Period-based mortality change: Turning points in trends since 1950

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Abstract

In this paper, we investigate a major turning point in mortality trends at adult ages that occurred for many developed countries in the late 1960s or early 1970s. We analyze patterns of total and cause-specific mortality over the past 60 years using data from the Human Mortality Database and the World Health Organization. We focus on four broad categories of causes of death: heart diseases, cerebrovascular diseases, smoking-related cancers, and all other cancers. We use a two-slope regression model to assess the timing and magnitude of turning points in mortality trends over this era, making separate analyses by sex, age, and cause of death. The age pattern of temporal changes is given particular attention. Our results demonstrate clearly that period-based factors were very significant in the onset of the "cardiovascular revolution" in the years around 1970. In general, although cohort processes cannot be ruled out as a driver of some recent improvements (especially for mortality due to smoking-related cancers), the evidence reviewed here suggests that period factors have probably been the dominant force behind the mortality trends of developed countries during this era.

Introduction

Three decades ago, Crimmins (1981) showed that after a worrisome levelling-off of mortality trends in the United States from the mid 1950s to the late 1960s – which had led some observers to speculate that progress against mortality in developed countries was slowing down or even coming to a halt – a steady decline in mortality rates resumed around the year 1968. Although a similar trend has sometimes been noted for other high-income countries, the generality of the phenomenon and its underlying causes have not been analyzed in a systematic way.

Crimmins argued, furthermore, that the similarity of this trend across adult age groups indicated the likely influence of a common set of contemporaneous determinants (medical advances and changing lifestyles), thus suggesting that period rather than cohort processes were the driving force behind the sudden U.S. mortality decline of the late 1960s. This conclusion was contradicted recently by Yang (2008), who argued that reductions in U.S. adult mortality from the late 1960s to the late 1990s were driven predominantly by cohort-based factors. In addition, a similar age-period-cohort analysis by Miller *et al.* (2011) concluded that recent reductions in U.S. mortality for black and white adults are attributable mostly to earlier changes in cohort life histories rather than to contemporaneous events and circumstances.

In this article, we exploit data for a large set of industrialized countries to follow up both on Crimmins' analysis of the 1968 discontinuity in U.S. mortality trends and on her interpretation of this phenomenon in the context of the ongoing debate about the relative importance of period versus cohort factors as drivers of mortality change. We first investigate the generality of the discontinuity among industrialized countries using all-cause mortality data. Then, using age- and cause-specific mortality data, we attempt to identify the age groups and disease categories that have most contributed to the discontinuity and subsequent trends. We conclude with a discussion of what can be learned about period versus cohort factors from such analysis.

Data and Methods

Data

We used two sources of data in this paper: the Human Mortality Database (HMD) (2011) for all-cause mortality data and the World Health Organization (WHO) Mortality Database (2011) for cause-specific data. All countries listed in the HMD are included in our analysis of all-cause mortality trends, except for Chile, Israel, Slovenia, and Taiwan because their data series are too short to provide the long-term perspective required for this study. For the remaining 34 countries, the period covered starts in 1950 for the majority of those outside Eastern Europe and ends with the most recent year available (Appendix Table 1). The former countries of East Germany and West Germany are treated separately throughout this study given their divergent mortality histories, especially prior to Reunification in 1990 (Höhn and Pollard 1991; Nolte, Shkolnikov, and McKee 2000; Luy 2004). From the HMD we extracted death counts and estimates of population exposure by sex, 5-year age groups (ages 40 and above), and single calendar years for each country.

Our analyses of cause-specific mortality trends rely on the official death counts by calendar year (starting in 1950 at the earliest), age (40 and above), sex, and cause of death available in the WHO Mortality database for all the countries in the all-cause mortality analysis, except the Eastern European ones and the members of the former Soviet Union. The latter countries were excluded from this part of the analysis because of discontinuities in their cause-specific mortality series. Indeed, for many of them, several years' worth of data are typically missing in the WHO database (Appendix Table 1). In addition, for the years when data are available, the classification of deaths by cause follows a different scheme than for other countries, which makes the construction of comparable series very difficult.

The resulting data set thus covers a total of 22 countries over four successive revisions of the International Classification of Diseases (from ICD-7 to ICD-10). Causes of deaths were aggregated into four broad categories designed to maintain consistency over ICD changes: heart diseases, cerebrovascular diseases, smoking-related cancers and all other cancers. The concordance table used for bridging the four revisions of the ICD is presented in the Appendix, with specific codes for each category in each time period (Appendix Table 2). Cardiovascular diseases and cancers represent the first two main causes of death above age 40 in all developed countries. We conducted separate analyses for heart diseases and cerebrovascular diseases because of the different risk factors to which these two groups of diseases are attributed. The motivation for separating smoking-related cancers (i.e. cancers of the lips, oral cavity, pharynx, esophagus, larynx, trachea, bronchus and lungs) from other cancers stemmed from the extensive literature pointing to the massive impact of cigarette smoking on level and trends in mortality from these specific cancer sites. A host of other factors are known to influence the risk of other cancers, including smoking for many, if not all of them but to a much smaller extent than for cancers of the upper respiratory track and digestive organs. Consequently, there was reason to assume that trends in mortality for this later group of cancer follow a different pattern than for cancers from other sites. Indeed, our analysis strongly validates this assumption. Taken together, these four disease categories accounted for 43 to 80 percent of total mortality at ages 40 and above throughout the period from 1950 to 2008; this percentage varies depending on the country and the time period, and these causes account for a slightly larger share of total deaths for women than for men (Appendix Tables 3a and 3b).

Methods

As a first step, we studied all-cause mortality data to identify any sudden mortality decline around the late 1960s for the various countries. We computed age-standardized death rates for ages 40 and above by single calendar year, sex and country, using the total (both sexes) population of all HMD countries by 5-year age groups in 1970 as our standard. To assess the timing and magnitude of the discontinuity (sudden mortality change), we fitted trend lines to these age-standardized death rates over time. Specifically, two-slope regression models were used and the turning point for the slope, indicating the timing of the discontinuity in the mortality trends over time, was allowed to occur in any year throughout the entire period. We selected the one providing the best description of the data, i.e.

maximizing goodness-of-fit in R^2. For example, for a country with all-cause mortality data starting in 1950 and a sudden mortality decline occurring in 1968, we would use the following regression model:

$$asdr = \beta_0 + \beta_1 (year - 1950) + \beta_2 (year - 1968) I_{year>1968} + \varepsilon,$$

where the variable $I_{year>1968}$ is an indicator variable that equals one after 1968 and zero otherwise. Among the three parameters of the model, β_2, is the one we are mostly interested in, as it corresponds to the change in the slope of the mortality trend before and after the turning point. Therefore, a higher estimate for β_2 (in absolute value) suggests a sharper mortality change and vice-versa. We thus used it to assess the magnitude of the discontinuity in trend, distinguishing three levels: "high", "moderate", and "low". Cut-off points were selected based on the sex-specific empirical cumulative distribution of β_2 estimates for all countries studied, using the Fisher-Jenks algorithm (Fisher 1958; Slocum et al. 2005).

In a second step, we used the cause-specific mortality data to identify the cause categories of diseases that contributed most to the all-cause mortality change observed in the various countries. Cause-specific age-standardized death rates were first computed for each calendar year and country by applying cause-specific and age-specific death fractions computed from the WHO mortality data to the age-specific death rates computed from the Human Mortality Database (HMD). In order to attenuate fluctuations, the cause-of-death fractions were applied to smoothed all-cause death rates. Specifically, the smoothed death rates were computed using pooled death counts and population exposure estimates over each successive and overlapping 5-year window. The two-slope regression models described above were similarly used to look for discontinuity in each of the four cause-specific age-standardized death rates trends over time for each sex, and assess when it occurred and how severe it was ("high", "moderate" or "low").

