al. 2000a; 2000b; Muller 2002; Shibuya, Hashimoto, and Yano 2002; Osler et al. 2002; McLeod et al. 2003; Messias 2003), although effects are beginning to be reported in less wealthy countries (Subramanian et al. in press).

The largely negative findings within wealthy nations other than the US may be because in those countries there has been more evenly distributed social investments in public health-relevant goods and services over time. As demonstrated in studies of US states (Kaplan et al. 1996), higher income inequality is strongly associated with more unequal distribution of many potentially powerful contemporary and historical determinants of health (Lynch, Harper, and Davey Smith in press). Thus there is no necessary link between income inequality and population health – it may depend on the current and historical distribution of other health-relevant resources and exposures that exist within a country and their correlation with income inequality. The distribution of health-enhancing resources is affected by economic, social, political, and cultural history. For example, low ischemic heart disease (IHD) in southern Europe may be related to high prevalence and low social inequality in healthy diets, while the relatively low life expectancy of Danish women is likely related to the high prevalence and low social inequality in smoking (Cavelaars et al. 2000). So in the first case, higher income inequality is associated with equitable distribution of an important determinant of population health (diet), while in the second, lower income inequality is correlated with a more even social distribution of another determinant of population health (smoking). Understanding how different countries generate particular patterns and trends in population health will require historically and culturally contextualized explanations to understand their different configurations of population health determinants and how these might be linked with income inequality (Kunitz 1994; Davey Smith, Gunnell, and Ben-Shlomo 2001; Lynch 2000; Davey Smith and Egger 1996). Thus, it may not be income inequality *per se*, that drives population health. Rather, what may be most important is the current and historical links between income inequality and the distribution of health-relevant resources and exposures, and how these links have played out over the lifecourse of different birth cohorts (Davey Smith, Gunnell, and Ben-Shlomo 2001; Davey Smith and Lynch in press). However, before dismissing the role of income inequality in affecting health in wealthy countries it is important to note that most of the evidence has focused on mortality or life expectancy at birth (a synthetic measure derived from current age-specific mortality rates, and heavily driven by infant mortality) as the measure of population health and it is possible that there are other important dimensions of health such as quality of life or psychological morbidity and malaise that are more strongly linked to income inequality.

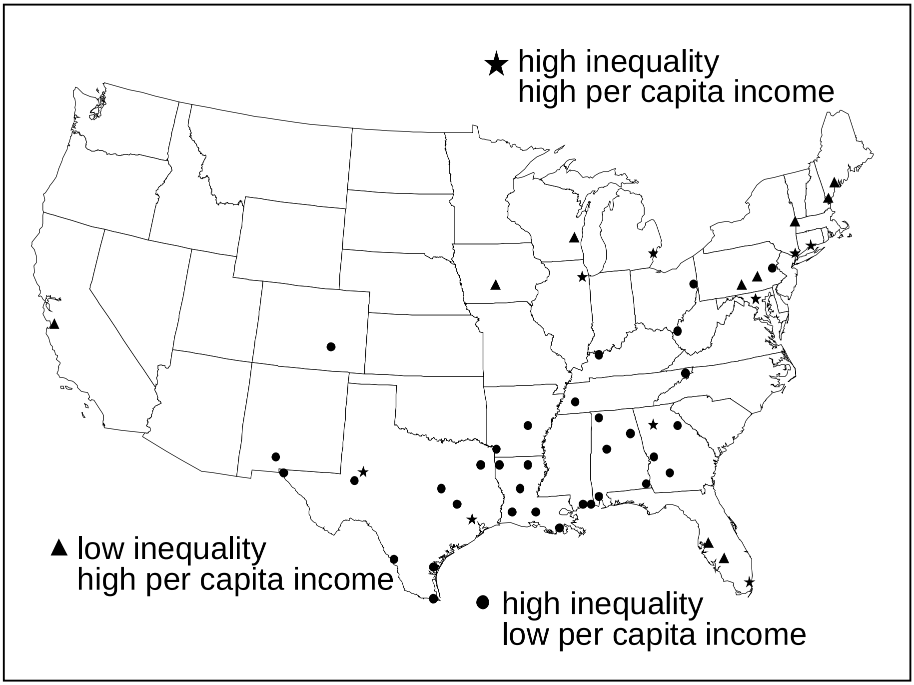
This brief review of the evidence suggests that this research theme is at something of a crossroads (Lynch and Davey Smith 2002; Lynch, Harper, and Davey Smith in press). We are left with the US evidence as being the most consistently in favour of a link between income inequality and population health. However, the bulk of this evidence is cross-sectional in nature with the small number of studies introducing a longitudinal component showing mixed results (Kaplan et al. 1996; Blakely et al. 2000; Deaton and Paxson 2001; Mellor and Milyo 2001). Our goal in the current paper is to expand the time-frame and examine evidence for longer-term influences of income inequality on mortality trends across regions of the US. The paper has three parts. First, we begin by presenting cross-sectional evidence of regional differences in the association between income inequality and mortality. Second, we present 30-year regional trends in cause-specific mortality, and data on regional shifts in income inequality. Finally, we present 20th century national trends in income inequality and, then 100-year national trends in cause-specific mortality, in regard to regional and national trends in income inequality. The premise is that if income inequality is indeed an important social determinant of population health, then its trends over time should in some ways be reflected in mortality trends. In other words, income inequality should leave a "population health footprint". Furthermore, we are presenting cause-specific mortality trends, because etiological studies of the social determinants of health may be most informative when examining more specific rather than more general outcomes, such as all-cause mortality or self-rated health. Different causes of death have distinct etiological pathways, so the mechanism through which a particular social exposure - such as income inequality - is linked to heart disease may be different than the mechanism through which it is linked to homicide. This potentially important mechanistic specificity is masked by examining general outcomes such as all-cause mortality. Thus we use extensive graphs of cause-specific mortality trends throughout the paper and in Appendix 1.

Source: Kaplan et al. (1996).

Figure 1: *Median Income Share and Age-adjusted Mortality, US States, 1990*

3. Part 1: Regional patterns of links between income inequality and mortality in the US

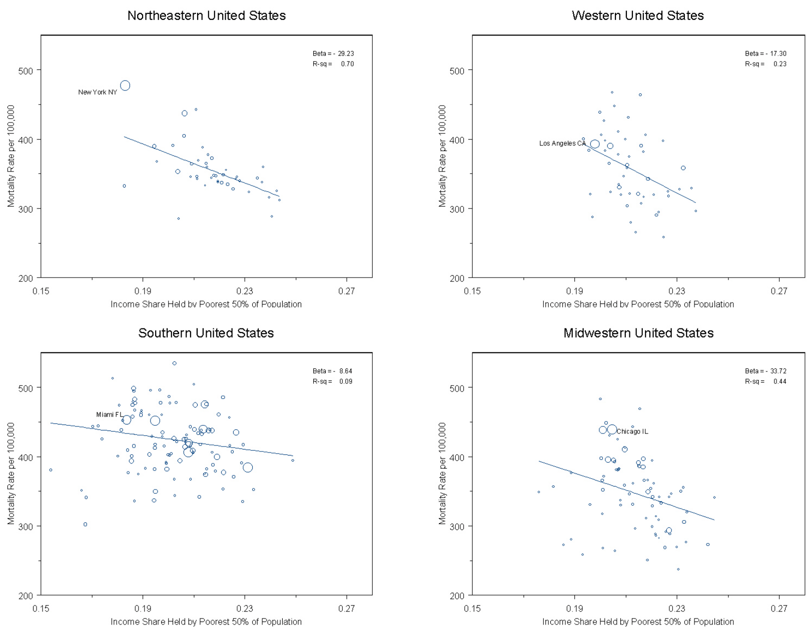
The first studies of US states showed an apparently strong regional pattern to the link between income inequality and mortality. Figure 1 shows that the most unequal, high mortality states were predominantly in the Southern US. The analysis of US metropolitan areas is somewhat less clear-cut but there is certainly some evidence that metropolitan areas in the south were in general more unequal and had higher mortality (Lynch et al. 1998). As shown in Figure 2, if we combine information on both low average income and income inequality, the places that receive the “double-whammy” of lower average income and higher income inequality in 1990 were overwhelmingly in the southern US.



Source: Lynch et al. (1998).

Figure 2: *Income Inequality and Per Capita Income, US Metro Areas, 1990*

So, at first glance there does appear to be evidence for a strong regional component to overall links between mortality and income inequality, in that southern US states and metropolitan areas have lower average income, higher income inequality and higher mortality. This fact underlies evidence by Mellor and Milyo (2003) that after adjustment for these regional differences, there is no overall effect of income inequality on health. In addition, it appears that there are regional differences in the strength of association between income inequality and mortality. Figure 3 shows the associations between income inequality and mortality (net median income differences) within broad regions of the US. The different markers within each region are the particular metro areas and their size reflects population count. While there is a statistically significant association between income inequality and mortality in all regions of the US, it is much stronger in the Midwest and Northeast than in the West, and interestingly the weakest association is among the Southern metropolitan areas. So while an important component of the overall national picture derives from the position of southern states and metro areas in relation to the others, within the South itself there is a much weaker link between income inequality and mortality. This is not the result of a truncated exposure distribution of income inequality. The range of exposure to income inequality within the south is at least as large as within other regions.



