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German East-West Mortality Difference: Two Cross-Overs Driven by Smoking

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Abstract

Before the fall of the Berlin Wall, mortality was considerably higher in the former East than West Germany. The gap narrowed rapidly after German unification, particularly for women, to the point that Eastern women aged 50-64 now have *lower* mortality, despite lower incomes and worse overall living conditions. Prior research shows that lower smoking rates among East German females was a major contributor to this cross-over. However since 1990, higher smoking rates have been observed among women in the eastern part of Germany. We forecast the impact of this changing smoking behavior on East-West mortality differentials and find that the higher smoking rates among younger East German cohorts will reverse their contemporary mortality advantage. Experience from other countries show that smoking can be effectively reduced by strict anti-smoking policies. Instead, East Germany is becoming a warning example of the consequences of weakening anti-smoking policies and changing behavioral norms.

Keywords: Smoking, Mortality Forecast, Germany

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Introduction

Germany was divided into East and West from 1949 until the fall of the Berlin Wall and unification in 1990. Over the decades of separation, the East increasingly lagged behind the West in living standards, health care, and ultimately life expectancy. By 1989 East German life expectancy was 2.4 years below that of the West for men, and 2.6 years below for women (HMD, 2014). Since the unification 25 years ago, East Germans have experienced remarkable mortality improvements. Among women, the mortality difference has practically disappeared, being 0.1 years in 2011; among men the gap has narrowed to 1.2 years in 2011.

The pre-unification mortality differential was mostly due to cardiovascular and respiratory diseases (Höhn & Pollard, 1991), which are usually attributed to differences in the economic, social, and medical environments (Diehl, 2008; Dinkel, 2000; Gjonça, Brockmann, & Maier, 2000; Luy, 2004). The factors driving the post-unification mortality convergence are less well understood. Reunification brought major changes to the living conditions of East Germans and the relative importance of the various factors continues to be debated (Diehl, 2008; Kibele, 2012). Following the adoption of the West German social, economic and political system, East Germans benefited from access to the modern western health system that helped to reduce circulatory mortality as the prime cause of death. Likewise, they witnessed a manifold increase in nominal income and purchasing power as the West German Mark was introduced at a highly beneficial exchange rate of 1:1. Social expenditures for health care and pensions converged to the generous western level which helped to reduce the mortality differentials between the two parts of Germany (Vogt & Kluge, 2014). In addition to improved living standards and the adoption of Western health care technology, it has been suggested that the convergence could have been driven in part by decreases in psychosocial stress resulting from the deprived living and working conditions in the East (Cockerham, 1999; Häussler, Hempel, & Reschke, 1995; Riphahn, 1999).

Despite these improvements, East Germany[i] continues to lag behind the West in terms of living standards. However for some age groups female mortality has declined below that of the West, as shown in Figure 1. This mortality cross-over has been documented before and attributed not to period changes following the unification, but to higher smoking prevalence among West German women in the 1940s-1950s birth cohorts (Myrskylä & Scholz, 2013). This is not surprising as smoking is the most important behavioral factor influencing mortality and one of the key elements in contributing to mortality differentials across (Preston, Glei, & Wilmoth, 2010) and within national populations (Preston & Wang, 2006). Other health behaviors could also be partially responsible for the convergence, but prior research suggests that at least for alcohol consumption, the trends declined in parallel in both East and West over the 1990s (Bloomfield, Grittner, & Kramer, 2005).

Women in East and West Germany exhibited different smoking patterns before and after reunification, which was not the case for men. East German women smoked little during separation when prevalence was high among East and West German men and rising among West German women. This changed abruptly after reunification. The female East German smoking prevalence over ages 25-69 increased by 42% between 1992 and 1998 alone, at a time when the prevalence was constant among West German women (Junge & Nagel, 1999). Among younger cohorts, smoking initiation has become higher and cessation rates lower for East German women compared to West German women in recent years (Junge & Nagel, 1999).

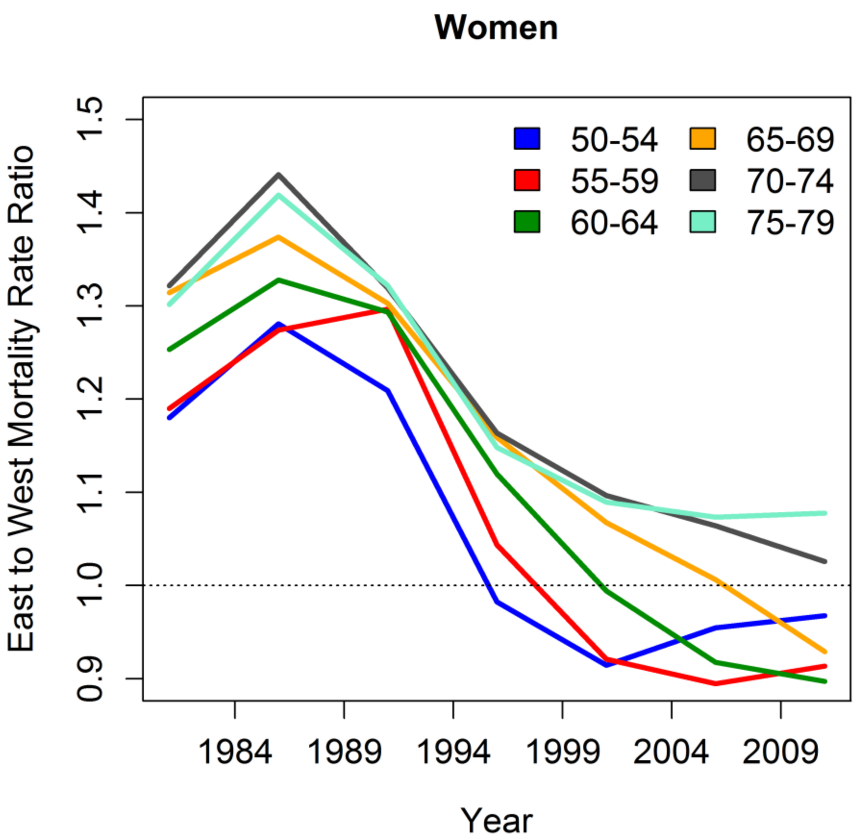

Figure 1: Mortality rate ratios for all-cause mortality showing convergence and crossover for women in Eastern and Western Germany, Source: HMD (2014). The equivalent figure for men can be found in the appendix. Note: Ratios above 1 indicate higher mortality for East German women.

