

BMJ Open Quantifying the contribution of smoking to regional mortality disparities in Germany: a cross-sectional study

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ABSTRACT

Objectives Substantial regional variation in smoking behaviour in Germany has been well documented. However, little is known about how these regional differences in smoking affect regional mortality disparities. We aim to assess the contribution of smoking to regional mortality differentials in Germany over the last four decades.

Design A cross-sectional study using official cause-specific mortality data by German Federal State aggregated into five macro-regions: East, North, South, West-I and West-II.

Participants The entire population of Germany stratified by sex, age and region during 1980–2019.

Main outcome measures Smoking-attributable fraction estimated using the Preston-Glei-Wilmoth method; life expectancy at birth before and after the elimination of smoking-attributable deaths.

Results In all macro-regions, the burden of past smoking has been declining among men but growing rapidly among women. The hypothetical removal of smoking-attributable deaths would eliminate roughly half of the contemporary advantage in life expectancy of the vanguard region South over the other macro-regions, apart from the East. In the latter, smoking only explains around a quarter (0.5 years) of the 2-year difference in male life expectancy compared with the South observed in 2019. Among women, eliminating smoking-attributable deaths would put the East in a more disadvantageous position compared with the South as well as the other macro-regions.

Conclusion While regional differences in smoking histories explain large parts of the regional disparities in male mortality, they are playing an increasingly important role for female mortality trends and differentials. Health policies aiming at reducing regional inequalities should account for regional differences in past smoking behaviour.

INTRODUCTION

Smoking is among the leading determinants of international differences in mortality,^{1–3} the gender gap in mortality^{4–6} and mortality differences between socioeconomic groups.^{7–8} However, only a few high-quality studies explore the impact of smoking on regional differences in mortality,^{9–11} partly because of the limited availability of regional long-term series of mortality by cause of death. This kind of data, specifically mortality

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ The analyses rely on high-quality, cause-specific, regional mortality data as well as harmonised data on population counts.
- ⇒ The study employs the Preston-Glei-Wilmoth (PGW) method, which is a solid and widely used indirect approach for estimating smoking-attributable fractions on the basis of lung cancer mortality.
- ⇒ The main limitation of the PGW method is its implicit assumption that time lags between smoking and mortality are the same for all smoking-related causes of death.

from lung cancer, is widely used to estimate smoking-attributable mortality at the national level.^{2 12}

Germany provides us with an interesting case to study the effect of smoking on regional mortality differences. First, there is substantial regional variation in both smoking behaviour^{13 14} and mortality patterns.¹⁵ The current smoking prevalence tends to be higher in the North than in the South, and higher in the East than in the West,¹⁶ mirroring known mortality disparities.

Second, as women experienced the onset and peak of the smoking epidemic later than men,¹⁷ one might expect the regional pattern of the smoking epidemic among women to mirror the male regional pattern, with a delay. However, peak smoking initiation among German men occurred before 1945 when the country was still unified. When the smoking epidemic spread to women, Germany was a divided country with the two parts varying in terms of smoking-relevant public policies. This variation in policies might have affected the degree to which the regional variation pattern of the smoking epidemic among women paralleled the one among men.

Until now, an assessment of the degree to which the regional variation in smoking behaviour is contributing to regional mortality disparities in Germany, and how this has changed over time, was lacking. This



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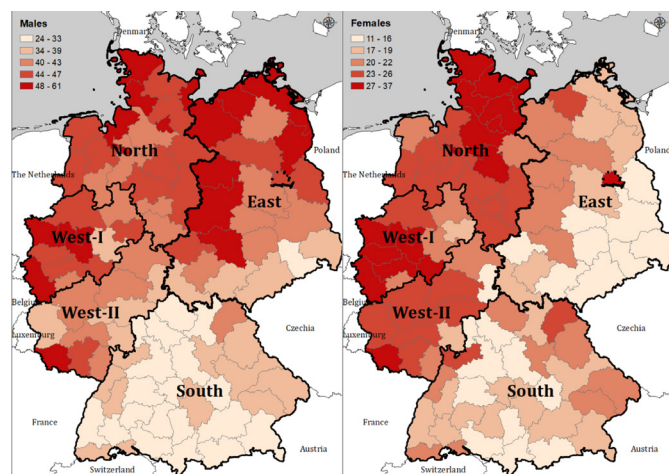


Figure 1 German macro-regions and the spatial distribution of mortality from lung cancer in 2019. Source: own calculations based on the official data on causes of death and population counts. Standardised death rates per 100 000 based on the European Standard Population (ESP) -1976.

paper aims to fill this gap by assessing the contribution of smoking to regional mortality differentials in Germany.