Source: Unpublished analyses, Nancy Ross, Statistics Canada.

Figure 3: *Associations Between Income Inequality and Age-adjusted Mortality Across Regions of North America, 1990*

The Southern region is recognized as generally having the worst population health profiles in the US (Pickle et al. 1996), although there is obviously a great deal of underlying heterogeneity by place and outcome. Nevertheless, these data suggest that for the region of the US with the worst population health profiles, the extent of income inequality (which has a similar range as nationally) within that region does not appear to be as strongly linked to variations in mortality within the region as it is in other regions of the US. Thus, there is some evidence that there may be region-specific compositional, historical and contextual factors that figure into the association between income inequality and mortality that require further investigation. Table 1 shows some basic demographic and economic differences between these US regions. It shows race/ethnic specific population distribution, income and income inequality for US regions. Population and income data are for 2000, but race-specific income inequality data by region require a special tabulation from US Census and this was only available for 1989. It is clear that there are different race/ethnic compositions of minority groups. Compositional differences and the way income inequality is expressed across these different groups may contribute to the regional differences in the strength of the association. In a highly racialized society such as the US, places with more minorities tend to under-invest across a broad spectrum of infrastructure that may influence health for everyone via “spillover effects” of racial discrimination. For instance, in states with higher proportions of blacks there are adverse conditions affecting whites as well, including greater overall poverty, lower average incomes, smaller monthly welfare support payments (but not welfare case loads), higher proportions of the population living in urban environments, more women without Medicaid insurance, less home ownership, less health insurance coverage, more female single-headed households and lower educational attainment. Thus, the uniformly less salubrious environment in the South may raise overall mortality for everyone and mute the effects of income inequality. Thus, in the cross-section it seems there is an interesting regional component behind the evidence that income inequality is linked to population health, with the South having higher income inequality and higher overall mortality, but that within the South itself, income inequality expresses itself less forcefully than in other regions.

Table 1: *Year 2000 Population Distribution[1] and Median Income[2] by Race/Ethnicity, and 1989 Income Inequality[3] by Race/Ethnicity, US Census Regions*

	Northeast	Midwest	South	West
% US Population	19.0	22.9	35.6	22.5
% White	79.1	85.0	74.1	72.0
% Black	12.2	10.6	19.5	5.5
% Hispanic[4]	9.8	4.9	11.6	24.3
Median Income (2000)	45,118	44,647	38,402	44,759
White	47,205	46,617	40,879	44,592
Black	30,426	30,053	29,778	36,975
White/Black Difference	16,779	16,564	11,101	7,617
White/Black Ratio	1.56	1.55	1.37	1.21
Income Inequality (Gini)	0.45	0.43	0.45	0.44
Among Whites	0.44	0.42	0.44	0.44
Among Blacks	0.46	0.48	0.46	0.44

Notes:
[1]Source: US Census Bureau, Profiles of General Demographic Characteristics, 2000.
[2]Source: US Census Bureau, Historical Income Tables from the Current Population Survey (2000 US dollars).
[3]Source: Gini Coefficient - authors' calculations based on special tabulation from 1990 US Census data. We did not have Race/Ethnic specific income inequality by region for 2000 Census.
[4]Note: Hispanics may be of any race.

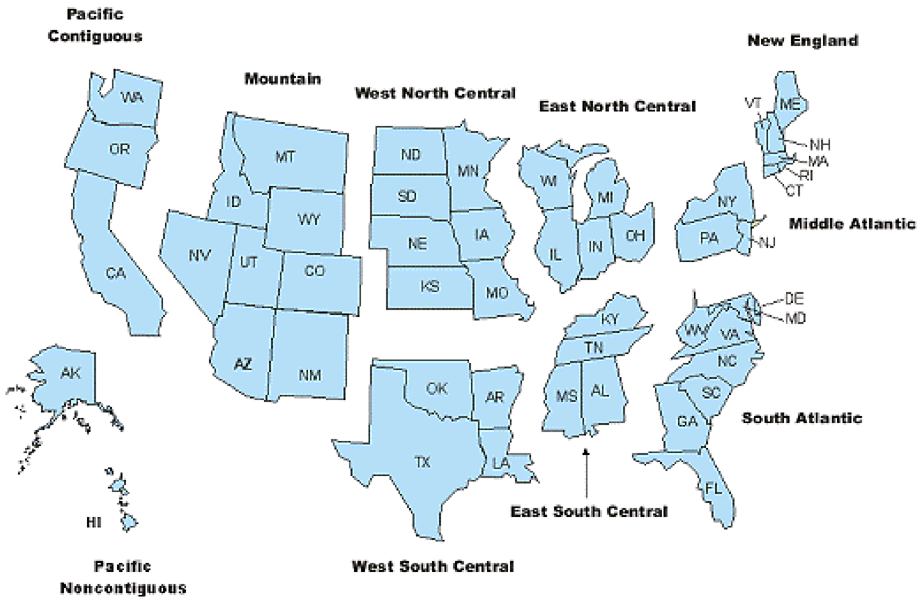
4. Part 2: Regional trends in cause-specific mortality and income inequality

It is worth noting that in the history of research on income inequality and health there have been very few studies that have included a longitudinal component (Blakely et al. 2000; Kaplan et al. 1996; Mellor and Milyo 2003; Subramanian, Blakely, and Kawachi 2003) and only one that has attempted to look at income inequality and mortality over the long-term (Deaton and Paxson 2001). In analyses at the national level, Deaton and Paxson argued that neither trends in income nor income inequality showed much resemblance to declining age-specific death rates in the US from 1950. Given the apparent importance of region to understanding the cross-sectional evidence in favour of links between income inequality and mortality, the next part of the paper examines whether income inequality affects regional trends in cause-specific mortality. We have chosen to examine trends from 1968-1998, because these are the years during which income inequality has rapidly risen to post WW2 historic highs (Ryscavage 1999).

Within a broader conceptual framework, we have stressed the need to consider time lags between relevant exposures and outcomes (Davey Smith and Egger 1996;

Davey Smith, Ben-Shlomo, and Lynch 2002; Leon 2001), and how our knowledge of individual-level risk factors might be profitably used to interpret temporal trends in population health (Davey Smith, Gunnell, and Ben-Shlomo 2001; Kuh and Davey Smith 1993; Leon and Davey Smith 2000; Leon 2001). This so-called "lifecourse approach" is beginning to be more fully articulated (Ben-Shlomo and Kuh 2002) and can be applied at both the individual and population levels. While some of these ideas are not really new - techniques such as birth cohort analysis have been used for decades (Kermack, McKendrick, and McKinlay 1934; Susser and Stein 1962; MacMahon and Terry 1958)- it can be argued that modern epidemiology is dominated by the identification of proximal (both biologically and temporally) risk factors for disease. It is important however, that we not loose sight of the fact that one of our fundamental tasks as epidemiologists is to understand why certain diseases wax and wane in different populations and population sub-groups over time. This involves understanding the dynamic interplay of individual risk and population level trends in particular diseases. Indeed, discussion and debate still occurs on the exact contributions of different factors to the 19th century transition from infectious to chronic diseases that occurred in wealthier countries (McKeown and Record 1962; Szreter 1988; 1994; 1997; 2002; Colgrove 2002; Link and Phelan 2002); what factors explain the precipitous rise and equally impressive fall in coronary heart disease in many countries (Lawlor, Ebrahim, and Davey Smith 2001; Stallones 1980; Vartiainen et al. 1995; Vartiainen et al. 1994); and what the real contribution of traditional risk factors such as smoking, lipids and hypertension were to trends in heart disease and stroke (Magnus et al. 2001; Lawlor et al. 2002). A recent example are the discussions over the rise and fall of peptic ulcer in the population – its association with *Helicobacter Pylori* infection and perhaps interactions with other factors such as social stress and diet (Susser and Stein 2002; Marshall 2002; Sonnenberg, Cucino, and Bauerfeind 2002) (Langman 2002; Levenstein 2002; Davey Smith 2001). The point here is that there seems something rather fundamental about being able to link our knowledge of risk exposures at the individual and social level with what we observe in population level health trends over time. In this case we are interested in understanding regional mortality trends.

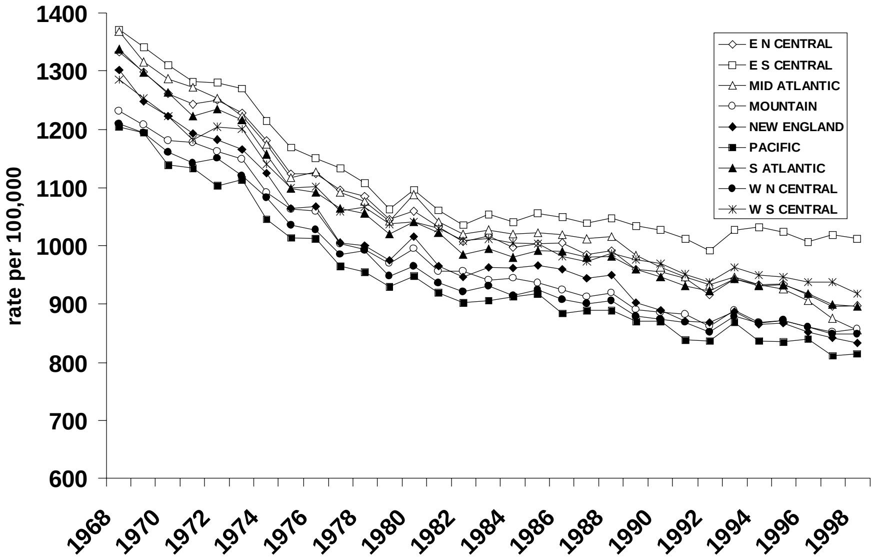
In thinking about how income inequality – a population-level characteristic – might be potentially linked to regional differences in health in the US we begin by displaying 30-year regional trends in some selected causes of death. There are 9 designated census divisions in the US depicted in Figure 4, which, for the sake of continuity, we will refer to as regions throughout the text.