Traditional mortality forecasting methods that do not account for smoking would forecast a widening mortality advantage for East German women[ii], which seems implausible given that younger East German women now smoke at higher rates than West German women and continue to lag behind in living standards. Our current forecasts which are based on a method that includes smoking histories (Wang & Preston, 2009) project a second crossover in mortality rates, with East German women forecasted to return to higher mortality than West German women for cohorts coming of age post-unification. The results have important implications for understanding the post-unification and future East-West mortality dynamics in Germany.

Data and Methods

Data

We used the German Socioeconomic Panel (SOEP)(DIW, 2015) to estimate cumulative years smoked by age 40 for East and West German cohorts. The question about the uptake and cessation of smoking was asked in waves 2002 and 2012. This allowed us to get precise information on the average number of years smoked before age 40 for each cohort born between 1922 and 1972. For cohorts born between 1973 and 1992 we predicted the cumulative smoking years at age 40 based on the cumulative number of years smoked at earlier ages and the smoking experiences from older cohorts (see Wang and Preston 2009 for more detail). We smoothed the cohort smoking histories using Lowess.

Our mortality data came from four sources. Lung cancer death counts for Western Germany came from the WHO mortality database(WHO, 2014) for years 1956-1990 and from the Federal German Statistical Office via the German health monitoring website (GBE-Bund)(Federal Statistical Office, 2014) for 1991-2011. We reconstructed the time series of lung cancer death counts in East Germany for the years 1956-1997.[iii] From 1998-2011 Eastern data was also obtained from the German health monitoring website. Further adjustments were made to the lung cancer death counts to correct for the inclusion of larynx cancer (1991-1997 in West; 1979 in East) and to separate East and West Berlin (1998-2011).[iv] Population exposure was retrieved from the Human Mortality Database (HMD) for years 1956-2011.

Lung cancer death rates were calculated for each year, 1956-2011, by 5-year age group (ages 50-54 up to ages 75-79).[v] These were the ages where changes in smoking habits were expected to make the largest differences to future all-cause mortality. Moreover, at older ages, there is some question about the validity of estimates regarding the relationship between lung cancer and all-cause mortality for females from the Preston-Glei-Wilmoth (PGW) method which we used (Preston et al., 2010; Preston, Glei, & Wilmoth, 2011; Rostron, 2010). The period trends in lung cancer were smooth in both East and West, and no breaks could be found over years transitioning between data sources or ICD (International Classification of Diseases) codes.

Forecasting mortality using cohort smoking histories

The method we use is based on the Preston, Stokes, Mehta, and Cao (2014) two-step projection method. The method first projects lung cancer mortality, and then bases all-cause mortality projections on the macro-statistical relationship between lung cancer mortality and mortality from other causes of death.

The first step, projecting lung cancer, was done by a modification of the Wang and Preston (2009) methodology. Rather than predicting the relationship between all-cause mortality and the cohort smoking years S^c, Preston et al. suggested to use the following negative binomial regression equation to estimate the relationship between lung cancer and cohort smoking patterns:

$$\ln(M_a^c) = A + \beta_a X_a + \beta_s \ln(S^c) \quad (1)$$

where M_a^c is the lung cancer death rate at age *a* in cohort *c*, X_a is an indicator of age category *a* and β_a its coefficient, β_s is the coefficient of $ln(S^c)$, log of the mean cumulative number of smoking years a cohort has smoked by the age of 40.

We created a data frame that combined the information on cohort smoking histories with observed lung cancer arranged by age, period and cohort as described in footnote 4 of Preston et al. (2014). We combined East and West German data to fit the model (1) in order to increase the statistical power of the estimate, and because we had no reason to believe that the relationship between the cumulative number of years smoked and lung cancer should differ between East and West. Our estimated β_s was 0.912. This was remarkably close to the 0.929 β_s estimated by Preston et al. (2014) for American females.

To validate our self-reported data on smoking from the German SOEP, we re-estimated the above equation for East and West Germany separately, substituting S^c with cohort lung cancer dummies. The estimated lung cancer cohort coefficients lined up well with the self-reported smoking histories over cohorts (Appendix Figure A2).

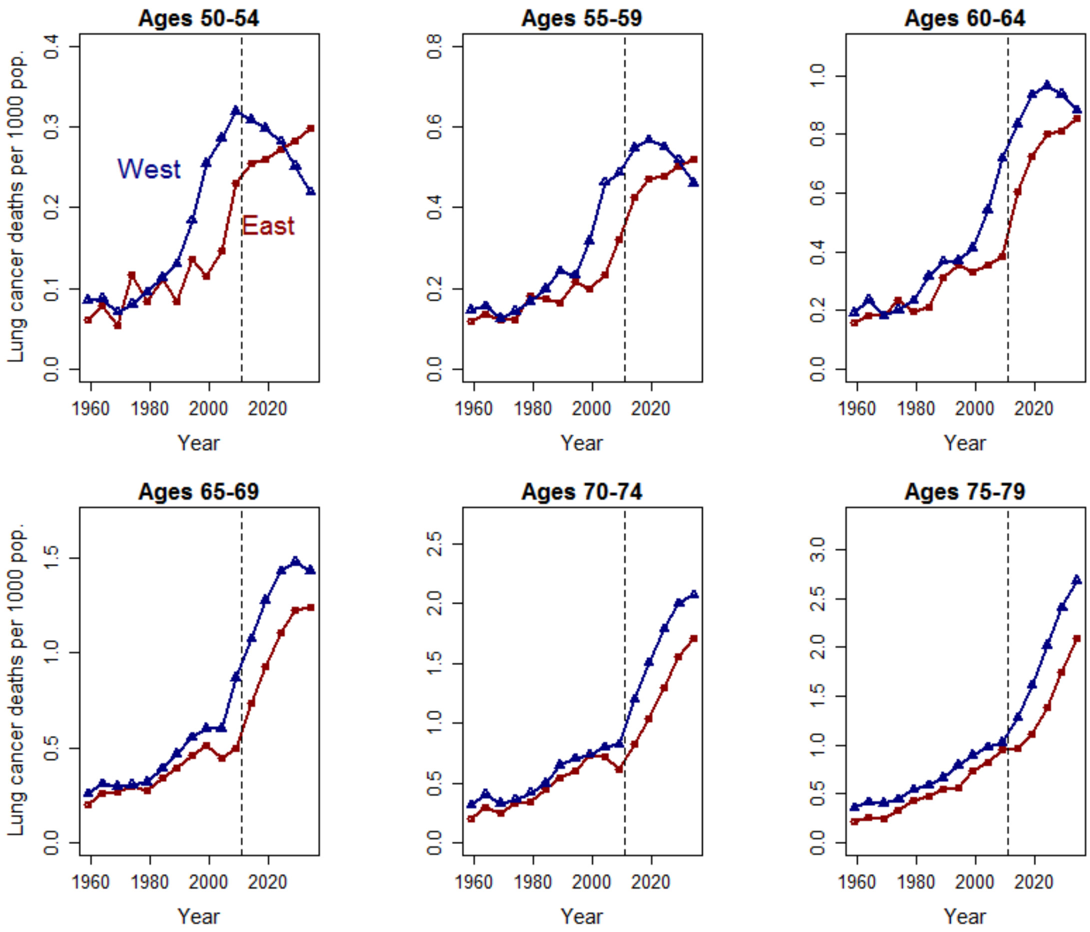

Figure 2: Lung cancer death rates for East and West Germany (observed 1959-2009, forecasted 2014-2034) showing first divergence, followed by convergence or even crossovers, Source: Federal Statistical Office (2014). Note: Please note the changing y-axis due to different lung cancer mortality levels by age.