Results

Mortality for all causes of death and ages combined

Figure 1 displays country-specific trends in age-standardized death rates over time since 1950, or a couple of years later depending on data availability, for males aged 40 and above. It shows clearly that the sudden mortality decline of the late 1960s was not restricted to the population of the United States. Many countries among those studied seem to have experienced such sharp decline towards the end of the 1960s or the beginning of the 1970s. According to the regression analysis results, it has specifically occurred also in twelve other countries, namely Australia, Belgium, Canada, Finland, France, Iceland, Luxembourg, New Zealand, Portugal, Spain, Switzerland, and West Germany (Table 1[1]). The turning point (discontinuity in the trend) occurred while these countries were exhibiting quite different levels of mortality in 1950, with death rates ranging from 37 per thousand in Finland, to 30

[1] All of the two-slope regression models that were used to identify the discontinuity year presented in this table provided a better description of the data than the comparable one-slope models (F-tests for nested models resulting in $p \leq .01$). Moreover, each of these statistical models accounted for more than 90% of variability in the data, except for Poland (R^2=86%), Slovakia (R^2=73%), Bulgaria (R^2=62%), and Hungary (R^2=62%).

per thousand in Australia, and to 23 per thousand in Iceland. In many of these cases, just as in the United States, the decline occurred after a long period of levelling-off in the mortality trend. In a few countries such as New Zealand and Luxembourg, it even marked the end of a recent rising trend. Unsurprisingly, these countries, along with a few others, have a "high" discontinuity magnitude (Table 1). In other countries like Portugal and Switzerland, the death rates were already on a declining trend since 1950, and although the pace of the mortality decline was slower than after the turning point, both still have a "low" magnitude discontinuity.

[FIGURE 1 about here]

A few additional countries, such as Ireland and Denmark for example, also exhibit a similar pattern but are slightly delayed, as the apparent discontinuity in the trend occurs after the mid-1970s (Figure 1). In fact, the regression analysis reveals that for seven countries among those under study (excluding Eastern European countries), namely Austria, Denmark, Ireland, Italy, Netherlands, United Kingdom, and Sweden, the change of trend occurred between 1975 (Austria) and 1990 (Denmark) (Table 1). As well, Norway belongs to that group of countries when a two-slope regression model is used to describe its mortality trend since 1950, but Figure 1 clearly shows that there were actually two turning points rather than only one throughout that period of time: the onset of mortality decline seems to have occurred around 1970, like in the United States and the other countries listed above, and then accelerated markedly towards the end of the 1980s. In fact, when a three-slope regression model is used to describe the mortality trend among Norwegian males over the last 60 years, the turning points providing the best fit (in R^2) are 1969 and 1989. The case of Japan is also worth mentioning because even though the regression analysis points out a discontinuity in 1986, this year inaugurates a period of slower decline compared to the previous 4½ decades, when the pace of mortality reduction was unusually rapid. None of the other countries studied here displayed such a trend for males.

Most Eastern European countries are characterized by an even later discontinuity in mortality trend, which was not observed before the 1990s (Figure 1 and Table 1), while the former Soviet Union (FSU) countries, except for Estonia and Latvia, have yet to experience this decline. In every part of Eastern Europe, death rates systematically increased from the 1950s up to the turning point year, thus resulting in "high" magnitude discontinuities. Countries such as the Czech Republic and Hungary reached death rates as high as 35 per thousand before mortality trends finally started to decline rapidly in 1985 and 1994, respectively.

The overall pattern of age-standardized death rates for all causes of death combined for females is very different than the one described above for males (Appendix Figure 1). In general, except for non-FSU Eastern European countries, disruptions in time-trends are weak and often barely visible. When such disruptions occur at some point in time, they tend to mark the beginning of a period where mortality declines at a slower pace than before. Ireland, Luxembourg, and Portugal stand out as the very few exceptions where female death rates declined more rapidly after than prior the turning point. Although all-cause mortality trends for females appear uninformative, our analysis of cause-specific mortality trends has revealed more interesting patterns.

[TABLE 1 about here]

Before moving on to the analysis by broad cause-of-death categories, trends over time in male age-specific death rates are worth exploring. These will indicate whether the sharp onset of mortality decline affected all age groups simultaneously as opposed to successive years. The former case would suggest that period rather than cohort processes were the driving force behind the onset of an accelerated mortality decline, and vice-versa. Given the observations made earlier regarding data availability and timing or specific circumstances in which the discontinuity took place, our analysis from now on focuses on countries others that those of Eastern Europe, the FSU, and Japan. Moreover, for illustrative purposes (figures only), three countries from three regions have been selected, namely Australia, Finland, and Italy. In both Australia and Finland, male death rates over time showed a strong and relatively early (1969) disruption, while in Italy, the discontinuity was moderate in magnitude and occurred relatively late (1977) (Table 1). Australia, above being part of English-speaking countries, also appears to be highly representative of most the remainder countries of that group as well as many others, such as those of Western Europe for instance (Figure 1). Similarly, Italy seems to be fairly representative of Southern European countries. On the other hand, Finland's unique profile among the Nordic countries, characterized by a substantially higher level of mortality in years prior to the discontinuity, makes it an interesting case to follow.

Mortality for all causes of death by age

Figure 2 displays 5-year age-specific death rate time-trends for males in the three countries selected for illustrative purposes. The simultaneity in the timing at which mortality suddenly started to decline in the late 1960s or early 1970s for all age groups is striking. Indeed, although the discontinuity in the mortality trends affected especially the population at ages 40 to 69 years, persons aged 70-84 also benefited strongly from the increase in survival chances in the three selected countries, and the oldest-old population benefited as well. This is also true for the vast majority of countries studied. These mortality trends by age among males thus provide first evidence that period effects are main drivers here. It is indeed clear that the onset of the mortality decline has been period- rather than cohort-based, since it was experienced simultaneously across a broad age range, thus affecting many different cohorts rather than being concentrated in a single cohort.

[FIGURE 2 about here]

Mortality by cause for all ages

First, overall, for men, the age-standardized series of death rates for the four broad categories of diseases (heart diseases, cerebrovascular diseases, smoking-related cancers, other cancers) all exhibit marked disruptions. The pattern is not as clear for women though instances of significant changes in mortality trends for these four groups of diseases are much more numerous and severe than for trends in mortality for all causes combined.

Second, the timing of disruption varies clearly depending on the type of diseases: while changes in cardiovascular mortality trends are typical of the 1960s and 1970s, changes in cancer mortality hardly nowhere take place before the 1980s and occur in the 1990s for a majority of countries, especially with respect to smoking-related cancers.

Cardiovascular diseases

For men, the discontinuity in mortality trends for all causes of death is clearly determined by changes in cardiovascular mortality, with a high degree of coincidence in the timing and severity of the breaks in both series of age standardized death rates for about three quarters of the study countries (Table 2[2]). Between the two sub-categories of cardiovascular disorders, we know that the share of heart diseases is nearly everywhere larger than that of cerebrovascular diseases (Appendix Tables 3a and 3b), except for a few countries located in Southern and Northern Europe. For men at least, breaks in heart diseases are also more severe, overall, than in cerebrovascular diseases, though there are several exceptions to this pattern (Figure 3). For women, with the exception of Northern Europe and a few countries in Western Europe, the reverse tends to be true: breaks in cerebrovascular mortality are more marked than in heart diseases. Both heart diseases and cerebrovascular diseases appear nonetheless to have contributed to the mortality disruptions of the late 1960s and 1970s, with a somewhat larger effect of cerebrovascular diseases for men.

[TABLE 2 about here]

Smoking-related cancers

An examination of cancer mortality trends shows clear disruptions in nearly all of the countries included in the present analysis (Table 2). In most instances, these disruptions have not influenced overall mortality trends because of the compensating effects on mortality from the two groups of cancers distinguished here. For women especially, trends have been clearly diverging for these two groups of cancers: while death rates from smoking-related cancers exhibit an increasing trend for the vast majority of the countries studied (and a relatively flat trend for Finland – Figure 4)[3], mortality from other cancers has been systematically declining, at least for part of the period under study, for all of them.

For men, disruptions in cancer mortality trends are more pronounced for smoking-related cancers than for other cancers (Figure 3). After a long period of regular increase, mortality from the former group of diseases has exhibited a steep decline since the break point year. Interestingly, there seem to be a correlation between the timing and the steepness of the

[2] Nearly all of the two-slope regression models that were used to identify the timing of the discontinuity in the various countries provided a better description of the data than the comparable one-slope models (F-tests for nested models resulting in $p \leq .01$). Exceptions are designated by ".." in this table and involve Iceland, Luxembourg, and Switzerland only. For heart diseases, cerebrovascular diseases, and smoking-related cancers, the two-slope models accounted for more than 90% of variability in the data in about 90% of cases. For other cancers, it accounted for more than 80% of variability in the data in 70% of cases.