METHODS

Our analysis is based on official mortality data by German federal states for the period 1980–2019. Those data include death counts by single year of age (all causes combined) as well as death counts by 5-year age groups tabulated in accordance to three-digit codes of the International Classification of Diseases (ICD-9 and ICD-10). To estimate mortality rates, we rely on official data on population counts for the periods 1979–1986 and 2012–2019. For the period 1987–2011, we use data on age/sex-stratified population counts adjusted to the results of the 2011 Census.¹⁸ The adjusted counts were used because the 2011 Census revealed that official counts were overestimated by 1.5 million residents.

The German Federal States are grouped into five macro-regions: North, West-I, West-II, South and East (figure 1). This division captures the long-standing macro-regional differences in social and economic development as well as in mortality.¹⁹ The North group consists of Schleswig-Holstein, Hamburg, Lower Saxony and Bremen. West-I is formed by the most populated German State of North Rhine-Westphalia. West-II includes Hesse, Rhineland-Palatinate and Saarland. The federal states Baden-Württemberg and Bavaria constitute the South group, while the territories of the former GDR (German Democratic Republic) (Brandenburg, Mecklenburg-Western Pomerania, Saxony, Saxony-Anhalt and Thuringia) form the East group. Our analysis does not cover the city-state of Berlin because the city of Berlin was divided into an eastern and a western part between 1945 and 1990. As these parts experienced distinct mortality patterns prior to and even after German reunification, the inclusion of the whole of Berlin into East would be inappropriate,

at least for the period before 1990. It is also infeasible to create a separated time series for the former divided parts of Berlin, as since 2001, mortality statistics no longer distinguish between these parts.

For each macro-region, we produce the complete set of Human Mortality Database (HMD) statistics according to version 5 of the HMD methodology.²⁰ These statistics include complete life tables and population counts for ages up to 110+ years.

We estimate smoking-attributable mortality using the Preston-Glei-Wilmoth (PGW) method.² Like another widely used method,¹² the PGW method relies on mortality from lung cancer (items C33–C34 and 162 in the ICD-10 and the ICD-9, respectively) as the proxy of past smoking behaviour. Specifically, the PGW method estimates the statistical association between lung cancer and other causes of death across 20 high-income countries over 56 years to predict the excess number of deaths attributable to smoking from any cause of death. To quantify the effect of smoking on regional mortality differences, we first removed the estimated age-specific smoking-attributable deaths from the respective number of deaths from all causes. Afterwards, we reproduce all life tables and compare the values of life expectancy at birth before and after the elimination of smoking-attributable deaths.

Patient and public involvement

No patient involved.

RESULTS

We begin with an overview of mortality trends from lung cancer by sex for our five macro-regions (the trends in overall mortality are provided in the online supplemental figure 1).

The burden of past smoking on mortality has been declining among men and growing among women. This reflects a typical pattern observed in many countries around the world.¹⁷ While the all-cause mortality pattern for men is still dominated by an East–West divide, figure 2 shows that a clear North–South divide is also apparent for lung cancer mortality (see also figure 1). Compared with the other four regions, South has considerably lower lung cancer mortality. Among women, the rising mortality from lung cancer has been accompanied by rapidly growing regional divergence, with West-I exhibiting the highest and East the lowest lung cancer mortality. For the four regions in Western Germany, we observe the same regional ranking for men and women. West-I displays the highest level, followed by North and West-II. South experienced much lower levels than the other three regions throughout the observation period. East is the only region where we see a different regional ranking for men and women. While Eastern German men experienced a trajectory very similar to the regions West-II and North in Western Germany, Eastern German women experienced even lower lung cancer mortality levels than the South region in Western Germany.