Using the coefficients estimated from equation (1), we forecasted lung cancer death rates separately for East and West Germany to 2034, the year when our youngest partially observed cohorts turned 40. The method performed well over the selected age range. No discernable jump was noticed at the jump-off period (Figure 2). Cohort patterns can be made out in the pattern of temporal change. For instance among West German women, a first lung cancer peak can be seen in the early 1980s for 60-64 year-olds. This peak becomes more pronounced as it progresses by 5 years for each successive 5-year age interval.

In the second step, Preston et al. (2014) translated lung cancer forecasts to all-cause mortality by using the PGW method (Preston et al., 2010; Preston et al., 2011). The PGW method estimates the macro-statistical relationship between lung cancer mortality and mortality from all other causes based on 21 countries over the period 1950-2006. The model included effects for age, sex, period, and country, and interactions among them. Our approach for translating the lung cancer mortality rate to mortality from other causes of death follows the spirit of Preston et al. but departs in the details. There are three reasons why we are using a modified approach. First, the 21 countries on which the PGW method is based on do not include Germany, so the validity of the translation coefficients for our purposes is questionable. We use German data to estimate comparable translation coefficients. We restrict the time period from which we estimate the coefficients to the years 1991-2012 in order to avoid complications arising from the sharp changes in mortality trends before and after the unification.

Second, direct implementation of the PGW method would result in a jump in the first forecast year. We translate the forecasting problem from forecasting the log of mortality from non-lung cancer causes $\ln(Mo)$ to forecasting the change in the East-West difference:

$$\ln\left(\frac{Mo_t^{East}}{Mo_t^{west}}\right) - \ln\left(\frac{Mo_{t-1}^{East}}{Mo_{t-1}^{west}}\right).$$

With this approach, we avoid jumps in the first forecast year, and also reduce the complexity of the forecasting model considerably, as explained below.

Third, we adopt the most parsimonious defensible regression model that links lung cancer mortality to non-lung cancer mortality. We do this because the database for estimating the relationship between lung cancer and other causes of death is much smaller than in the original PGW method: only 2 regions (East and West Germany) and 22 years. Thus instead of fitting categorical age and categorical age*lung cancer interactions, we use quadratic age for both. Instead of fitting annual year coefficients, we fit a linear time trend, although we allow the trend to differ between East and West. Moreover, we do not include the lung cancer-time interaction because this was not significant. Fenelon and Preston (2012) used a PGW-type approach to analyze smoking attributable mortality in the U.S., and dropped the time-lung cancer interaction for similar reasons. Appendix Figure 4 shows the estimated coefficients that we will be using. For ages close to 50 these are slightly higher than those given in the PGW papers. This might be expected given that the smoking epidemic is comparatively recent among German women by western standards. Fenelon and Preston (2012) found lower coefficients when the estimation was restricted to American women, which they attributed to the maturity of the smoking epidemic there. As a robustness check, we estimate our results also using coefficients that are 50% smaller than our preferred coefficients.

We use the PGW approach, with coefficients based on German data, to translate the forecasted lung cancer death rates into East-West differences in mortality from other causes of death. We assume that overall mortality trends that are not influenced by smoking are similar in the East and West in the future. This is a conservative assumption as the East has already caught up with the West, and it would be bold to assume that mortality in the East would continue to decline faster than in the West. With this assumption, the one step ahead forecast for East-West mortality rate difference (in %) for causes other than lung cancer is:

$$\ln\left(\frac{Mo_{t+1}^{East}}{Mo_{t+1}^{West}}\right) = \ln\left(\frac{Mo_{t}^{East}}{Mo_{t}^{West}}\right) + \beta\left[\left(ML_{t+1}^{East} - ML_{t+1}^{West}\right) - \left(ML_{t}^{East} - ML_{t}^{West}\right)\right]$$

where Mo_{t+1}^{East} and Mo_{t+1}^{West} are the one step ahead forecasts of non-lung cancer mortality, Mo, for East and West, Mo_{t}^{East} and Mo_{t}^{West} are the same for the observed time period t, β is the age-specific coefficient shown in Appendix Figure 4, ML_{t+1}^{East} and ML_{t+1}^{West} are lung cancer mortality rates for East and West.

Recursive use of the one step ahead forecast gives us forecasts up to the year 2034. The logic in this equation is to use changes in lung cancer mortality difference between East and West to inform changes in mortality from other causes between East and West. As seen from the equation, the number of unknowns is small. The limitation from using this simple equation is that we do not forecast levels of mortality, only differences.

Results

Figure 3 shows the observed and partially forecasted cumulative number of years smoked by age 40 for East and West German female cohorts born between 1935 and 1992. Among all female cohorts born before the year 1950, the cumulative years smoked are considerably lower in the East than in the West. For more recent cohorts, however, the number of years smoked is higher for East than West German women. The cumulative years of smoking peaked for West Germans around the 1960 birth cohort, but continue to increase among East German women.