[3] As mentioned at the bottom of Table 2, a single dagger next to the year of the turning point indicates that mortality decreased less rapidly after than before. A double dagger indicates that mortality has actually worsened, increasing after the turning point while it had been stable or declining before, or increasing more rapidly than before.

decline such that countries for which the onset of the decline has occurred in the 1980s have experienced a larger fall in tobacco-related mortality than countries for which the onset has occurred more recently (Norway, Iceland, Portugal, and Japan). Sweden is an exception to this pattern in that the decline in smoking-related cancers was both initiated earlier and was less pronounced than in the former countries (Table 2). However, in Sweden as in Norway, Iceland, Portugal, and Japan, mortality from these cancers never reached the level found in the other countries (Appendix Tables 3a and 3b).

Other cancers

For other cancers, the recent decline in mortality follows either a plateau or a moderate increase for men (Table 2). The main exception is here Portugal, the only country exhibiting a continuous increase with no sign of decline. For women, many countries, mostly located in Western and Northern Europe, already experienced significant decline in mortality prior to the 1990s but the trends accelerated during the past ten to fifteen years. The other countries show fairly stable mortality rates before the recent decline, sometimes preceded by a moderate increase, a pattern that is especially clear in the countries of Southern Europe and in Japan.

[FIGURE 3 about here]

[FIGURE 4 about here]

Age-specific mortality by cause

We now turn to an examination of mortality by age for these four groups of diseases. As for the age-specific death rates for all causes, there is a clear simultaneity in the cardiovascular mortality trends for all the age groups for both men and women (Figures 5 and 6). For heart diseases as for cerebrovascular diseases, the change in slope occurs on the same year for all ages and this is pronounced in all three illustrative countries on Figures 5 and 6. In contrast, trends in mortality from smoking-related cancers appear to be at least partly cohort-driven to the extent that we can often see a progressive shift from one calendar year or period to the next in the break point as we move from one age group to the next, especially for men. If the recent mortality trends for smoking-related cancers among men were mainly cohort driven, the mortality decline (following either an increasing or stagnating mortality trend) should roughly begin 5 years later in every given age group compared to the previous one, yielding a lag of about 40 years between the youngest (40-44) and oldest (80-84) men. Figure 5 instead suggests a much narrower lag in all three countries, an observation that is confirmed by two-slope regression models fitted to age-specific mortality trends (Table 3). Finnish men have the largest range of discontinuity years by age, but the lag between the youngest and oldest age groups is only 18 years. In Australia and Italy, the discontinuity years for the various age groups are concentrated into a much shorter interval (roughly 5 years). These findings thus suggest that with respect to the recent improvements in smoking-related cancer mortality, period effects have likely substantially moderated cohort effects, at least in these three countries.

Smoking-related cancer mortality trends for women shown in Figure 6 are less clear than those for men, in part because of large fluctuations that tend to blur the pattern. Indeed, female death rates from smoking-related cancers, though increasing, remain at a fairly low level. For other cancers, the potential effects of period- versus cohort-driven forces are much more difficult to identify. Indeed, for this group of diseases, mortality trends by age tend to show some variations by age but without the regular shift exhibited by smoking-related cancer mortality. In all three countries and for both sexes on Figures 5 and 6, mortality from other cancers appears to have been declining moderately for the youngest age groups (40 to 49 years old), to have been either stable or declining very little for the intermediate groups (50 to 69) while it has tended to reach a plateau or even, in the case of Portugal, to have increased for the oldest age groups (70 and above).

[FIGURE 5 about here]

[FIGURE 6 about here]

Discussion

This study contributes to the debate about the importance of periods versus cohorts in explaining the mortality decline of the past fifty years. The evidence presented here illustrates the importance of certain period-based changes, which are experienced by multiple age cohorts around the same time. Although we cannot rule out some cohort factors as drivers of the reduction in death rates, especially with regard to smoking-related cancers, period factors appear to have played a dominant role in the most significant epidemiologic transformation of this era, the cardiovascular revolution.

The literature on trends in mortality from cardiovascular disease has emphasized the positive impact of medical progress as the major cause of the survival increase experienced by many developed countries at the end of the 1960s (Julian 1989; McGovern et al. 1996; Pitt 1989). In general, more efficient management of the disease and its risk factors – including diagnostic methods, pharmacological regulation of blood pressure and cholesterol, and treatment options – led to both delayed onset and improved survival. The resulting reductions in cardiovascular disease morbidity and mortality were sufficiently large and rapid that various observers began to speak of a "cardiovascular revolution". It appears that changes of individual behavior also played a part in this revolution, in particular as regards tobacco consumption (Burke et al. 1989; Levis, Lucchini, Negri, and La Vecchia 2002). The available evidence suggests, however, that cardiovascular disease is affected more by current or recent smoking status than by the past smoking history, and therefore smokers have a higher cardiovascular disease risks compared to non-smokers regardless of their smoking history (Anthonisen et al. 2005; Ockene, Kuller, Svendsen, and Meilahn 1990). Assuming that the anti-smoking campaigns of the 1960s and 1970s influenced adult smokers of all ages (at least those over 40 years), the period basis of the decline in cardiovascular disease mortality identified here might well include some smoking-related factors.

By contrast, the risk of smoking-related cancers is determined not so much by current smoking as by a person's lifetime history (i.e., smoking duration and intensity). Individuals who have never smoked have a much lower risk of dying from cancers of the lung, pharynx or esophagus compared to individuals who have smoked moderately or who have stopped smoking; the latter, in turn, are at lower risk of dying from such cancers compared to individuals who have smoked heavily for many years (Anthonisen et al. 2005; Doll, Peto, Boreham, and Sutherland 2004; Ockene, Kuller, Svendsen, and Meilahn 1990). Thus, for certain cancers the long-term, cumulative effects of smoking are more clearly attached to specific cohorts as a result of their smoking histories (age of uptake, frequency of smoking, and kinds of tobacco products consumed). Smoking cessation has a smaller, delayed impact on such causes of death than on cardiovascular diseases.

As for mortality from other cancers, we found no strong evidence to suggest the dominance of period over cohort factors, or vice versa. A key issue is that, among the four broad categories of causes of death examined here, cancers other than those clearly related to smoking include diseases with a broad spectrum of risk factors, so that aggregate trends for may mask more systematic patterns of mortality change for cancers originating at different sites. Unfortunately, the data available at present (via the WHO mortality database) does not permit a more detailed disaggregation of cancer mortality in a consistent manner over all four versions of the ICD.

Tables and Figures

TABLE 1 Timing and magnitude of dominant turning point in the age-standardized death rate trend since around 1950, selected developed countries, males

Grouping/ Country	Discontinuity	
	Year[a]	Severity[b]
Late 60s - Early 70s discontinuity		
United States	1968	M
Switzerland	1968	L
Australia	1969	H
Finland	1969	M
Spain	1971[c]	L[c]
Luxembourg	1971	H
Portugal	1971	L
Iceland	1971	L
West Germany	1972	H
Belgium	1973	M
Canada	1973	L
New Zealand	1974	H
France	1974	L
Mid 70s or later		
Austria	1975	H
Netherlands	1976	M
United Kingdom	1976	M
Italy	1977	M
Sweden	1979	L
Norway	1981	H
Ireland	1985	H
Japan	1986	L[d]
Denmark	1990	M
Eastern Europe (excluding Former Soviet Union countries)		
Czech Republic	1985	H
East Germany	1986	H
Slovakia	1990	H
Poland	1992	H
Hungary	1994	H
Bulgaria	1998	H

[a]Years that maximized goodness-of-fit (in R^2) for males in each country.
[b]H: high; M: moderate; L: low.
[c]Based on smoothed (5-year moving windows) rather than observed age-standardized death rates, which were leading to a dominant turning point in 1952 mainly because of the 1951 spike in the trend (Figure 1).
[d]Mortality conditions in Japan improved at a slower pace after 1986 compared to previously.
SOURCE: Authors' calculations based on the HMD (2011).