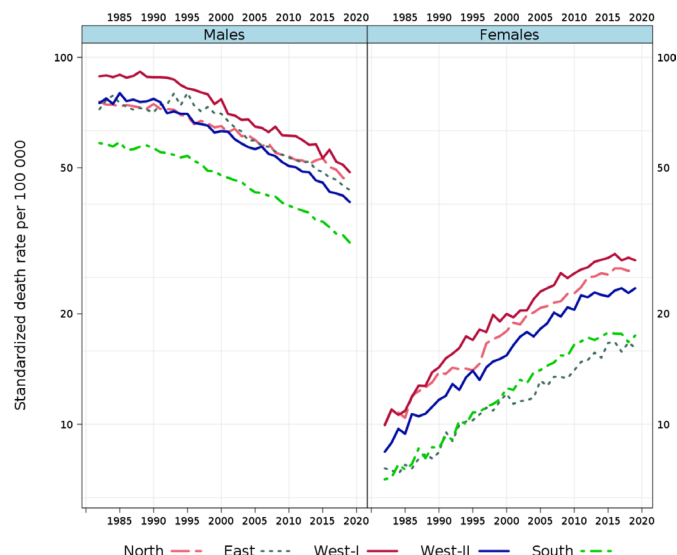


Figure 2 Mortality from lung cancer by five macro-regions of Germany, 1982–2019. Source: same as in figure 1.

Table 1 summarises the information on population attributable fractions due to smoking.

In 1982, for example, 26% of deaths among men at ages 50 years and above living in West-I were due to smoking. By 2019, this fraction decreased to 17%. In the early 1980s, smoking was responsible for a tiny fraction of female deaths (1%–2%). Now, it is substantial, especially in North and West-I at around 11%–12%, which corresponds to the level among men living in the South.

Figure 3 shows the impact of smoking on the life expectancy gap between the various regions to the highest-performing South region for men and women (the effects of the hypothetical removal of smoking-attributable deaths on life expectancy at birth in each macro-region are provided in the online supplemental table 1).

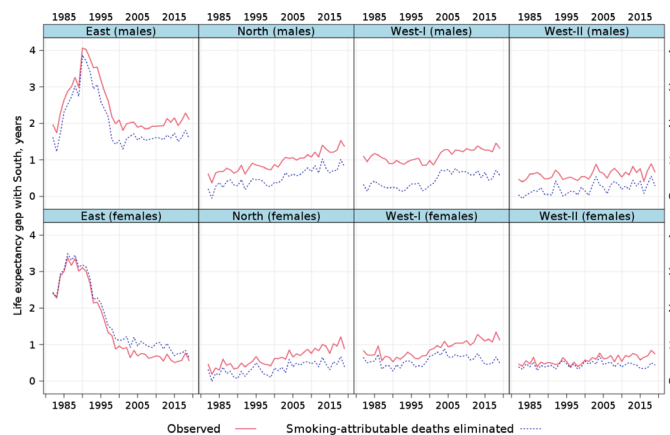


Figure 3 Deviation in life expectancy at birth from the best-performing region (South) before and after removal of smoking-attributable deaths, 1982–2019. Source: own calculations based on the official data on causes of death, all-cause death counts, life births and population counts.

Among women, smoking has become an increasingly important factor explaining regional life expectancy differences over the last four decades. In 1982, the life expectancy gap with the best-performing region (South) varied from 0.46 (North and West-II) to 2.41 (East) years. The hypothetical elimination of smoking-attributable deaths in all regions resulted only in marginal reductions in this gap. By contrast, in 2019, roughly half of the regional gap was determined by harm from smoking. The East is an exception, where the adjustment for smoking-attributable mortality did not have a notable impact on the difference with South until the late 1990s but resulted in the increase of the East disadvantage in more recent years.

Among men, smoking has remained a prominent and stable determinant of regional mortality differentials

Table 1 Smoking-attributable fraction by macro-regions of Germany; ages 50 years and above, 1982–2019

	1982	1990	1995	2000	2005	2010	2015	2019
Males								
North	0.23	0.22	0.22	0.21	0.20	0.18	0.18	0.16
West-I	0.26	0.27	0.26	0.25	0.22	0.22	0.19	0.17
West-II	0.22	0.23	0.22	0.20	0.19	0.18	0.15	0.14
South	0.18	0.17	0.17	0.15	0.14	0.14	0.12	0.11
East	0.18	0.19	0.24	0.23	0.20	0.19	0.17	0.15
Germany	0.21	0.21	0.22	0.21	0.19	0.18	0.16	0.14
Females								
North	0.02	0.04	0.04	0.06	0.07	0.08	0.09	0.11
West-I	0.01	0.04	0.06	0.08	0.10	0.11	0.12	0.12
West-II	0.01	0.03	0.03	0.04	0.06	0.07	0.08	0.09
South	0.01	0.01	0.02	0.03	0.03	0.05	0.06	0.07
East	0.01	0.01	0.02	0.04	0.04	0.05	0.06	0.06
Germany	0.01	0.03	0.04	0.05	0.06	0.07	0.08	0.09