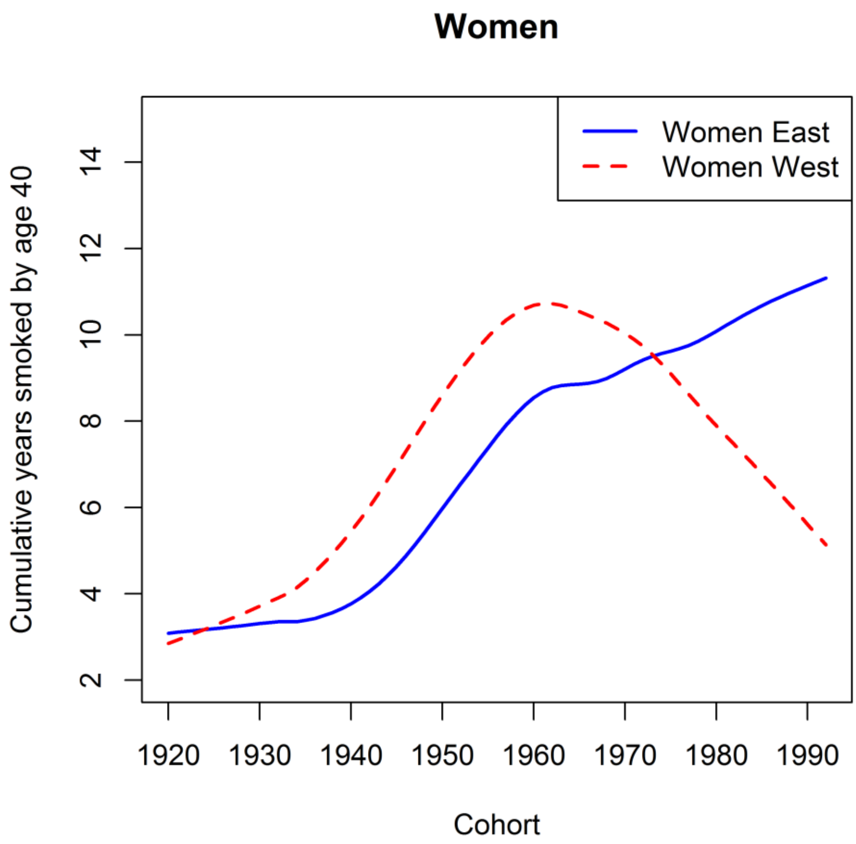

Figure 3: Cumulative years smoked by the age of 40 (smoothed) by birth year, Source: DIW (2015).
Note: The last fully observed cohort was born in 1972. We forecast the cumulative smoking years for the younger cohorts based on smoking patterns of older cohorts and the years smoked by each cohort at least by age 20. Therefore, our last cohort that was born in 1992 reached age 20 in 2012. The equivalent figure for men is in the appendix.

Figure 2 (shown in Methods section) depicts observed and forecasted lung cancer mortality rates for East and West German women by age. In most age groups and years, lung cancer mortality is higher in the West in the observed data. However, for the age groups 50-64 for which earlier research has shown that total mortality is lower in the East than in the West, the lung cancer mortality difference is projected to narrow and eventually reverse—lung cancer is forecasted to increase in the East as a result of increased smoking and decline in the West. The cross-over is expected to happen first for the youngest age groups, in around year 2020 for the ages 50-54, and by about 2035 we project that also for the age group 60-64 East German lung cancer mortality catches up with that of the West. For the older age groups, we forecast continued higher lung cancer mortality in the West. Eastern women at older ages benefit from lower smoking rates in the past and as such have a comparatively reduced risk to die from lung cancer in the future.

These different lung cancer risk patterns are a key marker of the harm done by cigarette smoking to different age groups over different time periods. Nevertheless, smokers have elevated risks for mortality from many other causes of death, notable circulatory disease and some cancers.

We forecasted mortality differences in East and West Germany for all causes other than lung cancer, which include the bulk of smoking-attributable mortality, by accounting for differences in smoking histories in the two regions. Mortality from causes other than lung cancer among East German women aged 50-64 declined below that of West German women in the late 1990s and early 2000s. Our forecasts suggest that this advantage is at risk given the very different cohort smoking patterns for cohorts born in the 1980s and 1990s (Figure 4). Mortality among East German women aged 50-54 has already surpassed that of the West, and for the age groups 55-59 and 60-64 the second cross-over is projected to happen in around 2015 and 2025, respectively.

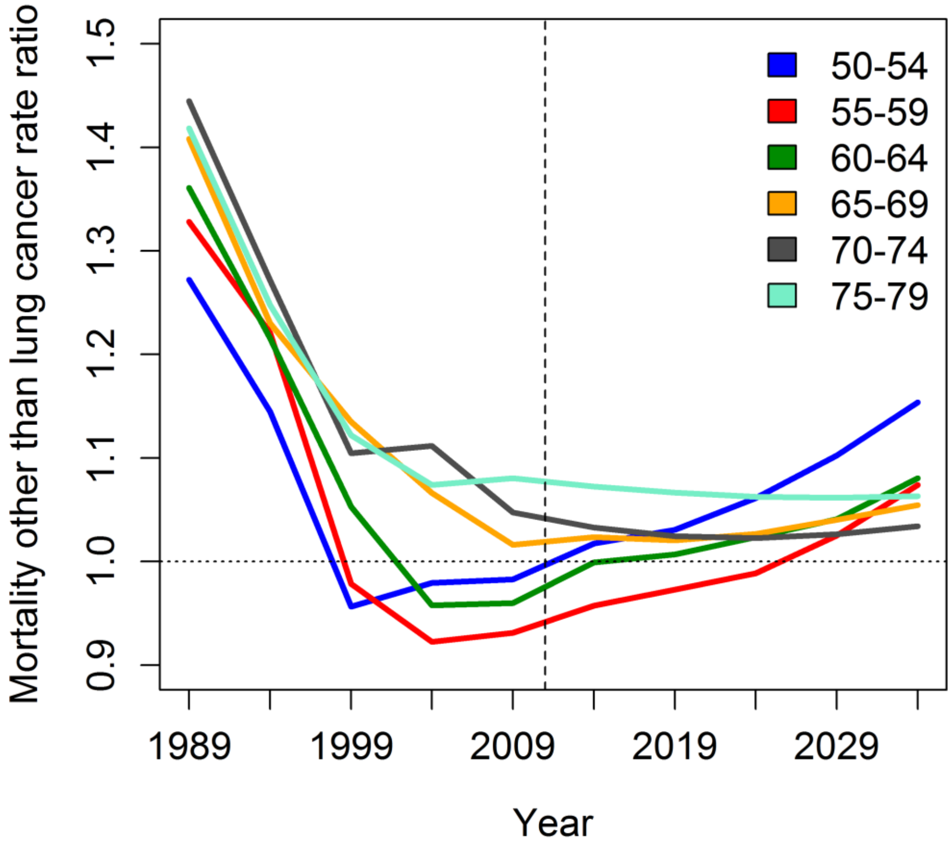

Figure 4. Observed and forecasted mortality rate ratios from causes other than lung cancer between Eastern and Western German women. Note: Ratios above 1 indicate higher mortality for East Germany.