Source: US Department of Energy (http://www.eia.doe.gov/cneaf/electricity/epav1/figa1.html)

Figure 4: *Standard US Census Regions*

The figures present trends in age-adjusted all-cause mortality, ischaemic heart disease (IHD), stroke, lung, breast and prostate cancer, suicide, homicide and diabetes across these 9 regions. For simplicity, we have combined male and female mortality, which of course will conceal important differences in some causes of death, especially for IHD and lung cancer where there are significant generational differences in the sex-specific trends. Additionally, we could have shown state-level trends or perhaps even different theoretically driven groupings of states, but for simplicity we chose to show the trends in the 9 standard Census regions.



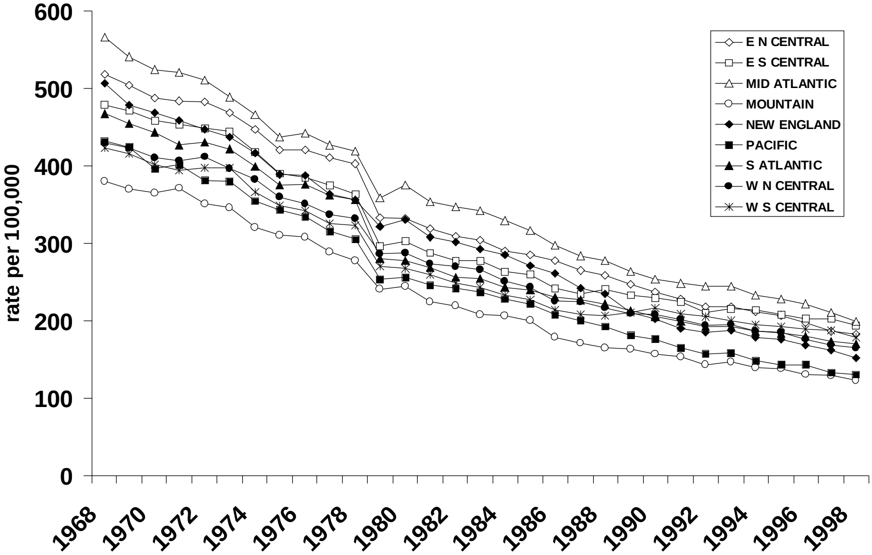
Source: Authors' tabulations of the Compressed Mortality Files (National Center for Health Statistics 2000; 2001b; National Center for Health Statistics 2001b)

Figure 5: *30-Year Trends in Age-adjusted All-Cause Mortality, US Regions*

Trends in all-cause mortality over the last 30 years (Figure 5) show that every region of the US has improved substantially, but with some widening of regional inequality, whereby there is now a larger absolute gap between the highest and lowest mortality areas - the East-South-Central and Pacific regions. Between 1968 and 1998 absolute regional differences increased from 168 to 198 deaths per 100,000 while relative regional inequality, calculated as the ratio of the region with the highest to that with the lowest mortality, increased from 1.14 to 1.24. What is also striking about these trends is the stability of the relative positions of the regions. The Pacific region has demonstrated the healthiest mortality profile, and it has done that over 30 years, perhaps because of something in the context of the Pacific region and/or because of the composition of the population in the Pacific region. In contrast the opposite is true in the East-South-Central region and as shown in Figure 2, this is the area with the highest concentrations of higher income inequality and low per capita income. So these trend data suggest that the cross-sectional picture described above has some continuity. The southern region has lagged others for at least 30 years. This may be important in terms of lifecourse influences on different birth cohorts.

There is evidence of slower declines in all-cause mortality in the West and East-South-Central regions from the early 1980s that may coincide with the period of widening income inequality, but this region of the US is also where the links between income inequality and mortality are weakest. So if rising income inequality is driving this slower decline, it does so in a region where the links between income inequality and mortality are the weakest in the US. Another feature of these trends is that some regions such as the Middle Atlantic shifted relative position. Nevertheless, the over-riding impression is that knowing where a region started in 1968 tells you a lot about where it is likely to be relative to other regions 30 years later.

This relative stability in regional trends is also clear when examining cause-specific 30-year mortality trends. Figure 6 shows that the Middle Atlantic region has had historically the highest levels of ischaemic heart disease (IHD) and the Mountain region the lowest. In 1968, they differed by 186 IHD deaths per 100K, corresponding to a rate ratio of 1.5. Thirty years later they still hold those same positions but with narrower absolute differences of 77 IHD deaths per 100K and similar relative inequality of 1.6. However, within these relatively stable patterns, New England shows strong improvements over 30 years, going from 3^{rd} worst to 3^{rd} best, while the West-South-Central reversed its declines in IHD in the late 1980s and for a period of about 3 years is the only region in the US to show increasing IHD death rates. So over 30 years these two regions swap their relative positions.

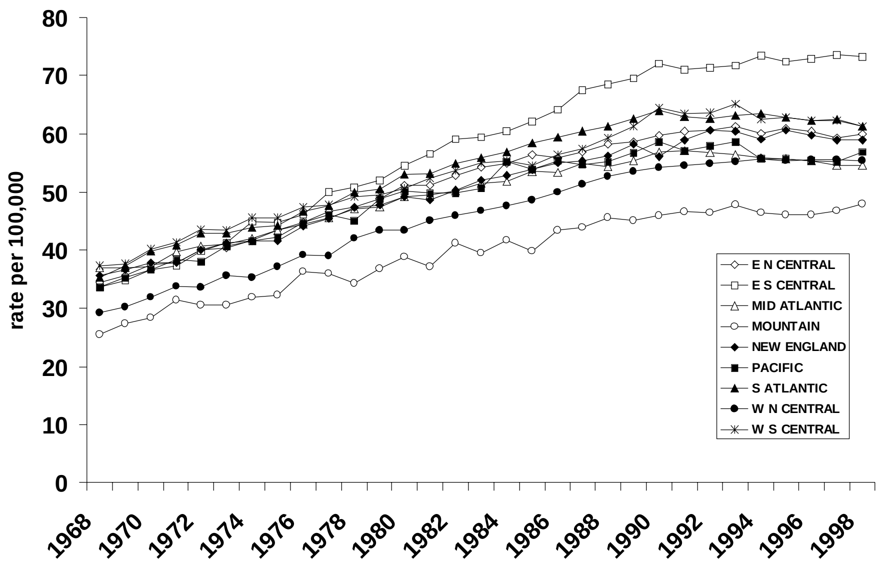


Source: Authors' tabulations of the Compressed Mortality Files (National Center for Health Statistics 2000; 2001b). (National Center for Health Statistics 2001b)

Figure 6: *30-Year Trends in Age-adjusted IHD Mortality, US Regions*

Stroke mortality - especially haemorrhagic stroke - has declined spectacularly since the 1900s and that decline is still evident from 1968-1998 with especially steep declines up until the early 1980s, with the East-South-Central region experiencing declines of 50% in the 15 years between 1968 and 1983 (See Figure 1 in Appendix I). This is in stark contrast to the generally slower declines in overall mortality and speaks to the value of examining trends in different causes. Now, cause-specific differences across regional trends also begin to emerge. For stroke, it is the Middle-Atlantic and New England regions that have had the historically lowest rates - almost the opposite pattern to IHD, where the Middle Atlantic had the highest rates. What is also striking about the trends in stroke is the narrowing of absolute regional inequality and despite the enormous secular changes in stroke over time the relative positions of the US regions again stay rather stable.