TABLE 2 Timing and magnitude of dominant turning point for cause-specific age-standardized death rate trend since around 1950, selected developed countries

	Men				Women			
Region/ Country	**Heart diseases**	**Cerebro-vascular diseases**	**Smoking-related cancers**	**Other cancers**	**Heart diseases**	**Cerebro-vascular diseases**	**Smoking-related cancers**	**Other cancers**
English-speaking								
Australia	1967***	1969**	1980***	1994**	1967***	1970**	1994**	1993**
Canada	1966**	1989*†	1986***	1992*	1991*†	1984*†	1966***‡	1992*
Ireland	1984***	1971**	1985**	1996***	1995**	1970**	1988***	1991***
New Zealand	1970***	1972**	1981***	1994***	1985*	1971**	1991**	1991***
United Kingdom	1980**	1965*	1975***	1994**	1995*	1964*	1990***	1990**
United States	1966**	1990*†	1983**	1993**	1990*†	1989**†	1996***	1996*
Northern Europe								
Denmark	1978***	1977*†	1984**	1997*	1993*	1976**†	1969***‡	2000***
Finland	1969***	1964*	1972***	1997*	1963***	1981**†	1970**‡	1993*
Iceland	1980***	..	1996**	..	1987**	1982**†	..	1962***
Norway	1978***	1966**	1990*	1994**	1963***	1959**	1977***‡	1995**
Sweden	1979***	1970*†	1978*	1975*	1962**	1971**†	1977**‡	1974*
Western Europe								
Austria	1982**	1974**	1979*	1992*	1982**	1974**	1977*‡	1990*
Belgium	1970***	1969***	1983***	1982**	1967**	1970***	1978*‡	1988*
France	1976*	1971*	1981***	1990***	1981*	1972*	1983*‡	1974*
Luxembourg	1984*	1982***	1986***	1987**	..	1982***	..	1994***
Netherlands	1976**	1955**	1981***	1988**	1972*	1983*†	1979***‡	1968*
Switzerland	1982*	..	1979**	–	1973*†	..	1974**‡	–
West Germany	1979***	1970*	–	–	1974***	1966*	1977**‡	–

TABLE 2 Timing and magnitude of dominant turning point for cause-specific age-standardized death rate trend since around 1950, selected developed countries (continued)

	Men				Women			
Region/ Country	**Heart diseases**	**Cerebro-vascular diseases**	**Smoking-related cancers**	**Other cancers**	**Heart diseases**	**Cerebro-vascular diseases**	**Smoking-related cancers**	**Other cancers**
Southern Europe								
Italy	1974**	1979*	1985***	1989***	1963**	1982*	1992*	1989**
Portugal	1959*†	1975***	1993*	1964**	1973**†	1974***	1968*	1965**
Spain	1977*	1974**	1994**	1961***	1976*	1974**	1961**	1962***
East Asia								
Japan	1969*	1962***	1992*	1997***	1973**	1963***	1984*	1960**

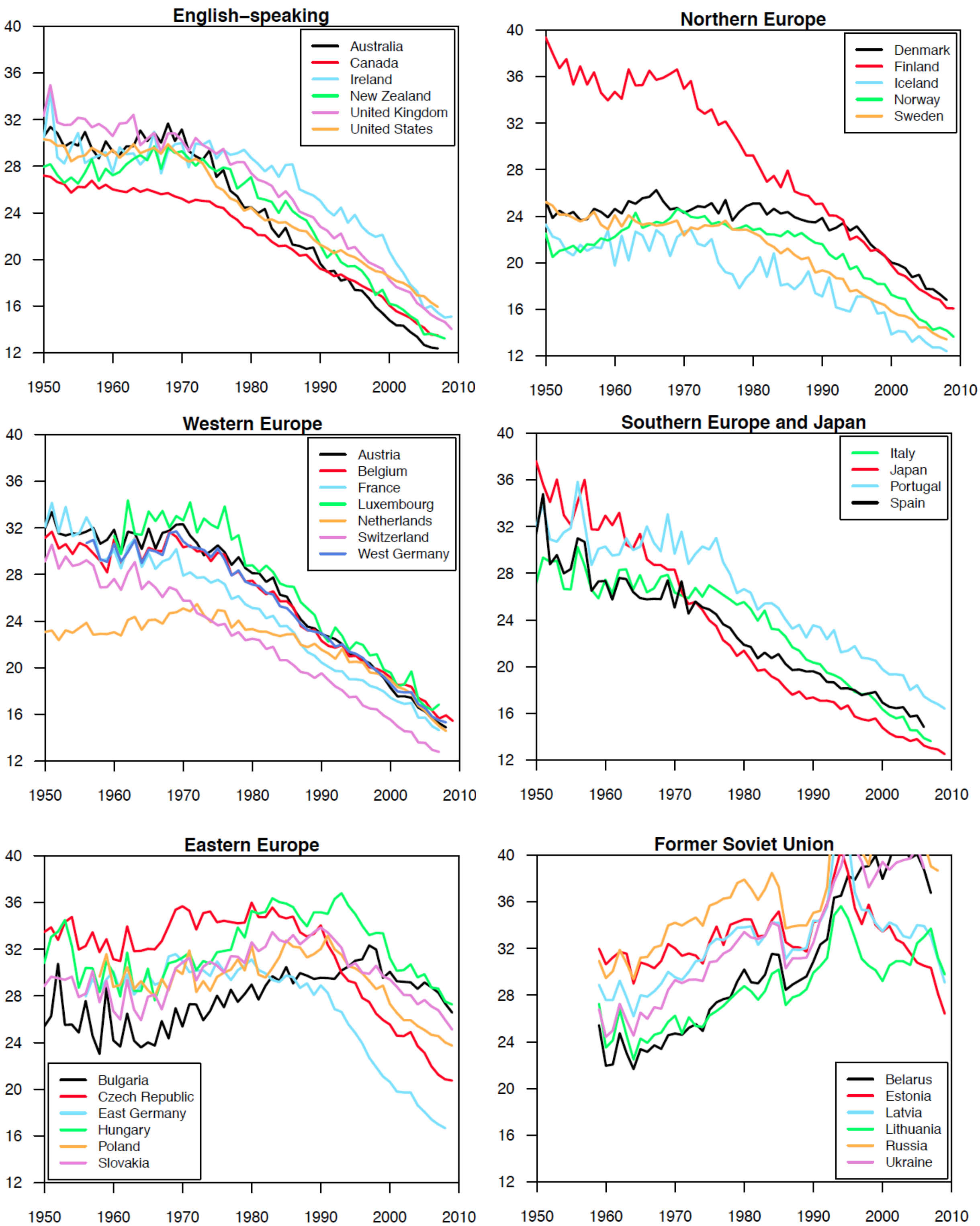
NOTES: "–" indicates that the data series were too short to perform the regression analysis.
".." indicates that the two-slope model did not provide a better description of the data than the comparable one-slope model (F-tests for nested models resulting in $p > .01$).
"†" indicates that mortality conditions for that specific cause-of-death category improved at a slower pace after the turning point year compared to previously.
"‡" indicates that mortality conditions for that specific cause-of-death category worsened after the turning point year compared to previously.
Magnitude of the discontinuity: ***High, **Moderate, and *Low.
SOURCE: Authors' calculations based on the HMD (2011) and WHO Mortality Database (2011).

TABLE 3 Timing of dominant turning point for age-specific smoking-related cancer death rate trends since around 1950, males

	Year		
Age group	**Australia**	**Italy**	**Finland**
40-54	1976	1981	1961
55-69	1981	1987	1970
70-84	1980	1985	1979