If we combine the qualitative message of these mortality forecasts for other causes than lung cancer (Figure 4) with those for lung cancer (Figure 2), we can expect that for total mortality, East will fall behind West in the age group 50-54 by 2020 at the latest. For ages 55-59 and 60-64 the second cross-over for total mortality is expected to happen around years 2025 and 2030 (respectively) at the latest. For age groups 65-79 we expect that mortality from causes other than lung cancer will continue to be higher in the East than in the West (Figure 4).

Discussion

After the reunification in 1990 the German East-West mortality difference narrowed rapidly for women, and by late 1990s and early 2000s mortality in the age groups 50-64 had declined below that of the West. This mortality cross-over has been attributed to higher smoking of the West German cohorts. In this study we show that the survival advantage of the East German cohorts is ending, and use demographic forecasting methods to study the implications of the reversing smoking advantage to mortality differentials between the East and West German women. Our results show that the increases in smoking rates among younger cohorts will have a strong impact on the future mortality differentials. East German women between the ages 50 and 64, who currently enjoy a lower mortality than their West German peers, will in the next two decades fall again behind West Germany both in terms of lung cancer mortality and all-cause mortality.

Past research on the post-unification mortality differences between the East and the West have often treated the unification as a “natural experiment” and interpreted the post-unification changes in mortality as arising from factors related to the unification (Chruscz, 1992; Cockerham, 1999; Dinkel, 1992; Häussler et al., 1995; Vaupel, Carey, & Christensen, 2003). Four main factors are often attributed to the sharp declines in post-unification mortality decline in the East: medical care, living standards, psychosocial stress, and health behaviors (for a review see Kibele 2012, Diehl 2008). Each of these four factors may have been important in the past convergence. However, there has been only convergence, not cross-overs in these factors. Smoking, in contrast, shows a fluctuating pattern across East and West female German cohorts. As smoking is the most important behavioral factor influencing mortality, we would expect these changes to help explain past cross-overs in mortality, and also inform us about future changes. The effect of smoking on mortality is lagged, with a gap of two-to-three decades between a population-level increase in smoking prevalence and marked increases in smoking-related mortality. This is critically important and useful for forecasting as we can use observed smoking behavior to forecast future mortality rates.

Our results suggest that the mortality advantage of the Eastern 50-64 year old age group will disappear as mortality improvements in the East in comparison to the West are suppressed because of increasing smoking. Our prediction rests on the assumptions that the general living conditions in terms of health care, wealth or pollution will not diverge again in the future. This is a reasonable assumption as we do not expect that the two former parts of Germany will follow different political, social or economic paths as they did in the past. There might still be regional differences in these realms 25 years after reunification but there is a growing differentiation to a North-South pattern replacing the general East-West difference (Kibele, Klüsener, & Scholz, 2015).

Other approaches to forecasting mortality based on smoking histories have been proposed. Wang and Preston 2009 based forecasts on the statistical relationship between all-cause mortality and smoking histories (Wang & Preston, 2009). We found this approach to be overly sensitive to the inclusion or exclusion of certain cohorts. Janssen, van Wissen, & Kunst (2013) suggested an age-period-cohort model that required as input the peak smoking period by cohort. Given the immaturity of the epidemic in East Germany, there was too much uncertainty in this model.

We tested the robustness of our results to our forecasting model. Our forecasted 2nd cross-over that is driven by differential smoking patterns is based on a regression model that links lung cancer mortality to mortality from other causes of death. It is possible that we have overestimated the strength of this association. We conducted a robustness test that halves the original coefficients to see if the qualitative conclusions are sensitive to changes in the model coefficients (see Appendix Fig A4). Even with these diluted coefficients, we forecast that East falls behind West in each of the age groups between 50-64 in the years 2019-2034. Moreover, the age coefficients linking smoking history and mortality estimated from German data closely resemble international age coefficients estimated from 18 high income countries in the widely used Preston-Glei-Wilmoth model (see Appendix Fig A5).

These findings highlight the importance of policies to combat the uptake of cigarette smoking. In this respect, Germany's reunification is an example of the severe effects of lax anti-tobacco regulations. Marketing efforts in general were not necessary in the planned East German economy as product competition or market entry preparation did not exist (Feick & Gierl, 1996). At the same time, there was no oversupply but rather shortages of certain consumer goods and services (Kopstein, 2000). The rare attempts of the statutory promotion caused suspicion among East Germans as they believed that something must be wrong if advertisement was necessary (Feick & Gierl, 1996). This changed completely with the adoption of the West German free market economy where marketing was a well-established feature. At the beginning of the 1990s, West Germany had very weak tobacco marketing regulations (Bornhäuser, McCarthy, & Glantz, 2006; Mons & Pötschke-Langer, 2010) making it a "tobacco industry paradise" (Poetschke-Langer & Schunk, 2001). East Germans that were generally more credulous towards West German marketing (Feick & Gierl, 1996) were confronted with this sudden change in tobacco marketing regulations. The availability of cigarettes and the images that advertisements or product placements convey are all associated with early initiation of smoking (Biener & Siegel, 2000; Dalton et al., 2003; DiFranza et al., 2006; Hanewinkel, Isensee, Sargent, & Morgenstern, 2011; Hanewinkel & Sargent, 2008; Titus-Ernstoff, Dalton, Adachi-Mejia, Longacre, & Beach, 2008). When international tobacco companies entered the East German and Eastern European market they used these strategies and targeted population subgroups that had previously low smoking rates (Connolly, 1995; LeGresley, Muggli, & Hurt, 2006). Advertisement efforts that were not only not necessary but strictly forbidden before reunification (Heinemann, Barth, & Hoffmeister, 1995), were particularly geared towards younger age groups and women (Amos & Haglund, 2000; Hafez & Ling, 2005). In combination with the absence of adequate policies or preventive health campaigns, these efforts had a major impact on smoking habits in East Germany and throughout Eastern Europe.

In addition to increased exposure to cigarette marketing campaigns, changing fertility behaviors and selective migration could be partially responsible for the increasing smoking prevalence in the East. Pregnancy is a time when women often quit smoking (Schneider, Huy, Schütz, & Diehl, 2010). After the reunification, a large number of East German women in their fertile ages decided to postpone or give up childbearing. Between 1991 and 1996, the total fertility rate dropped below one child per women, a lower level than during both world wars (Huinink & Kreyenfeld, 2006). At the same time, the mean age at first birth rose by 2 years from 25.2 years in 1989 to 27.2 year in 1998 compared to the small rise from 28.2 to 28.9 in West Germany (HFD, 2014). A later mean age at birth means a longer period of smoking prior to pregnancy, and a longer time to become dependent on nicotine. A comparison of smoking habits among German women shows that, in 1991, more East than West German women at all ages gave up smoking (Robert Koch Institute, 2012). By 1998, this pattern had reversed and fewer East German women gave up smoking (Robert Koch Institute, 2000).