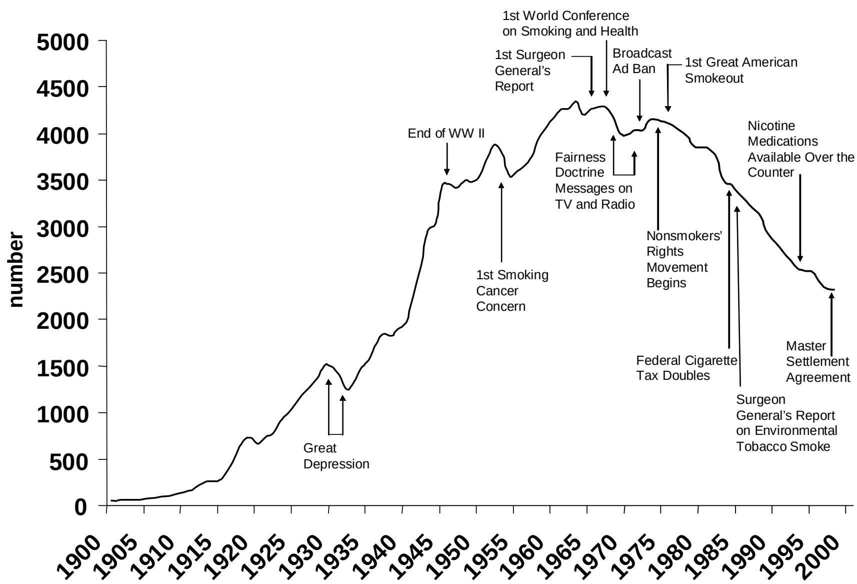
However, this picture may be misleading as it is complicated by the underlying heterogeneity in the outcome itself (Lawlor et al. 2002). It is possible that there are geographic differences in the relative contributions of haemorrhagic and ischaemic strokes to these trends. It would be interesting to know if there was higher concentrations of haemorrhagic stroke in the south of the US, where rates have historically been highest and have disproportionately affected African-Americans. Studies within and across other countries have suggested that there is a strong component of early-life socioeconomic disadvantage evident in the social group and geographic distribution of haemorrhagic stroke (Hart and Davey Smith 2003). This opens the intriguing possibility that the historically higher stroke rates in the southern US are related to factors associated with early-life deprivation of the African-American population and their later susceptibility to haemorrhagic stroke.



Source: Authors' tabulations of the Compressed Mortality Files (National Center for Health Statistics 2000; 2001b).

Figure 7: *30-Year Trends in Age-adjusted Lung Cancer Mortality, US Regions*

Figure 7 shows regional lung cancer mortality trends that demonstrate widening regional inequality between 1968 and 1998. The overall increase follows the rise in smoking prevalence during World War 1, to its peak in the mid 1960s shown in Figure 8. Increases in smoking map onto trends in lung cancer mortality for all regions given a time-lag of about 40 years. In 1968 (40-50 years after the first cohorts took up smoking in large numbers), Figure 8 shows there was a relatively tight clustering of lung cancer rates across regions, with the exceptions being substantially lower rates historically evident in Mountain and West-North-Central regions.



Source: Office on Smoking and Health (Office on Smoking and Health, National Center for Chronic Disease Prevention and Health Promotion, Centers for Disease Control and Prevention 1999).

Figure 8: *Historical Points in Annual Adult Per Capita Cigarette Consumption in the US, 1900-1998*

Over 30 years the regional disparity in lung cancer, unlike stroke, has increased with the East-South-Central and South-Atlantic showing the largest increases in lung cancer mortality. These are also the main tobacco producing regions of the US. However, whatever was initially protective (contextual and compositional) for the uptake of smoking and of later lung cancer mortality in the Mountain and West-North-Central regions, it continued to generate the lowest rates of lung cancer over the next 30 years. It is perhaps not coincidental that the East-South-Central and Mountain regions also have the highest and lowest IHD rates respectively, but of course the time lags between smoking and lung cancer and smoking and IHD are different. It is also important to remember that these regional trends in lung cancer mortality may be sensitive to race and sex-specific birth cohort effects associated with the differential uptake and cumulative exposure to smoking (Strachan and Perry 1997). For instance, white males born in the decades immediately before and after World War I were the first to adopt smoking in large numbers, with smoking among women and minorities becoming most prevalent in cohorts born around World War II (Escobedo and Peddicord 1996; Burns et al. 1997). Thus, divergent regional trends in lung cancer mortality shown in Figure 7 may also reflect differential regional uptake and cessation of smoking by different population sub-groups. While it may be possible to speculate that rising income inequality might have affected these regional patterns, it seems more likely that a simpler explanation exists, related to the differing historical roles of tobacco use in the economies and cultures of these contrasting regions – the tobacco producing areas of the Southern US vs. the more religiously and socially conservative Midwest and mountain areas.

Figures 2 to 5 in Appendix I show 30-year mortality trends for breast and prostate cancer, suicide and homicide. Note the regional heterogeneity by cause of death, with the Mountain region having the lowest breast cancer rates but the highest prostate cancer and suicide rates. The initial regional differences in suicide remain in place over the 30 year period from 1968-1998. Some of the strongest arguments in support of the theory that greater income inequality produces worse population health have come from analyses of homicide. Inequality is postulated to engender negative emotions of distrust and hostility in individuals that lead to a breakdown of social cohesion (Wilkinson 1996), which in turn affect homicide and violence, presumably within a relatively short time frame. Thus, there should be a relatively short lag between change in the exposure and trends in the outcome. These data suggest that any changes in income inequality between 1968 and 1998 do not produce any obvious trend changes in homicide mortality in any region of the US. In some regions homicide is rather stable, while in others it fluctuates throughout the time period that income inequality was consistently rising.

Examination of these disease specific regional trends suggests there is a good deal of heterogeneity of trends across causes. The relative rankings of the regions by cause also shows no clear patterns, whether the secular trends are stable, increasing or decreasing. Perhaps the most enduring impression is the cause-specific stability of regional differences over time - in general, a region's relative position in 1968 appears to be the strongest determinant of its position in 1998. There are exceptions and it may be interesting to examine some of the more dramatic shifts in regional trajectories over time – such as the upturn in IHD deaths in the West–South–Central region in the early 1980s, but the main pattern is one of relative regional stability. This suggests regions get on trajectories for different causes of death that seem relatively stable over time.

What can be said about the potential for income inequality to influence these disease specific trends? First, we chose to examine regional trends during the period 1968-1998 because this is precisely the period when levels of income inequality rose sharply in the US - at least relative to post-war levels. The rise in income inequality experienced in the US as a whole from the mid-1960s onwards was evidenced in every state and region to a greater or lesser extent. A recent report based on the Current Population Survey (CPS) by Bernstein et al. (2002), has shown some variability in changes in income inequality, measured by the "top-to-bottom ratio" (incomes of the top 20% vs. incomes for the bottom 20% of the population), across regions of the US for the period 1978-2000, which corresponds to the period of the largest rise in inequality. As shown in Table 2, the largest increases in this measure of income inequality were observed down the eastern seaboard of the US - in the Middle and Southern Atlantic states and New England. There is no obvious association between the starting levels of income inequality in 1978 and the changes experienced over the next 20 years. For instance, in 1978 New England had the lowest "top-to-bottom" ratio at 6.3 and then experienced a large absolute and percentage increase to 9.0 (43%). In contrast, the highest levels of inequality in 1978 were in the West and East-South Central region (which generally has the poorest population health profiles), but they experienced some of the smallest increases from 1978-2000.

Table 2: *Changes in Regional Population[a] and Income Inequality[b], US, 1978-2000*

Division	% Change in share of total US population 1978-80 to 1996-98	Proportion Black 1978-80	Proportion Black 1996-98	Increase in Proportion Black Absolute (%)	Top-to-bottom income ratio 1978-80	Top-to-bottom income ratio 1998-2000	Increase in Top-to-bottom Ratio Absolute (%)	Reduction in Total Mortality Absolute (%)
Middle Atlantic	-13.7	12.0	14.6	2.6 (21.6)	7.1	10.4	3.3 (46.5)	222 (20.6)
South Atlantic	11.5	20.7	21.6	1.0 (4.7)	7.8	10.4	2.6 (33.3)	159 (15.1)
New England	-9.5	4.0	5.7	1.7 (43.8)	6.3	9.0	2.6 (42.9)	167 (16.7)
East North Central	-11.7	10.8	12.0	1.3 (11.8)	6.5	8.7	2.2 (33.8)	188 (17.0)
Pacific	15.5	6.3	6.4	0.1 (2.2)	7.5	9.5	2.0 (26.7)	141 (14.8)
East South Central	-5.9	19.5	20.2	0.6 (3.3)	8.3	10.1	1.9 (21.7)	95 (8.6)
Mountain	25.8	2.3	3.3	0.9 (39.9)	6.8	8.6	1.8 (26.5)	137 (13.8)
West South Central	7.0	14.8	15.0	0.2 (1.3)	8.5	10.2	1.8 (20.0)	148 (13.9)
West North Central	-9.3	4.5	5.6	1.0 (23.1)	6.6	8.1	1.5 (22.7)	143 (14.4)
Average		11.7	12.7	1.1 (9.2)	7.2	9.3	2.1 (29.2)	156 (15.0)

Note: Regions are sorted in order of largest-to-smallest absolute change in top-to-bottom ratio.
[a]Taken from the National Center for Health Statistics Compressed Mortality Files, 1968-88 and 1989-98. Population data based on the US Bureau of the Census intercensal estimates of the July 1 resident population, with the exception of 1980, which is based on the modified age-race-sex (MARS) census counts.
[b]Adapted from Bernstein et al. (2002)

Nor is there any obvious association between regional changes in income inequality and reductions in total mortality. The regions with above average absolute and relative increases in income inequality all had above average absolute and relative decreases in mortality. In fact, the region with the largest absolute and relative increase in income inequality from 1978 to 2000 – the Middle Atlantic – experienced the largest absolute and relative reductions in mortality over the same time period. We summarized the data on these changes in income inequality and changes in mortality by correlating the change in the top-to-bottom income ratio and the reduction in mortality from 1978-2000. The Pearson correlation is 0.76 for the absolute change in income inequality with all-cause mortality change, and 0.81 for the change in relative inequality and mortality. Thus, from these numbers we would conclude that *increasing* income inequality was associated with *decreasing* mortality rates – the exact opposite of what would be hypothesized by a theory that income inequality directly affected mortality with little time lag.