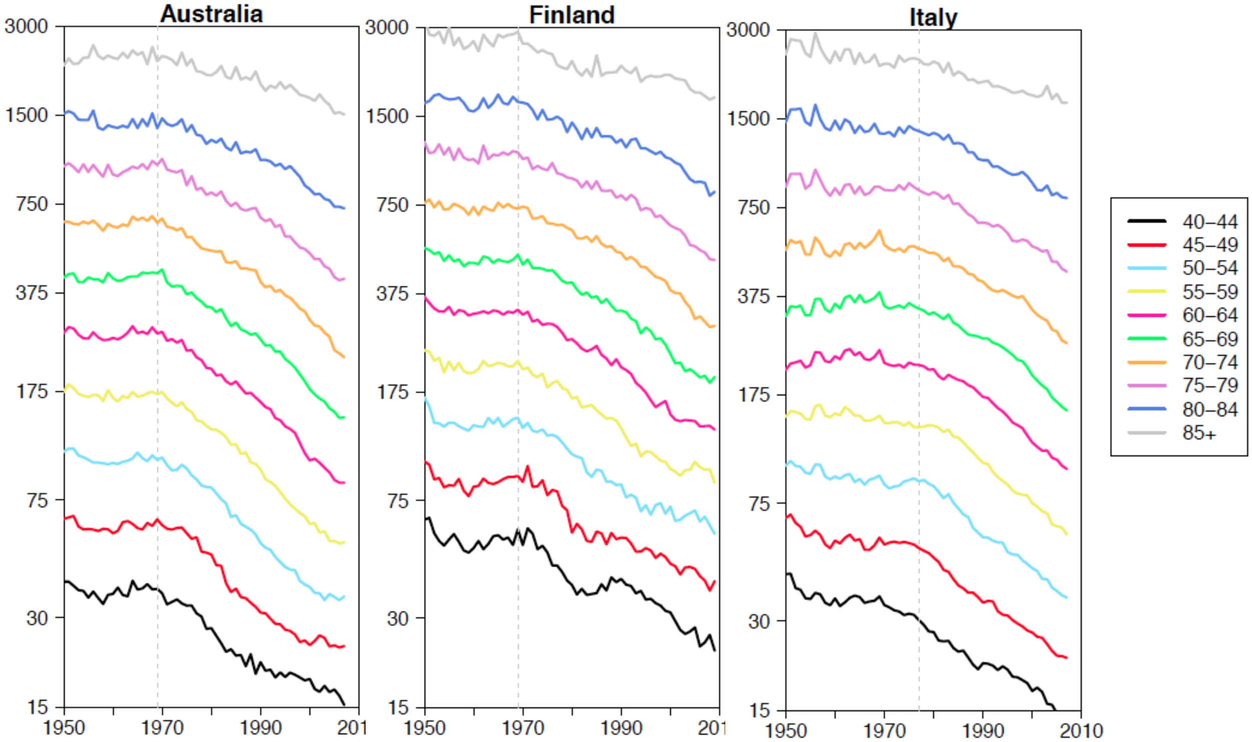
SOURCE: Authors' calculations based on the HMD (2011) and WHO Mortality Database (2011).

FIGURE 1 Age-standardized death rates (per 1,000 population) in selected developed countries, males, ages 40 and above, 1950-2009



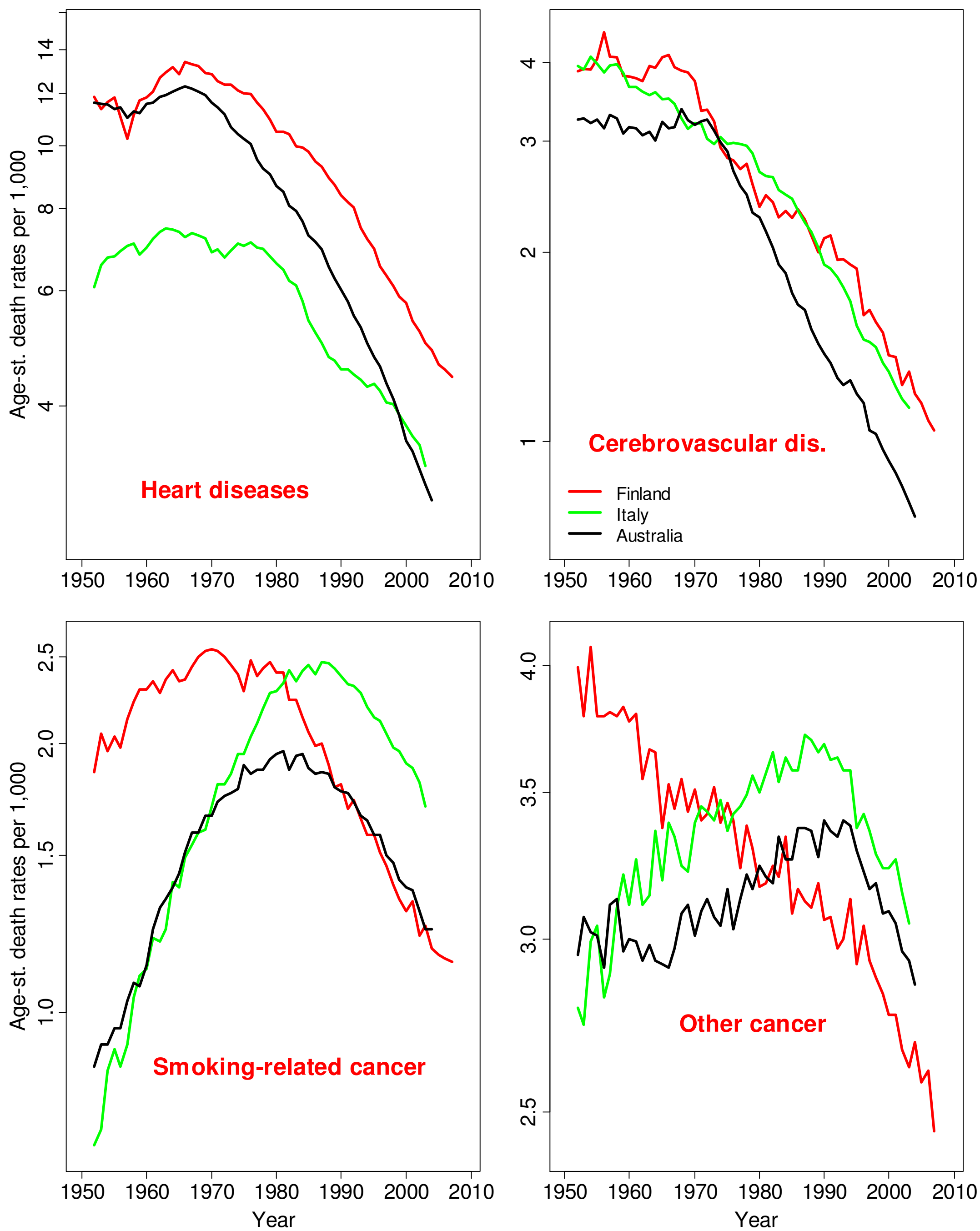
NOTE: The standard population corresponds to the total (both sexes) population of all HMD countries in 1970.
SOURCE: Authors' calculations based on the HMD (2011).

FIGURE 2 Age-specific death rates (per 10,000 population) in three selected developed countries, males, ages 40 and above, 1950-2009



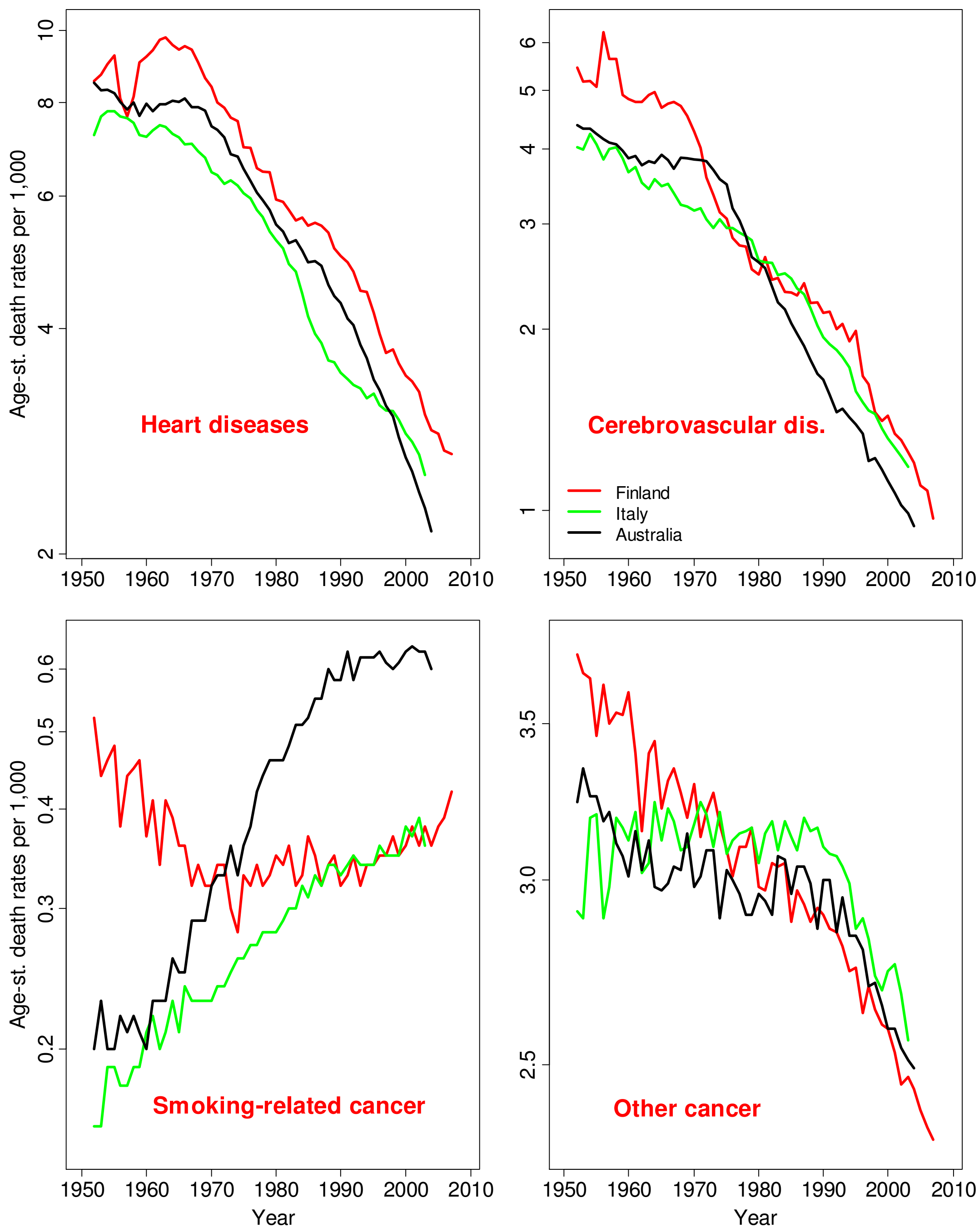
SOURCE: Authors' calculations based on the HMD (2011).