Another potential explanation for the changing smoking patterns is selective outmigration of women with higher education and, thus, different smoking habits. If smoking was lower among highly educated women in the East, their observed higher outmigration rates (Melzer, 2013) would increase the smoking prevalence in the East and could decrease it in the West. East-West migration was at its peak during the 1990s and the beginning of the 2000s (Heiland, 2004). Migration was not restricted to the young but was a common feature of all working ages (Fuchs-Schündeln & Schündeln, 2009). This included the age groups where mortality was lower in the East than in the West beginning in the mid-1990s, which would not be consistent with the non-smokers selectively having migrated to the West. Since the mid-1990s, migration within East Germany has overtaken migration to the West leading to an agglomeration of cities and an increasing depopulation of rural areas (Sander, 2014). Thus if smoking and migration were both strongly socially patterned by education, recent migration flows would have contributed little to East-West German differences.

Once smoking habits are established, younger age groups are more likely to start when someone in the household, their peer group or the general neighborhood smokes (Hill, Hawkins, Catalano, Abbott, & Guo, 2005; Kobus, 2003; Lee & Cubbin, 2002). The chances of becoming and staying a smoker are higher in socially deprived areas or for networks of lower socioeconomic status (Chandola, Head, & Bartley, 2004; Gilman, Abrams, & Buka, 2003). This might contribute to high female smoking rates in East German regions that still suffer from continued high unemployment rates, outmigration of the more educated and a general lack of prospects (Federal German Government, 2014).

Our analysis is not able to predict future all-cause mortality for German women. Yet, the aim of our study was to exemplify how plastically smoking impacts observed mortality differences. Past smoking behaviors first allowed East German women to reach lower mortality levels than women in the West. Contemporary smoking habits are projected to again reverse the differential within the next 20 years. Since the smoking prevalence among women in the East increased after reunification, the low mortality success story of East German women is anticipated to end as they return to higher overall mortality. This study is another shocking example how enduring the consequences of changing smoking habits are. Mainly younger East German cohorts that were exposed to the post-reunification tobacco campaigns and formerly unknown cigarette advertisements will experience higher mortality from smoking-related diseases. Thus, our findings on the role of smoking have important implications for understanding the future mortality dynamics among the more than 40 million German women.

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Appendix Figures

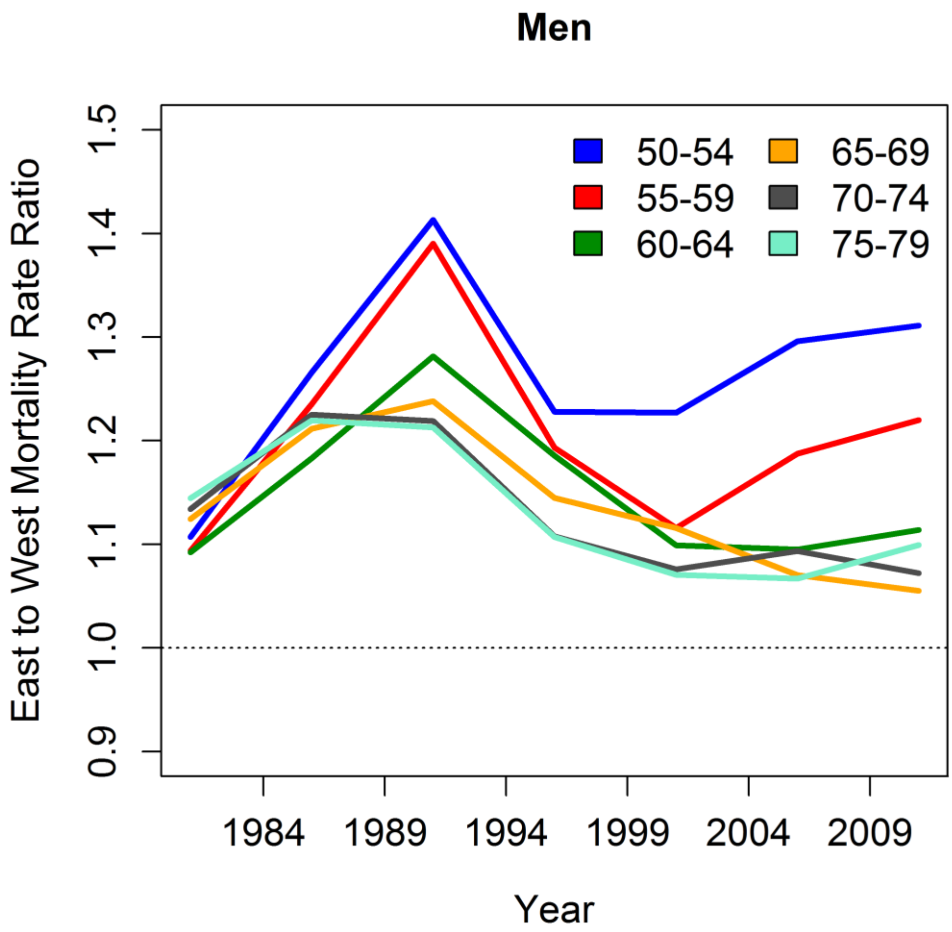
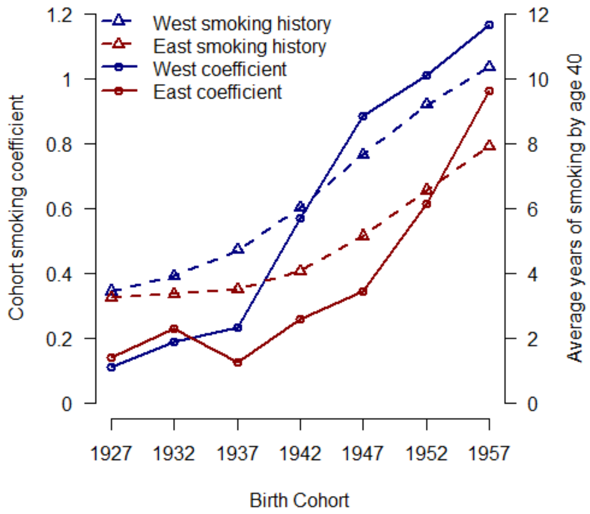


Figure A1: Mortality risk ratios for all-cause mortality convergence for men in East and West Germany, Source: HMD (2014).