It has also been argued that associations between income inequality and mortality are confounded by race/ethnic composition, where the higher poverty and increased mortality rates of blacks lead to spurious ecological associations between income inequality and mortality (Deaton and Lubotsky 2003). If true, then we might expect regions experiencing larger increases in the proportion of blacks in the region to have smaller reductions in mortality over time. Table 2 also presents data on the proportion black in US regions from 1978-98. Similar to the trend for income inequality, the region with the largest absolute increase in proportion black (Middle Atlantic) had the largest total reduction in mortality – the exact opposite of what the racial composition argument would predict, but of course this may depend on the age structure of in-migration. There also does not seem to be any relationship between changes in proportion black and changes in income inequality, a finding that has been replicated in other studies of the determinants of changes in income inequality among US metropolitan areas (Madden 2000). In addition, there appears to be no systematic relationship between initial proportion black and reduction in mortality. The region with the highest initial proportion black (South Atlantic, 20.7%) had a better-than-average absolute mortality reduction of 159 per 100,000, while the region with the second highest proportion black (East South Central, 19.5%) saw mortality reduced by only 95 – the smallest reduction among all regions.

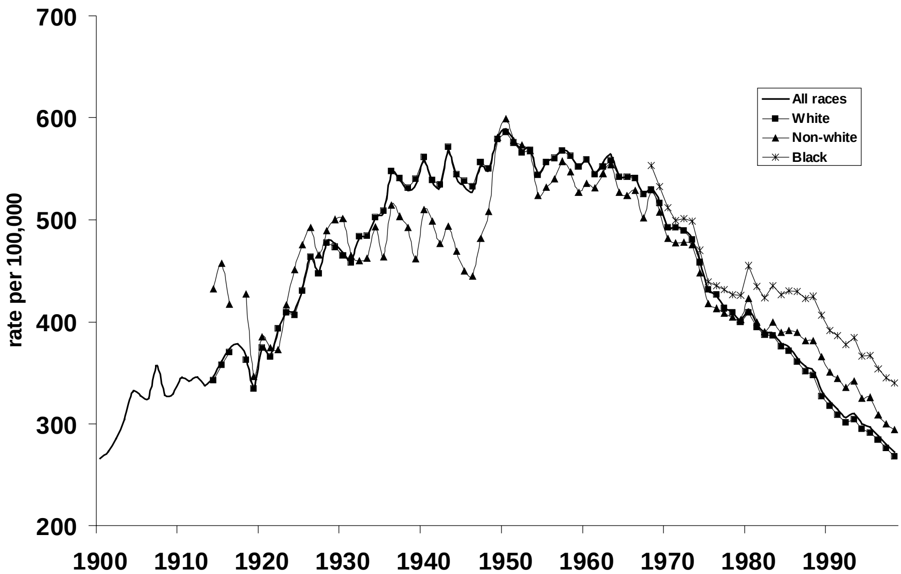
Knowing something about initial mortality conditions in a region seems to say a lot about where that region will be 30 years later and implies that whatever distinguishes the initial mortality differences between regions - which also differs by cause - to a large extent, still distinguishes them 30 years later. This is despite changes in the population composition that might occur through regional migration (Lynch, Harper, and Davey Smith in press). If it is the historical levels of income inequality that help determine the different starting mortality levels across regions, then it seems to do so cause-specifically, because the relative orderings of the regions differ according to cause of mortality. Nevertheless, if historical starting levels and changes in income inequality are important determinants of these mortality trends, it seems difficult to come up with a straightforward hypothesis for how it could account for the different secular trends in disease, relative inter-regional stability over time, and the heterogeneity of the ordering of the regions by cause of death. There would appear to have to be a number of different mechanisms and time lags involved in producing these patterns, which do not fit easily into a notion that levels of income inequality, *per se*, are driving all these cause-specific mortality trends. It seems already evident that this may argue against any simple understanding of how income inequality, which has increased over this same time period across all US regions, may have expressed itself in these mortality trends.

5. Part 3: National mortality trends and income inequality over the 20th century

The final part of these analyses broadens the time frame and focuses on the issue of time lags between longer term national trends in income inequality and one of the most important diseases of the 20th century – heart disease. As the analyses above suggest, regional differences in IHD appear rather stable over the 30 years between 1968 and 1998 (with some exceptions noted above). In any event, the trend data on income inequality (shown in Table 2) suggest that if changes in regional income inequality do affect regional mortality trends, the associations are complex, so the somewhat more simple national data are a useful place to start, especially in trying to investigate time lags.

Heart disease is a potentially good example for this sort of trend analysis, because it is probably the most studied disease in human history and a great deal is known about its causes. It is important to remember however, that the category of "heart disease" is comprised of a fairly diverse set of pathological entities with potentially disparate causal mechanisms. The generic term of heart disease includes not only IHD, but also congestive heart failure, rheumatic heart disease, hypertensive heart disease, arrhythmia and others. To make things even more complicated, the relative contributions of these sub-components to the generic category of heart disease has changed over time. Nevertheless, it is reasonable to propose that the largest contributor to the 20th century epidemic of heart disease was IHD and that it is the major component of heart disease from the 1950s to the present. Smoking, blood lipids and hypertension have emerged as the three most recognized risk factors for IHD (Yusuf et al. 2001a; 2001b). While all these relatively proximal factors clearly have complex social and biological antecedents of their own, there is little doubt that they play a major role in contributing to IHD.

Figures 9 and 10 show the race and sex-specific rates of heart disease from 1900-1998. The designation for heart disease is broad because definitions and diagnoses have changed over time (See Appendix 2 for ICD codes) so that it is virtually impossible to examine long-term trends in IHD alone (National Center for Health Statistics 1978). Thus, the broad definition of heart disease that we are forced to use here, while not directly comparable to what we know today as IHD, does provide reasonable comparability across time.

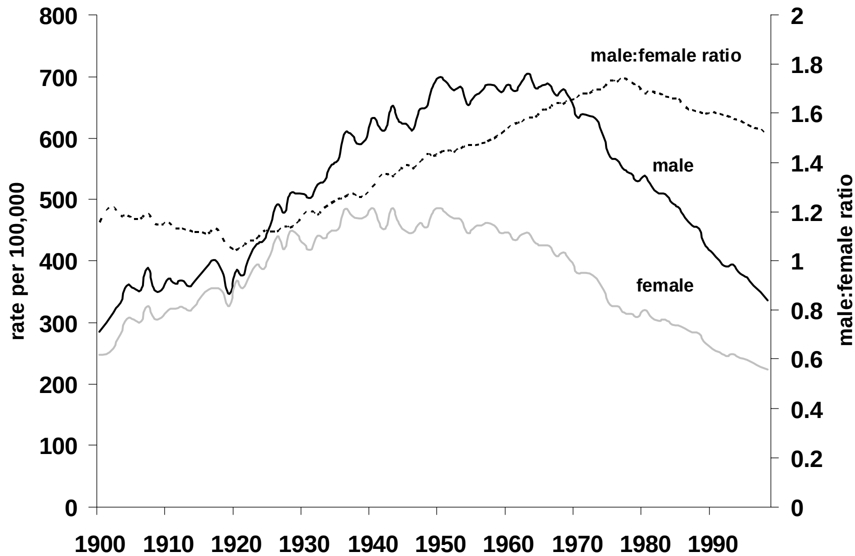


Source: National Center for Health Statistics (2001a).

Figure 9: *Race-specific Age-adjusted Heart Disease Mortality, US 1900-1998*

Figure 9 shows that in some ways we have come full circle, so that current rates of heart disease are now back to the levels observed at the turn of the century – 265 in 1900 and 272 per 100,000 in 1998. However, we reiterate the importance of recognizing that the composition of the category of heart disease at the beginning of the century was very different than at mid-century or at the millenium. Over the course of the century IHD became an increasingly important component of all heart disease, with rheumatic heart disease declining in significance. The epidemic of IHD is one of the most prominent features of population health in the 20th century, not just in the US but in many other developed nations as well (Yusuf et al. 2001a; 2001b). (2001b) While it is clear that traditional risk factors such as smoking, high fat diet and hypertension, and advances in medical care have played an important role in explaining this mortality trend (Lawlor, Ebrahim, and Davey Smith 2001), - especially the decline - we still do not know the precise ways in which risk factors combined to produce the 20th century epidemic of

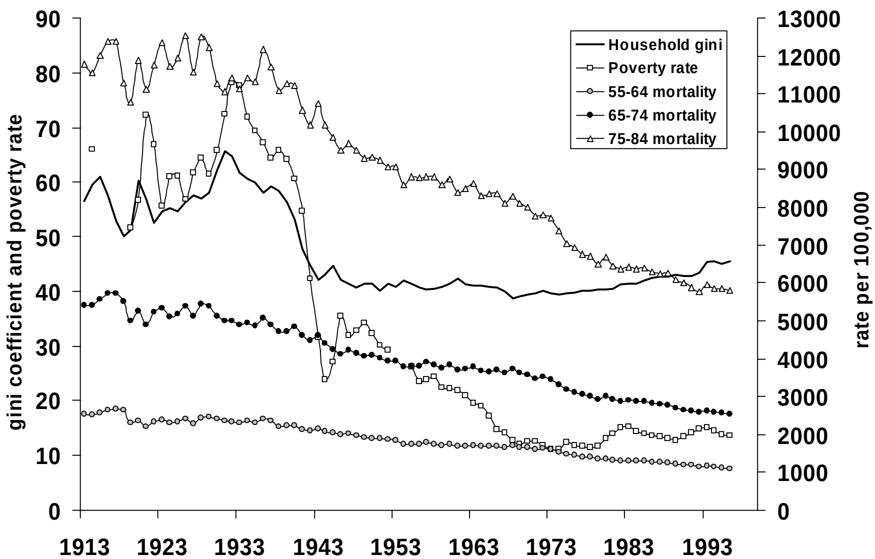
IHD (Kelleher, Harper, and Lynch 2003). Nevertheless, if income inequality is to be considered as a major determinant of population health in the 20th century, it has to affect the century's most common cause of death – heart disease.