FIGURE 3 Age-standardized death rates for selected causes of death, males, Australia, Finland, and Italy, ages 40 and above, 1950-2009



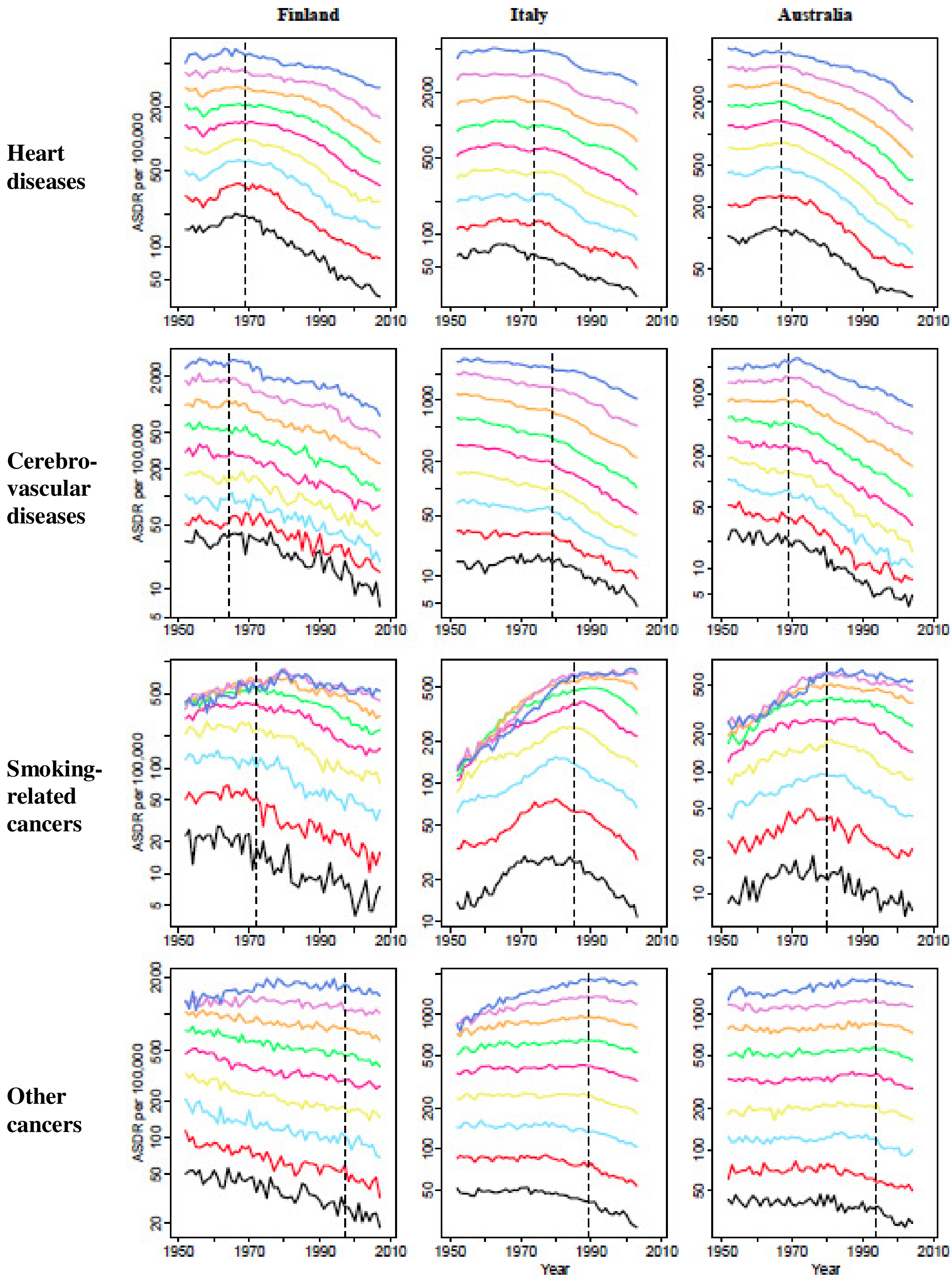
NOTE: The standard population corresponds to the total (both sexes) population of all HMD countries in 1970.
SOURCE: Authors' calculations based on the HMD (2011) and WHO Mortality database (2011).

FIGURE 4 Age-standardized death rates for selected causes of death, females, Australia, Finland, and Italy, ages 40 and above, 1950-2009



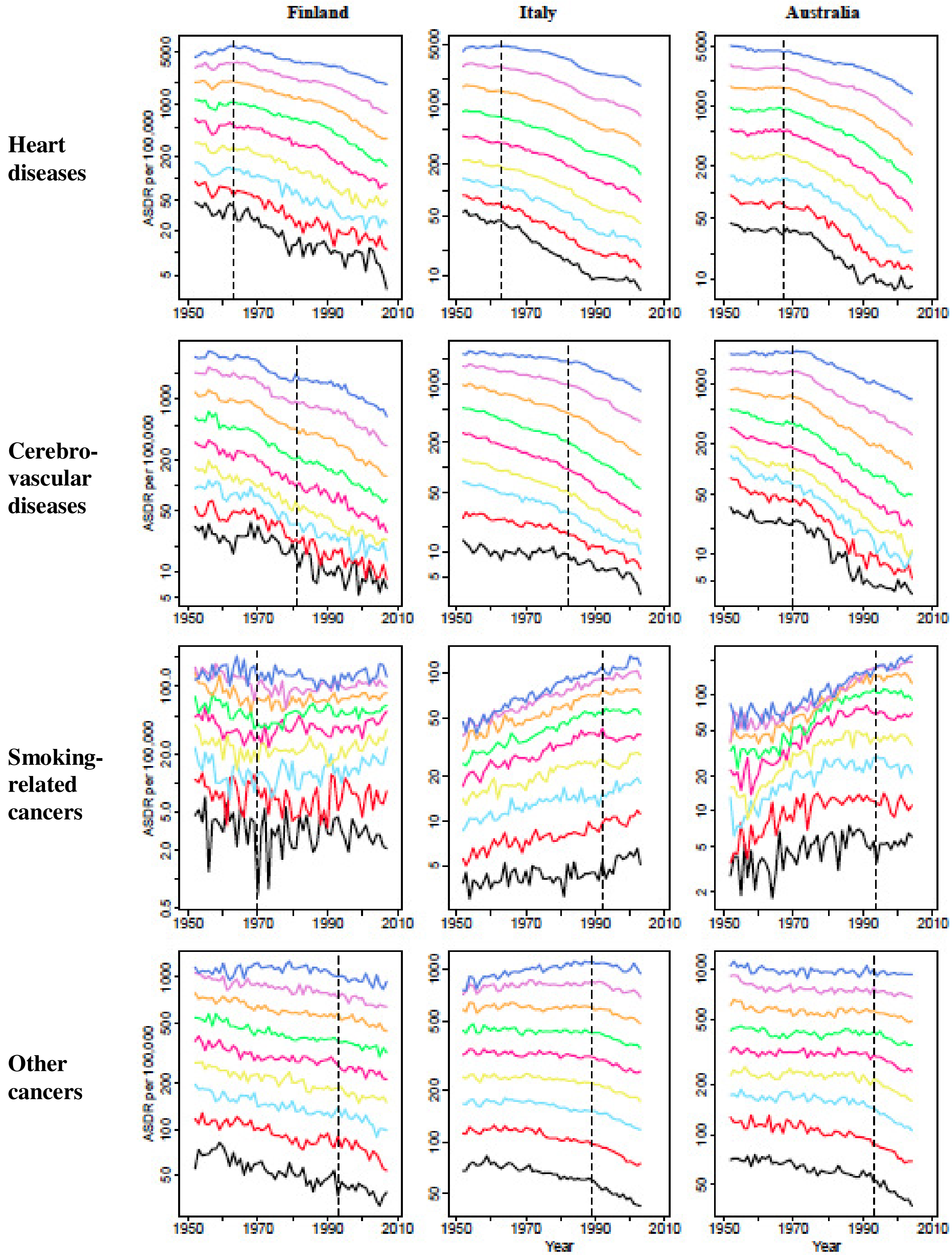
NOTE: The standard population corresponds to the total (both sexes) population of all HMD countries in 1970.
SOURCE: Authors' calculations based on the HMD (2011) and WHO Mortality database (2011).