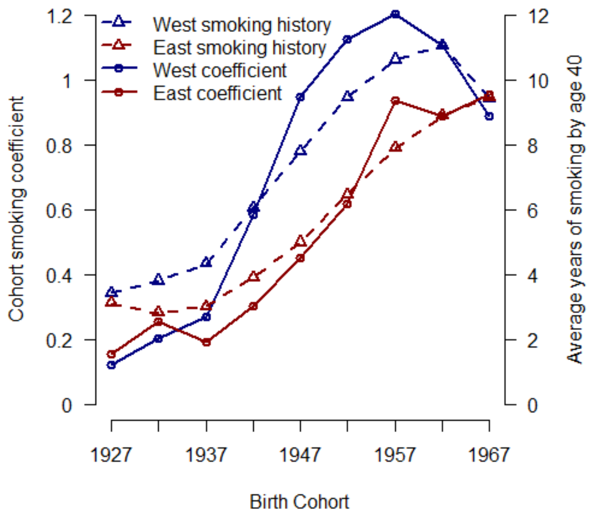


Figure A2: A comparison of the cohort smoking coefficients obtained using regression equation 2 from Preston et al. (2014: 40) [left y-axis] and the mean cumulative number of years that each cohort spent as a smoker by the age of 40, based on data averaged over the two SOEP rounds for cohorts fully observed to at least age 50 (above) and age 40 (below). What is noteworthy is that the regression equation was based on cohort lung cancer deaths and did not include the self-reported data from the SOEP. The similar time trend in the two sets of lines gives us confidence in the accuracy of our SOEP data which we used to project lung cancer to 2034.

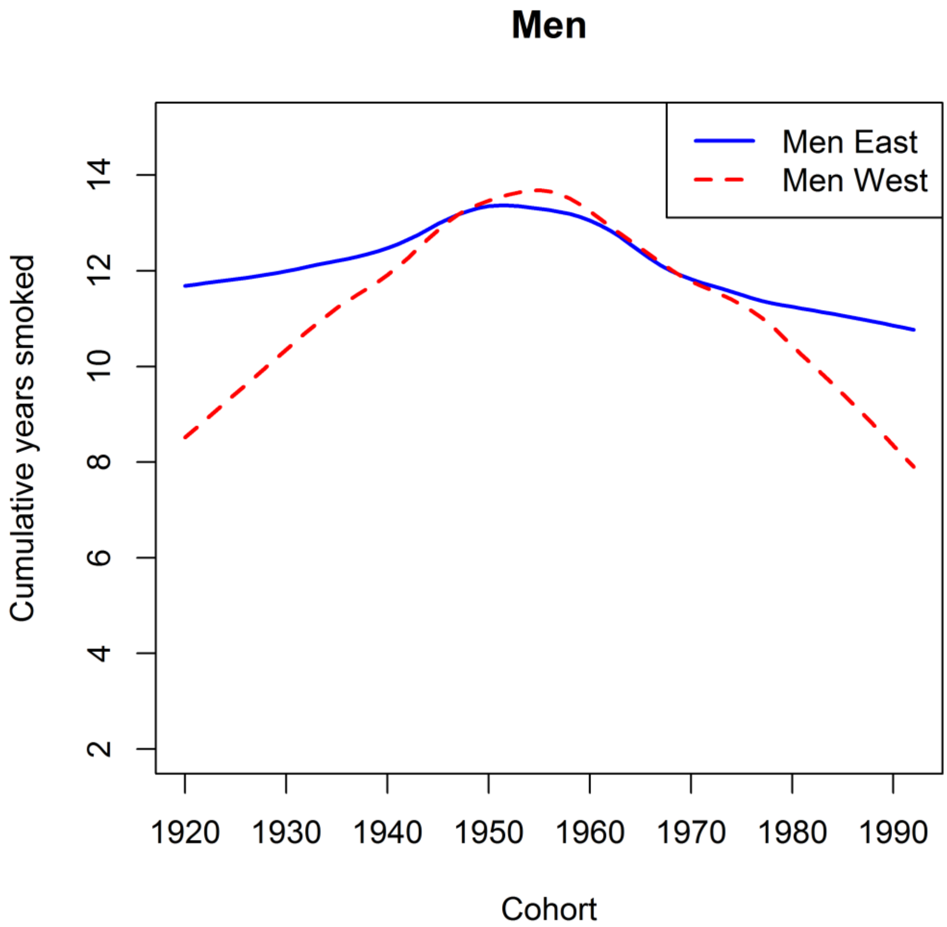


Figure A3: Cumulative years smoked by the age of 40 (smoothed) by birth year, Source: DIW (2015). Note: The last fully observed cohort was born in 1972. We forecast the cumulative smoking years for the younger cohorts based on smoking patterns of older cohorts and the years smoked by each cohort at least by age 20. Therefore, our last cohort that was born in 1992 reached age 20 in 2012.

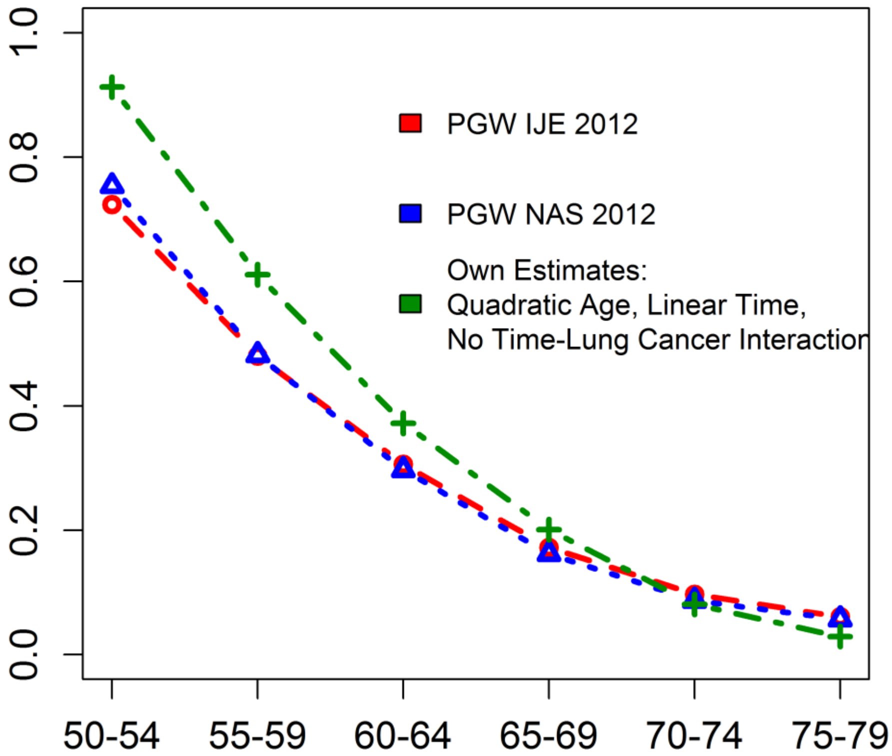


Figure A4. Coefficients that are used to estimate the relationship between lung cancer mortality and mortality from other causes of death. PGW-IJE and PGW-NAS refer to S Preston et al. (2010) and S. H. Preston et al. (2011). We use the coefficients estimated using German data (Own estimates).