Source: National Center for Health Statistics (2001a).

Figure 10: *Age-adjusted Mortality Rates From Heart Disease by Sex, US 1900-1998*

One important feature of Figure 9 is how the decline of heart disease has diverged for blacks and whites during the mid 1970s. From 1975 to 1990 the decline in rates of heart disease for blacks was significantly slower than for whites – perhaps even stalling, potentially due to less progress in control of hypertension in the black population (Cooper et al. 2000). Nevertheless, even this is hard to match with simultaneous income inequality trends, which continued to rise after the 1990s, when the rates of decline for blacks and whites were virtually identical. Figure 10 clearly shows the increasing sex ratio in heart disease from the rise of the epidemic in the 1920s. This has also been documented for other countries (Lawlor, Ebrahim, and Davey Smith 2001). Whatever combination of factors caused the rapid increase in heart disease they did so in men to a much greater extent than in women. This likely reflects different sex distributions of the main risk factors (Lawlor, Ebrahim, and Davey Smith 2001) and perhaps underlying biological differences in lipid metabolism. This means that if income inequality is implicated in these changing sex ratios, then it would probably have to affect the sex distributions of the risk factors, so that rising income inequality would be more potent in its effects on risk factors like smoking, hypertension and fat consumption for men than for women. Given these race and sex-specific patterns of heart disease over the century, how do they coincide with trends in income inequality?



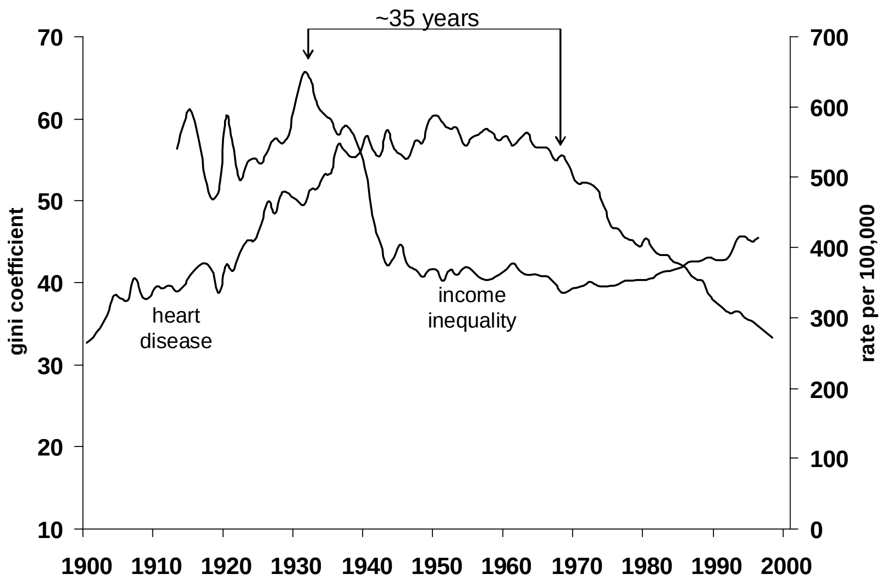
Source: National Center for Health Statistics (2001a); Plotnick et al. (2000).

Figure 11: *Household Income Inequality, Poverty, and Prime Age-Specific, All-Cause Mortality, US 1913-1998*

Figure 11 shows trends in poverty, income inequality (measured by the household Gini coefficient) and prime age mortality among 55-64, 65-74 and 75-84 year olds. Reliable income data became available in 1913 (Plotnick et al. 1998), and we note three important features. First, the really big income inequality story in the 20th century seems to be the rise during the inter-war period and the depression, followed by massive declines during and after World War II. Second, after World War II, income inequality has been relatively stable - at least as measured by the Gini coefficient relative to earlier periods. Thus, the recent increases that have drawn so much academic and popular attention are rather modest compared to the huge declines witnessed after the late 1930s that helped establish the advantageous economic conditions for the baby-boom generations. Perhaps this also has relevance for why changes in income inequality from the late 1960s appear to have no simple association with disease trends over the same time period. This in no way trivializes the negative impacts of these more recent increases in income inequality, but for our purpose here it is important to consider that if income inequality does leave a "footprint" on population health, then these recent increases were rather modest when tested against the historical record. Third, overall long-term trends in prime age mortality seem relatively immune to the changes in income inequality, although there is some evidence that the steeper mortality declines that occurred among those aged 75-84 and 65-74 coincided with the massive reductions in income inequality beginning in the early 1930s. However, it is also important to recognize that this massive reduction in income inequality also coincided with huge declines in poverty and the establishment of other welfare state policies such as social security in 1935 (Piketty and Saez 2003). Thus, as we have argued elsewhere (Lynch et al. 2000; Lynch et al. 2001), income inequality is tightly linked to other aspects of social policy and this may make it difficult to isolate its independent effects on population health.

So, if we assume that income inequality does play an important role in determining levels of population health, then it is the much larger changes from the 1930s to the mid 1940s that should be discernible. Additionally, given the evidence on the rise of late 19th century wealth inequality it seems reasonable to assume that income inequality was also rising during the later part of the 19th century (Lindert 2000). Turning now to heart disease mortality trends, if a 30-35 year time-lag were imposed on the link between exposure to income inequality and heart disease mortality, it might be possible to build a story of how the rise from the late 19th century to a peak in the early 1930s, followed by massive declines up to the late 1940s affected the subsequent rise and fall in heart disease.

Overlaying the trends in income inequality and heart disease (Figure 12) with a 35-year time lag shows that at least the decline in income inequality fits reasonably well with the decline in heart disease. We do not know precisely what happened to income inequality prior to 1913, but it is perhaps plausible that, as was the case in Britain, it rose during industrialization from the 1850s (Williamson 1985) and was relatively stable from 1890 to the 1920s when it peaked after the depression. If that is plausible, then one might be tempted to argue a case that a 35-year time lag fits these heart disease trend data reasonably well. Those who may wish to propose such a seemingly heroic hypothesis would, however, also have to propose plausible mechanisms. In general, we have argued against the usefulness of such meta-theoretical explanations for population health phenomena (Davey Smith and Egger 1996; Lynch et al. 2001).

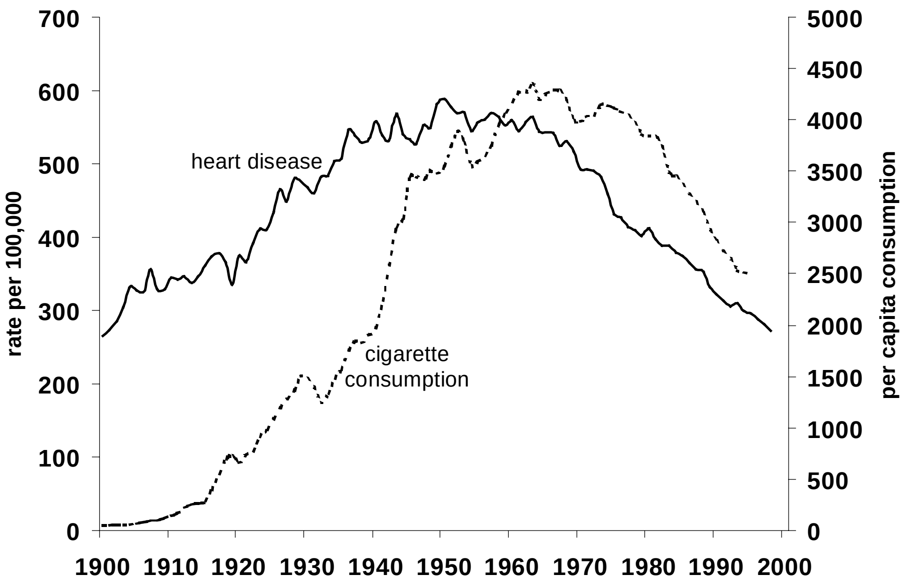


Source: National Center for Health Statistics (2001a); Plotnick et al. (2000)

Figure 12: *Age-Adjusted Heart Disease Mortality 1900-1998 and Household Income Inequality 1913-1996*

Nevertheless, it is worth at least exploring such a possibility. One place to start is to examine how long-term trends in income inequality align with the known risk factors (at least for the IHD component of heart disease) and ask how well income inequality and heart disease trends are consistent with our knowledge of trends in the main individual-level risk factors for IHD – smoking, blood lipids and hypertension?