FIGURE 5 Age-specific death rates for selected causes of death, males, ages 40-44 to 80-84, 1950-2009



NOTE: The colors designate the same age group in all twelve graphs. Lines are stacked from the lowest age group (40-44 years) at the bottom to the highest (80-84) at the top.
SOURCE: Authors' calculations based on the HMD (2011) and WHO Mortality database (2011).

FIGURE 6 Age-specific death rates for selected causes of death, females, ages 40-44 to 80-84, 1950-2009



NOTE: The colors designate the same age group in all twelve graphs. Lines are stacked from the lowest age group (40-44 years) at the bottom to the highest (80-84) at the top.
SOURCE: Authors' calculations based on the HMD (2011) and WHO Mortality database (2011).

Appendix Tables and Figures

APPENDIX TABLE 1 List of selected developed countries with corresponding period covered by all-cause and cause-specific mortality data

	Period covered	
Region/ Country	**All-cause mortality data**[a]	**Cause-specific mortality data**[b]
English-speaking		
Australia	1950-2007	1950-2004; 2006
Canada	1950-2007	1950-2004
Ireland	1950-2009	1950-2009
New Zealand	1950-2008	1950-2007
United Kingdom	1950-2009	1950-1999; 2001-2009
United States	1950-2007	1950-2005; 2007
Northern Europe		
Denmark	1950-2008	1951; 1953-2006
Finland	1950-2009	1952-2009
Iceland	1950-2008	1951-2008
Norway	1950-2009	1951-2009
Sweden	1950-2008	1951-1996; 1999-2008
Western Europe		
Austria	1950-2008	1955-2008
Belgium	1950-2009	1954-1999; 2004-2005
France	1950-2007	1950; 1952-2007
Luxembourg	1960-2007	1967-1997
Netherlands	1950-2008	1950-1995; 2000-2008
Switzerland	1950-2007	1951-1994
West Germany	1956-2008	1952-1990
Southern Europe		
Italy	1950-2007	1951-2003; 2006-2007
Portugal	1950-2009	1955-2003; 2007-2009
Spain	1950-2006	1951-2006
East Asia		
Japan	1950-2009	1950-2009

APPENDIX TABLE 1 List of selected developed countries with corresponding period covered by all-cause and cause-specific mortality data (continued)

Region/ Country	Period covered All-cause mortality data[a]	Cause-specific mortality data[b]
Eastern Europe and Former Soviet Union		
Bulgaria	1950-2009	1964-2008
Czech Republic	1950-2009	1986-2009
East Germany	1956-2008	1973-1978; 1980-1990
Hungary	1950-2009	1955-2009
Poland	1958-2009	1959-1996; 1999-2001
Slovakia	1950-2009	1992-2005; 2008-2009
Belarus	1959-2007	..
Estonia	1959-2009	1994-2000
Latvia	1959-2009	1996-2000
Lithuania	1959-2009	1993-2000
Russia	1959-2008	..
Ukraine	1959-2006	..

[a]HMD (2011).
[b]WHO Mortality Database (2011).
NOTE: ".." indicates that no data were available for that specific country.

APPENDIX TABLE 2 Concordance table used for bridging four revisions of the International Classification of Diseases for selected broad cause-of-death categories

	ICD categories			
Cause of death	**ICD-7**	**ICD-8**	**ICD-9**	**ICD-10**
Cancer (malignant neoplasms)	**140-205**	**140-209**	**140-208**	**C00-C97**
Smoking-related cancer	140-148, 150, 161-163	140-149, 150, 161-162	140-150, 161-162	C00-C15, C32-C34
Other cancer	151-160, 164-171, 172-205	151-160, 163-209	151-160, 163-208	C16-C31, C35-C97
Diseases of the circulatory system	**330-334, 400-468**	**390-458**	**390-459**	**I00-I99**
Cerebrovascular diseases	330-334	430-438	430-438	I60-I69
Heart diseases	400-456	390-429, 440-458	390-429	I00-I52

SOURCE: Created by the authors from various sources.

APPENDIX TABLE 3A All-cause age-standardized death rate at ages 40+ years and mortality share for selected causes by sex in 1955

Country	All-cause death rate (per 100,000)		Mortality proportion (in %): Heart diseases		Cerebrovascular diseases		Smoking-related cancers[a]		Other cancers		Total share of selected causes	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Canada	2,358	2,042	44.4	39.4	11.2	16.7	4.1	1.2	13.5	18.0	73.1	75.2
United States	2,636	2,094	46.5	43.3	11.2	15.8	4.3	1.1	11.8	17.1	73.9	77.2
Japan	3,061	2,707	11.2	11.5	23.7	23.7	1.7	0.7	11.6	11.0	48.3	47.0
Austria	2,819	2,464	26.9	29.4	12.0	16.1	6.3	1.1	14.7	17.9	59.9	64.4
Belgium	2,701	2,378	24.5	24.6	5.3	6.4	4.3	0.9	13.4	17.4	47.4	49.3
Denmark	2,129	2,239	35.9	32.9	13.7	17.9	4.3	1.2	18.1	21.2	72.0	73.3
Finland	3,262	2,705	36.3	34.2	12.4	18.8	6.2	1.8	11.6	12.8	66.5	67.5
France	2,890	2,285	19.7	20.6	11.9	14.3	4.8	0.9	11.8	15.8	48.3	51.6
West Germany[b]	--	--	--	--	--	--	--	--	--	--	--	--
Iceland	1,864	1,827	30.3	26.5	13.9	19.1	4.2	1.1	18.6	21.0	67.1	67.7
Ireland	2,593	2,547	38.5	36.3	9.4	13.3	4.0	1.6	11.2	12.0	63.2	63.2
Italy	2,508	2,386	26.9	32.6	15.9	17.0	3.6	0.8	12.1	13.4	58.6	63.9
Luxembourg[c]	--	--	--	--	--	--	--	--	--	--	--	--
Netherlands	2,049	2,136	30.2	29.8	13.0	17.9	5.7	0.9	16.5	19.4	65.4	68.0
Norway	1,885	1,877	30.8	27.9	15.0	19.8	2.6	0.9	17.9	18.8	66.3	67.3
Portugal	2,893	2,464	22.3	24.9	11.7	14.2	2.2	0.7	7.5	9.6	43.8	49.4
Spain	2,631	2,351	17.7	20.1	12.2	14.5	3.0	0.7	10.1	11.3	42.9	46.6
Sweden	2,110	2,197	35.1	33.0	13.6	18.3	2.5	1.1	15.1	16.4	66.2	68.8
Switzerland	2,576	2,344	30.3	34.4	13.0	17.0	6.4	0.9	14.5	16.9	64.2	69.2
United Kindgom	2,828	2,243	36.4	36.8	12.7	18.2	7.2	1.7	11.5	15.6	67.9	72.3
Australia	2,684	2,173	42.3	37.9	12.1	19.5	3.6	0.9	11.2	15.0	69.3	73.3
New Zealand	2,437	2,099	42.8	38.1	10.4	18.1	4.7	1.3	13.2	17.0	71.0	74.6