Source: own calculations based on the official data on causes of death, all-cause death counts, life births and population counts.

throughout the analysed period. Despite rapidly declining smoking-attributable mortality everywhere, past differences in smoking still explain a large proportion of the regional gap in male mortality. As online supplemental table 1 infers, the hypothetical removal of deaths attributable to smoking would eliminate more than half of the contemporary all-cause mortality advantage of the South over West-I and West-II. Smoking-attributable deaths are responsible for just under half (0.56 years) of the South–North difference in life expectancy observed in 2019 (1.37 years). Again, compared with the other macro-regions, the East exhibits a different pattern. The removal of smoking mortality would result in the reduction of the East–West mortality gap from 2.11 to 1.58 years, which suggests that smoking explains just around a quarter of the existing difference.

DISCUSSION

Main findings

There is a general tendency to explain the existing regional differentials in Germany by the role of contemporary factors, notably by differences in socioeconomic conditions.^{21 22} Contrary to this traditional view, the present analysis highlights the prominent role of past smoking behaviour.

We have shown that the burden of past smoking behaviour on mortality has been declining among men but growing steadily among women in all German macro-regions. The observed patterns are typical for the last stage of the four-stage smoking epidemic model.^{17 23} Briefly, during the third stage of the smoking epidemic, male smoking prevalence declines rapidly whereas the percentage of female smokers approaches its peak and remains at a plateau. Because of lags between smoking initiation and mortality, there is a rapid increase in smoking-attributable mortality among men and a very slow one among women over this stage. During the fourth and final stage, smoking prevalence declines for both sexes. After reaching its peak, male smoking-attributable mortality decreases steadily while it increases for women. The model assumes a three-decade to four-decade lag between the peak of smoking prevalence and the subsequent peak in smoking-related mortality. This implies that a decline in smoking prevalence can still be accompanied by rising smoking-attributable mortality. Our results suggest that German men have surpassed the last stage of the transition. Women are likely to be situated somewhere in the middle of the fourth stage. In other words, they have not yet approached the peak of the smoking epidemic in terms of its mortality effects, although they have already reached peak smoking prevalence.²⁴ Thus, in the coming years, past smoking is expected to be an increasingly important factor driving female mortality trends in Germany.

Despite the overall declining mortality burden from smoking among men, differences in smoking histories continue to drive regional mortality differences. The

hypothetical removal of deaths attributable to smoking would eliminate a large part of the Southern German mortality advantage over the other macro-regions, apart from Eastern Germany. For the latter, smoking explains only about a quarter of the 2-year difference in male life expectancy at birth between the East and the South observed in 2019, according to our estimates. That Eastern Germany stands out is strongly related to its communist past and the post-communist transition process with decades of high unemployment rates that resulted in increases in stress-related illnesses and deaths.²² As a result of the abrupt socioeconomic transition triggered by German reunification, East German men experienced a notable short-term increase in mortality. This increase was particularly reflected in mortality rises from socially sensitive causes such as accidents, alcohol-related diseases and acute myocardial infarction.²⁵ Our results suggest that past smoking behaviour does not explain the persistent health disadvantage of Eastern men that has been observed during the last two decades. It has been suggested that in addition to the differences in socioeconomic conditions, a substantially higher proportion of men with severe health problems in the East could explain the disadvantageous position of the East.²⁶

Among women, the elimination of smoking-attributable deaths within Western German regions would halve the current life expectancy gap with the vanguard region South. The elimination of smoking-attributable deaths had little effect on the gap between the regions East and South until the late 1990s. Afterwards, adjusting for smoking put the East in an even more disadvantageous position compared with the other macro-regions of Germany. This is explained by the fact that Eastern German women experienced the smoking epidemic later. However, there was a tremendous increase in smoking uptake after reunification.²⁷ Thus, their current survival advantage at ages below 70 years, compared with Western Germany as a whole, is expected to turn soon into a disadvantage.¹³

Previous studies highlighted the importance of a cohort perspective for understanding the evolution of the smoking epidemic.^{28 29} The age aggregation of lung cancer mortality hindered our ability to make out clear cohort trends. However, we find cohort patterns for all-cause mortality, for which we have data by single year of age, for each macro-region (online supplemental appendix figures 1 and 3). Among women, slow rates of mortality improvements and more recently, mortality increases among 1940–1950 birth cohorts, are consistent with cohort patterns of smoking prevalence.²⁷ The cohort pattern of mortality increases for the women aged between 60 and 75 years at the end of the analysed period is particularly pronounced in West-I, the region exhibiting the highest lung cancer mortality. Cohort all-cause mortality patterns among men are not as clearly differentiable.