In Figure 13 we overlay smoking trends over the century, onto the heart disease trends and show that the effect of smoking on heart disease is rather immediate, in that there seems little or no time lag between the rapid rise of smoking in the population and the equally steep increase in heart disease. Furthermore, it would be important to examine sex-specific smoking trends, as men were much more likely to adopt smoking earlier and had higher rates of both smoking and heart disease throughout the epidemic.



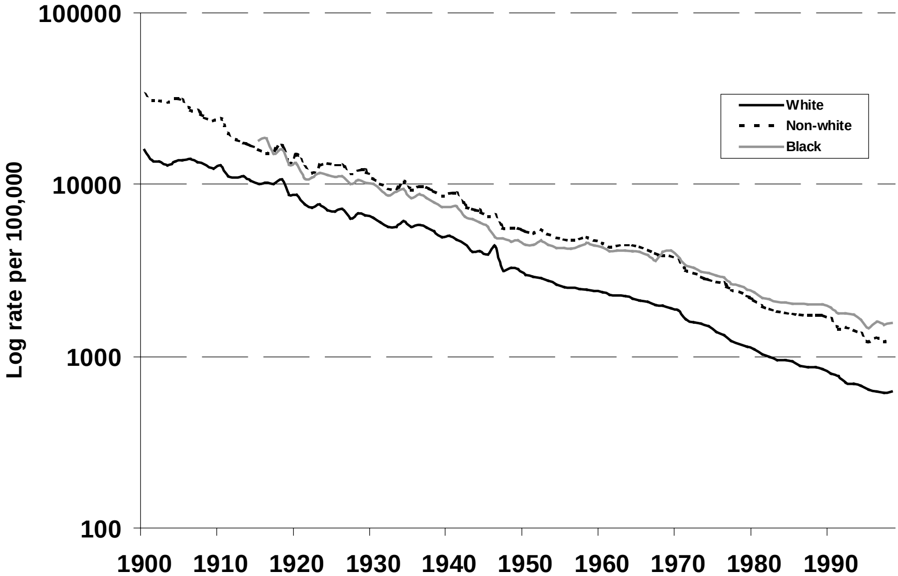
Source: National Center for Health Statistics (2001a), Burns et al. (1997), Centers for Disease Control and Prevention (2002), U.S. Department of Agriculture (2001).

Figure 13: *Age-Adjusted Heart Disease Mortality and Annual Adult Per Capita Cigarette Consumption, 1900-1998*

The same causal immediacy is not true for lung cancer, where there is a considerable time lag of 40 or more years between the exposure of different birth cohorts to smoking and the subsequent population yield in lung cancer mortality. There are three main processes implicated in heart disease – the development of atheroma, thrombo-embolic processes, and arrhythmia. While development of atheroma occurs over time, smoking may operate through the thrombo-embolic and/or arrhythmic pathways, thus plausibly being able to almost instantaneously influence heart disease given some underlying susceptibility - perhaps through the development of vulnerable atherosclerotic plaque - itself associated with blood lipids and haemostatic function. So, if rising income inequality caused people to smoke more and given that smoking maps almost directly onto heart disease trends - especially for men - the data here suggests that there would have to be a 30-35 year time lag between increased income inequality and increases in smoking. This seems rather implausible. In fact, what these data do suggest is that at the very time income inequality was dramatically falling, smoking was dramatically increasing.

Thus, while it may be possible to attempt to build a case that long-term trends in income inequality play some role in the rise and fall of heart disease, it seems unlikely that it could plausibly work through the major established risk factors for IHD such as smoking. Proponents of the “relative deprivation” version of the income inequality hypothesis (Lynch et al. 2000) have suggested two pathways for income inequality to affect health – behaviors and stress. We have already shown that trends in income inequality do not map easily onto trends in smoking. That leaves dietary, hypertension or the stress pathway to be explored but it is difficult to see how the stress pathway could be tested using historical trend data.

One final piece of evidence – several cross-sectional studies of income inequality have shown strong effects on infant and child health, perhaps because the time lags between exposure and outcome may be relatively short (Kramer et al. 2001). So is there any evidence that the long-term trends in income inequality affect infant mortality trends? Figure 14 shows 20^{th} century trends in infant mortality by race/ethnic group. The Y-axis is on a logarithmic scale to overcome the distorting effect on contemporary trends of very high infant mortality rates up until the 1920s. There is no clear link between 100-year trends in income inequality and the inexorable decline in infant mortality in all race groups over the same time period. So even for a cause of death that has been strongly linked to relative inequality in both national and international cross-sectional studies (Lynch et al. 1998; Lynch et al. 2001), and may be plausibly linked to proposed income inequality mechanisms that do not involve long time lags, there appears to be no clear association between long-term trends in infant mortality and income inequality trends.



Source: National Center for Health Statistics (2001c).

Figure 14: *Infant Mortality by Race, US 1900-1998*

6. Conclusion

So, does income inequality leave a footprint on population health? Several points have emerged from these analyses.

Figure 4 clearly shows that in the cross-section, income inequality is associated with all-cause mortality in each region of the US, but that association is the weakest in the South, where overall levels of population health are poorer than other US regions.

30-year trends in different causes of mortality show reasonable inter-regional stability over time, whether the secular trend is increasing, decreasing or flat. This implies that whatever processes generated the starting mortality conditions in each region help set that region on a trajectory that is relatively stable over 30 years and highlights the importance of an historical perspective on understanding population health trends.

There is considerable heterogeneity in the relative positions of regions in regard to different causes of mortality. For instance, over 30 years, the Middle Atlantic region has the highest heart disease rates but the lowest stroke mortality rates.

Given the regional trends in income inequality, there appears no direct way that income inequality could explain both the initial levels and ordering of these regional mortality differences, or their trends between 1968 and 1998. Any such explanation would be further complicated by different time lags for different outcomes.

At the national level, massive declines in income inequality around World War II appear somewhat reflected in steepening declines in mortality among 65-74 and 75-84 year olds, but this is likely confounded by coincident changes in rates of old-age poverty and the establishment of state sponsored welfare programs like social security aimed at those over 65 years of age.

At the national level, 20th century trends in heart disease (although clearly comprised of different sub-components at different historical periods, that have different determinants) appear more compatible with what is known about trends in the established risk factors for ischaemic heart disease - such as smoking - than with trends in income inequality or importantly, with how income inequality trends could be linked with trends in the major risk factors for IHD. In fact, smoking prevalence was undergoing its steepest increase in precisely the same time period that income inequality witnessed its most dramatic fall of the 20th century.

At the national level, 20th century trends in infant mortality do not appear sensitive to changes in income inequality.

The evidence that income inequality affects population health in the US is built on cross-sectional data. However, it appears difficult to reconcile either 30-year regional differences in cause-specific mortality with regional patterns and trends in inequality, or with 100-year national trends in income inequality, heart disease or infant mortality. This raises some potentially difficult issues that require further investigation. For instance, the data shown here illustrate how theories concerning the social determinants of population health which are based on seemingly plausible cross-sectional or short-term prospective evidence, can fail to generate support when examined over longer periods of time. The time trend data shown here force us to ask how we can reconcile the fact that cross-sectionally in the US, geographic variation in income inequality has been strongly linked to geographic variation in infant and child outcomes, homicide, heart disease and many other causes of death (Kaplan et al. 1996; Daly et al. 1998; Lynch et al. 2001; Kennedy, Kawachi, and Prothrow-Stith 1996; Kennedy et al. 1998; Kennedy et al. 1998; Szwarcwald et al. 1999). Yet, when examined here over longer periods of time, such clear links are not evident.

We have raised more questions than supplied answers, but our purpose here was to describe these trends and discuss the patterns in regard to the potential for income inequality to affect mortality trends regionally and nationally. We have attempted to show the value of examining potential determinants of population health from an historically contextualized perspective that uses information gathered from individual level studies about known risk factors for different outcomes, to better comprehend the role of income inequality on mortality trends in the US. While the evidence presented here does not categorically exclude a role for income inequality in affecting levels of population health in the US, it does suggest that such effects cannot be reduced to simple processes that operate across all contexts and in all time periods. The main finding is that, due to the sheer heterogeneity of secular and regional mortality levels and trends, there seems little evidence for a unilateral mechanism linking income inequality to health. Thus, if income inequality does indeed drive population health, it implies that income inequality would have to be linked and de-linked across different time periods, with different exposures to generate the observed heterogeneous trends and levels in the causes of mortality shown here.