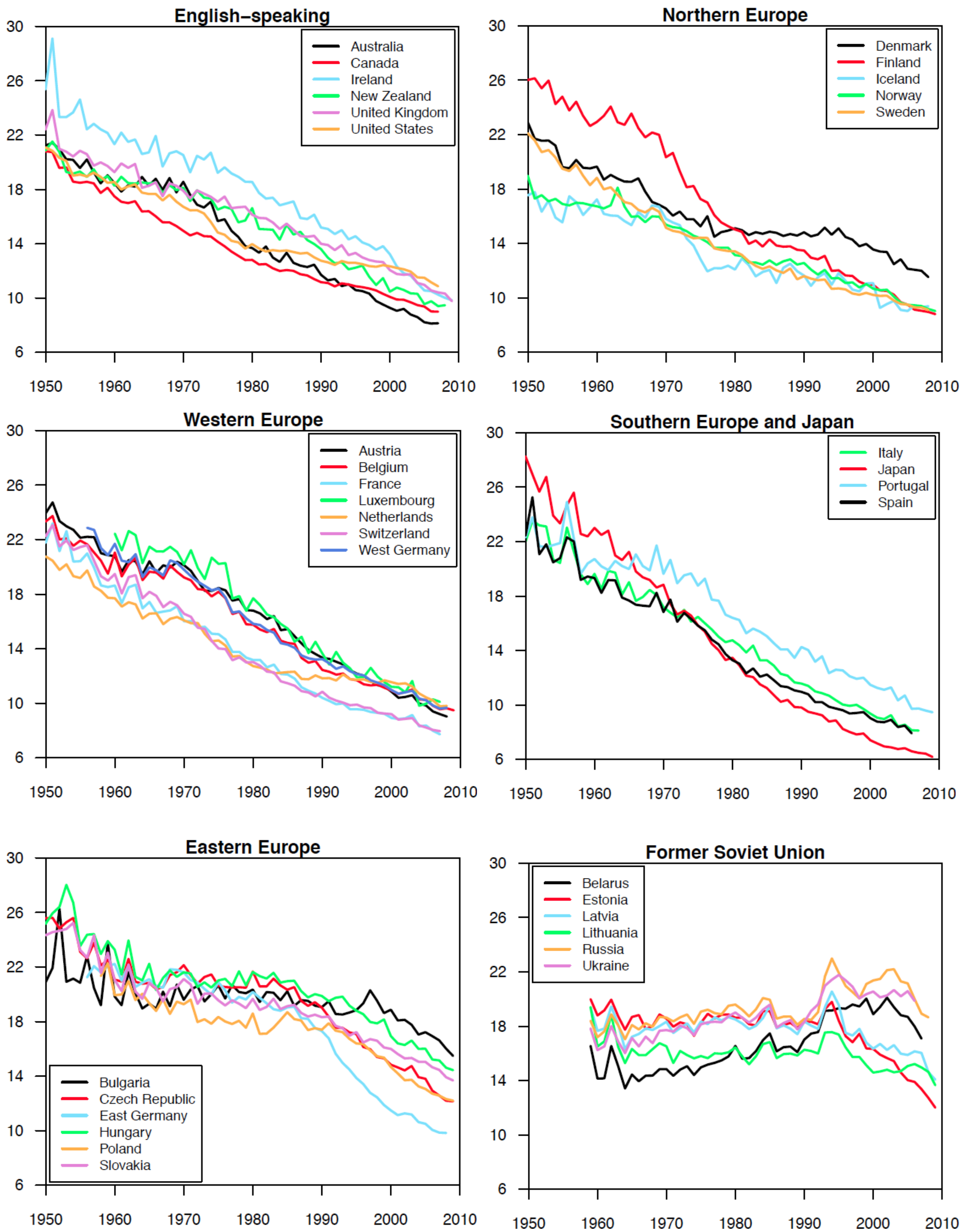
[a]Includes malignant neoplasms of lip, oral cavity, pharynx and larynx, trachea, bronchus, and lung.
[b]Cause-specific mortality data series for West Germany are not available before 1956 (Appendix Table 1).
[c]Cause-specific mortality data series for Luxembourg are not available before 1967 (Appendix Table 1).
SOURCE: Authors' calculations from WHO Mortality database (2011).

APPENDIX TABLE 3B All-cause age-standardized death rate at ages 40+ years and mortality share for selected causes by sex in 2000

			Mortality proportion (in %)									
Country	**All-cause death rate (per 100,000)**		**Heart diseases**		**Cerebrovascular diseases**		**Smoking-related cancers**[a]		**Other cancers**		**Total share of selected causes**	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Canada	1,418	1,115	27.0	23.7	5.6	7.8	12.2	9.0	20.9	24.4	65.8	64.9
United States	1,648	1,342	31.2	28.7	5.4	7.6	11.2	7.9	16.6	19.3	64.4	63.5
Japan	1,302	822	14.2	17.0	11.8	15.1	10.7	4.8	25.8	27.0	62.5	63.8
Austria	1,623	1,202	35.2	36.0	8.6	12.5	9.9	4.1	19.6	24.2	73.3	76.7
Belgium	1,711	1,225	23.3	25.1	6.3	9.0	13.5	3.6	18.5	24.0	61.7	61.7
Denmark	1,783	1,490	24.4	20.3	7.0	8.9	11.1	7.9	20.1	24.8	62.5	62.0
Finland	1,759	1,202	32.7	28.8	7.8	12.0	7.4	3.0	15.8	21.5	63.6	65.2
France	1,558	997	18.6	19.6	5.5	7.9	13.6	3.4	22.7	26.1	60.4	57.1
West Germany[b]	--	--	--	--	--	--	--	--	--	--	--	--
Iceland	1,274	1,136	32.3	23.6	7.3	11.1	8.7	8.2	22.6	24.4	70.8	67.3
Ireland	1,805	1,430	32.0	26.3	6.9	10.2	9.5	6.1	18.6	22.1	67.0	64.8
Italy	1,448	1,044	25.7	27.7	8.9	12.7	13.1	3.6	22.3	26.2	70.0	70.2
Luxembourg	1,715	1,251	25.4	23.8	8.6	14.2	12.8	3.8	19.8	24.6	66.6	66.4
Netherlands	1,644	1,272	25.1	22.3	6.8	9.7	12.5	5.6	19.9	23.8	64.3	61.4
Norway	1,525	1,187	28.5	25.9	8.0	10.2	8.0	5.4	21.4	24.2	65.9	65.7
Portugal	1,763	1,281	15.9	17.8	16.1	22.4	8.0	1.9	17.9	19.0	57.9	61.1
Spain	1,509	1,011	20.4	23.6	7.5	11.7	13.4	2.0	21.0	23.6	62.3	60.8
Sweden	1,386	1,132	31.6	26.4	8.5	11.0	6.3	4.8	21.1	24.5	67.6	66.8
Switzerland[c]	--	--	--	--	--	--	--	--	--	--	--	--
United Kindgom	1,657	1,364	30.2	24.0	7.6	11.0	10.4	6.8	18.5	21.7	66.6	63.5
Australia	1,306	1,035	27.0	26.0	7.2	10.8	10.6	6.1	23.7	25.0	68.4	67.9
New Zealand	1,441	1,192	30.6	27.1	7.5	11.5	9.5	6.3	24.0	26.0	71.5	70.9

[a]Includes malignant neoplasms of lip, oral cavity, pharynx and larynx, trachea, bronchus, and lung.
[b]Cause-specific mortality data series for West Germany are not available after 1990 (Appendix Table 1).
[c]Cause-specific mortality data series for Switzerland are not available after 1994 (Appendix Table 1).
SOURCE: Authors' calculations from WHO Mortality database (2011).

APPENDIX FIGURE 1 Age-standardized death rates (per 1,000 population) in selected developed countries, females, ages 40 and above, 1950-2009



NOTE: The standard population corresponds to the total (both sexes) population of all HMD countries in 1970.
SOURCE: Authors' calculations based on the HMD (2011).

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