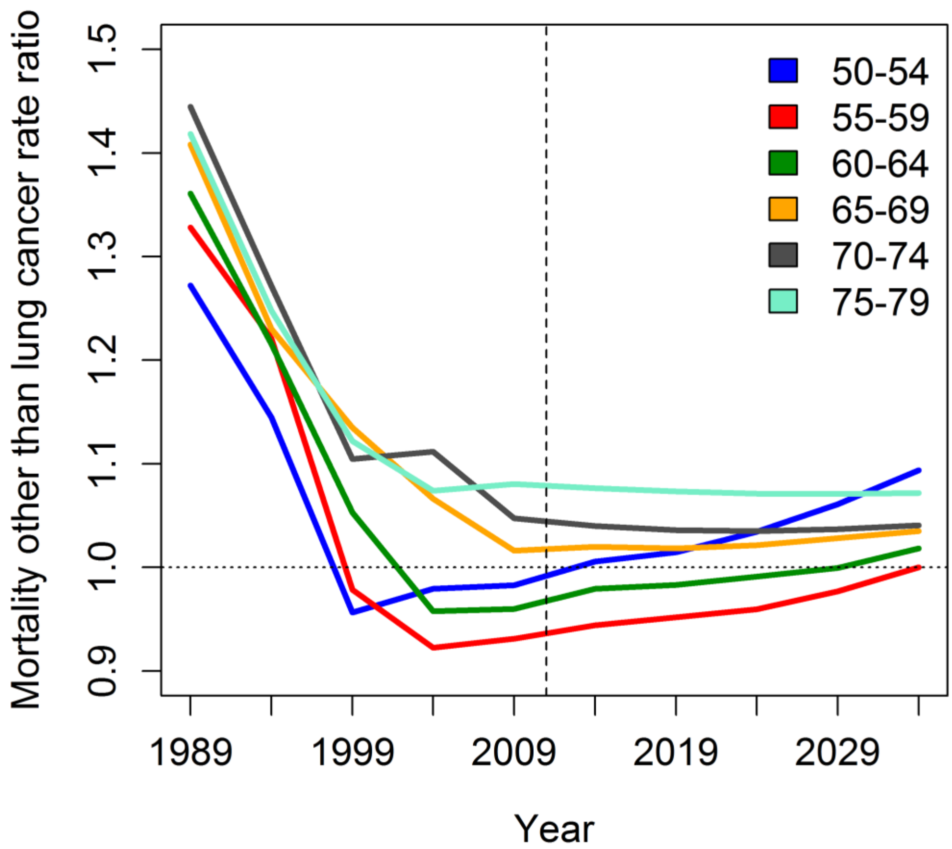


Figure A5: Robustness test: Observed and forecasted mortality difference from causes other than lung cancer between East and West German women. Translation of lung cancer difference to mortality from other causes based on coefficients shown in Figure 4 multiplied by 0.5.

Notes

[i] For the purposes of the present analysis the territory of the former German Democratic Republic (GDR) is referred to as *East Germany*. The area designated as East Germany contains the federal states of Mecklenburg-Western Pomerania, Brandenburg, Saxony-Anhalt, Saxony, Thuringia, and East Berlin.

[ii] Rising differentials (increasingly lower mortality in the East) were observed in Lee-Carter forecasts for East and West German women for ages 50-64, based on observed all-cause mortality (Lee & Miller, 2001; Lee & Carter, 1992). This was observed regardless of whether the fitting period included only the post-reunification period with high rates of mortality improvement in the East or when the fitting period included periods of pre-unification stagnation. Results are not shown but available from the authors.

[iii] Lung cancer was designated as item "Malignant neoplasm of trachea, bronchus, and lung". This item was present in all German Democratic Republic (GDR) classifications of causes of death. For years 1956–1959, however, it did not appear as such in statistical tables. Instead, item 735 "Bösartige Neubildung der Luftröhre, Bronchien und Lunge" is incorporated into a broader category 73 "Bösartige Neubildung der Ohres und des Atmungssystems". Following standard reconstruction procedures (Meslé & Vallin, 1996) it was possible to estimate death counts for these earlier years on the basis of the composition of group 73 observed in 1960. Item 735 dominated group 73, accounting for 92 and 79 per cent of all deaths for males and females, respectively. Year 1979 was a particular one. This was the first year of the transition to a new cause-of-death classification, the ICD-9 (East). However, mortality data for 1979 were available for 35 items only. Fortunately, item "Malignant neoplasm of larynx, trachea, bronchus, and lung" which combines item 161 "Malignant neoplasm of larynx" and 162 "Malignant neoplasm of trachea, bronchus, and lung" was among them. A correction factor was applied to remove larynx cancer from the 1979 data as described in the text.

[iv] Two adjustments needed to be made to the GBE-Bund data. First, the original data combined ICD categories "Malignant neoplasm of larynx, trachea, bronchus and lung" for years 1991-1997. This was also the case for the East German series in 1979. Using WHO data, we averaged the proportion of larynx cancer death counts in a combined lung and larynx cancer category by age, across the years where this was available (1973-1990 except 1979 in the East, 1956-1990 in the West). Making the assumption that this proportion was stable over time (no discernable time trend was noticed), we applied these age-specific proportions (East and West separate) to the GBE-Bund data to subtract the larynx cancer death counts. Second, data from 1998 onward do not contain separate estimates for East and West Berlin. To split lung cancer death counts in Berlin, we assumed that the lung cancer proportions in East and West Berlin were similar to the all-cause mortality proportions in East and West Berlin. The latter was calculated by taking the difference between East and West German death counts estimated in the HMD and East and West GBE-Bund death counts which did not include Berlin. This assumption poses greater concern for bias in the East, since East Berlin makes up a larger percent of the Eastern German population than West Berlin does of western Germany.

[v] Given the different data sources for the numerator and denominator, we multiplied lung cancer death counts with the ratio of all-cause mortality deaths from the numerator data source to the HMD death counts for each age and period. In most cases the ratio was 1.0.