7. Acknowledgements

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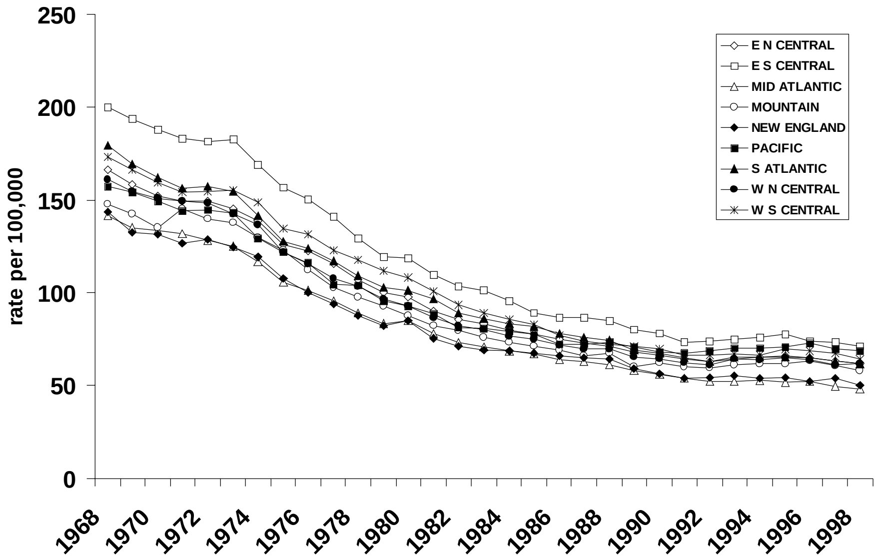
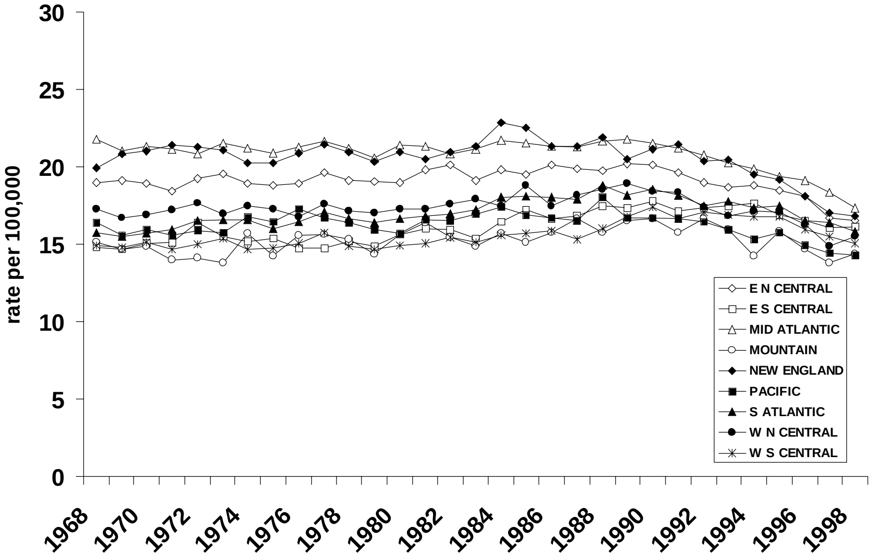
Appendix 1



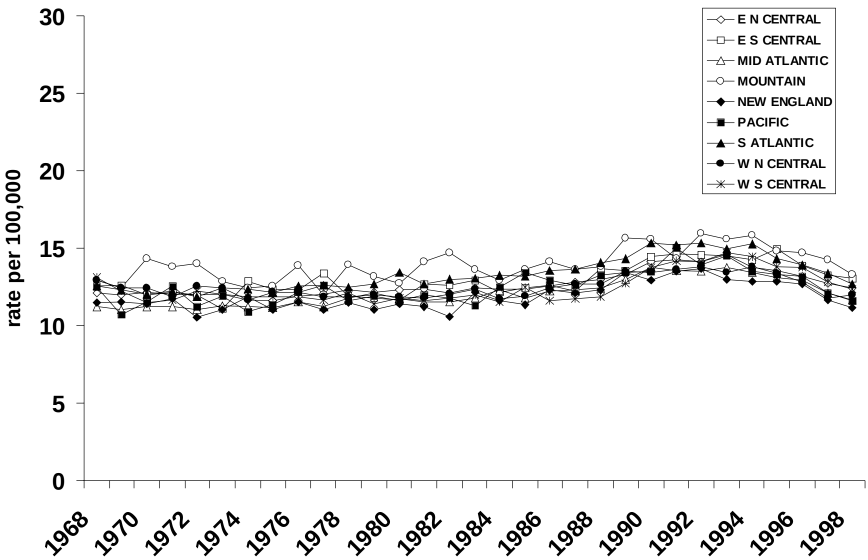
Source: Authors' tabulations of the Compressed Mortality Files (National Center for Health Statistics 2000; 2001b).

Figure 1: *30-Year Trends in Age-adjusted Stroke Mortality, US Regions*



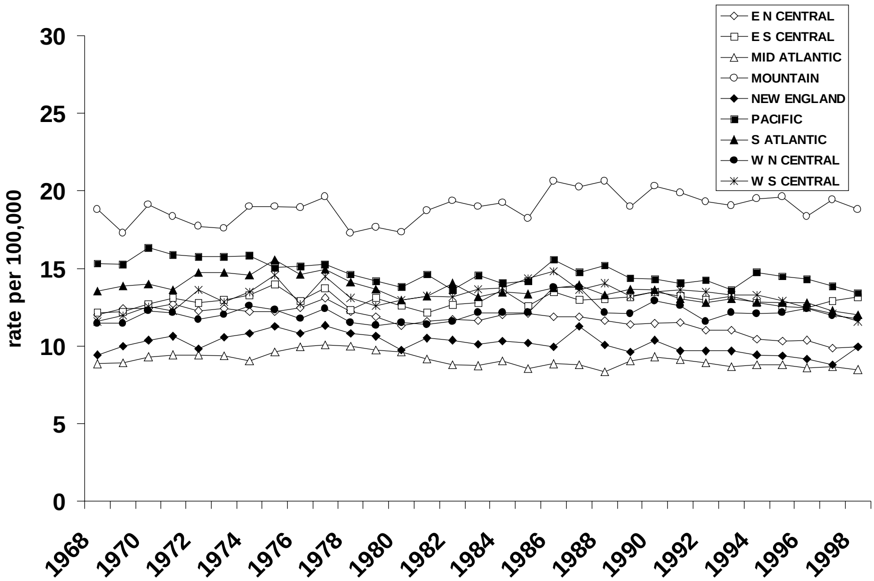
Source: Authors' tabulations of the Compressed Mortality Files (National Center for Health Statistics 2000; 2001b).

Figure 2: *30-Year Trends in Age-adjusted Breast Cancer Mortality, US Regions*



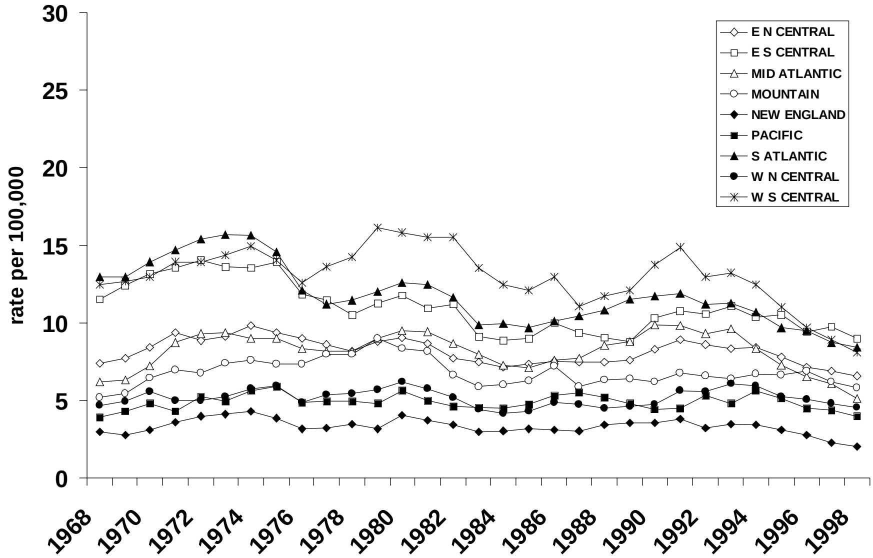
Source: Authors' tabulations of the Compressed Mortality Files (National Center for Health Statistics 2000; 2001b).

Figure 3: *30-Year Trends in Age-adjusted Prostate Cancer Mortality, US Regions*



Source: Authors' tabulations of the Compressed Mortality Files (National Center for Health Statistics 2000; 2001b; National Center for Health Statistics 2001b).

Figure 4: *30-Year Trends in Age-adjusted Suicide Mortality, US Regions*



Source: Authors' tabulations of the Compressed Mortality Files (National Center for Health Statistics 2000; 2001b; National Center for Health Statistics 2001b).

Figure 5: *30-Year Trends in Age-adjusted Homicide Mortality, US Regions*

Appendix 2

ICD-Codes
DISEASES OF THE HEART

ICD Revision	Years in use	ICD Nos.
First	1900-1909	(77-80)
Second	1910-1920	(77-80)
Third	1921-1929	(87-90)
Fourth	1930-1938	(90-95)
Fifth	1939-1948	(90-95)
Sixth	1949-1957	(410-443)
Seventh	1958-1967	(400-402, 410-443)
Eighth	1968-1978	(390-398,402,404,410-429)
Nineth	1979-1998	(390-398,402,404-429)