Like elsewhere, smoking initiation was socially patterned in Germany. The highly educated women born between

1920 and 1930 were the first to smoke in Germany. At the second stage, less-educated women were catching up with their higher-educated counterparts.²⁷ This transition is reflected by a sharp increase in smoking prevalence: from 25% of women born between 1930 and 1934 to 40% born between 1950 and 1959, to 50% born between 1945 and 1954, and finally hitting about 60% for cohorts born between 1955 and 1964.³⁰ Although smoking prevalence is higher in the more recent cohorts, these cohorts have yet to reach ages when smoking-attributable mortality peaks. A similar social patterning of smoking uptake was also likely for men; however, we do not have a long enough time series of mortality or survey data to observe the early stages.

The results of this study provide valuable context on the diffusion of smoking behaviour between the sexes. Generally, the rise and fall in female smoking uptake and in smoking-attributable mortality lagged behind that of men by 20–30 years in countries that adopted smoking earliest.²³ Our findings for Western German regions indicate that the intensity of the smoking epidemic among men had an effect on the intensity at which women caught up once the smoking epidemic started to spread among them. This fits with findings that the social context has a strong impact on the likelihood that a person starts to smoke.³¹

However, Eastern Germany is an outlier in this regard. Based on the intensity of the smoking epidemic among Eastern men, one would have expected a much earlier smoking epidemic among Eastern women. That this did not occur suggests that different social norms were protective in deterring smoking uptake among Eastern German women. In West Germany, the uptake of smoking among women could be connected with the social upheavals of the 68-movement.³² At that time, many West German women perceived smoking uptake as a signal that they strive for higher gender equality. By contrast, East German women did not experience such large social upheavals in the late 1960s. Across the socialist East, smoking among women was considered inappropriate. In addition, East German women were strongly integrated in the labour market, and as a result, less disadvantaged in their social and economic standing in society compared with West German women, who were fighting for their right to work as a route to self-fulfilment.³³ Thus, there were fewer incentives to use smoking as a signal to strive for gender equality. Moreover, it was common to have first births at a comparatively young age in East Germany, and the risks of smoking during pregnancy were already well known at the time.³⁴ At the same time, later marriage and childbearing in West Germany gave women there more time to forge individualistic identities and habituate to smoking.

Additional reasons behind different regional cohort smoking patterns are more speculative. We can largely rule out regional variation in smoking-related policies as a viable explanation. Although the German federal states have some degree of autonomy in terms of implementing tobacco control, such policies operate at the national

level. The only exception could be East–West differences. Unlike in the Federal Republic of Germany, in the former GDR, smoking advertisement was strictly prohibited until 1990.³⁵ Despite this, there were no East–West differences in smoking prevalence among men,²⁷ which could be due to the fact that peak smoking initiation occurred in the early 20th century, in the formerly united country. That was not the case for women whose peak smoking initiation occurred already after separation. This could explain why Eastern Germany is a clear outlier with still comparatively low female smoking-attributable mortality. However, since tobacco control policy remained relatively weak in both sides, we would argue that East–West variation in social conditions was a more important driver of differences in smoking initiation among women than East–West differences in smoking control policies.

The differences in the regional population composition could further explain some of the observed regional differences in smoking prevalence and smoking-attributable mortality in Germany. It is well known that smoking relates closely to socioeconomic status (SES) differences in health behaviours.³⁶ With the progress of the smoking epidemic to its most advanced stage, unhealthy behavioural patterns are concentrated in low SES population groups.³⁷ Therefore, one could assume that the German regions with higher shares of individuals having low SES also exhibit higher mortality rates attributable to smoking. The ecological analysis (district level) of the association between mortality from selected cancers and the German Index of Socioeconomic Deprivation (GISD, see Kroll *et al.*³⁸ for more details) revealed an association between the GISD and lung cancer mortality, but only among men. That is, the least deprived areas (Southern Germany) had the lowest male lung cancer mortality whereas the most deprived areas had highest mortality.³⁹

A potential fruitful avenue for future research would be to study smoking-attributable mortality in a broader, European perspective by analysing both the time trends and spatial patterns across a large number of countries. Several studies have provided evidence of the North–South gradient in smoking-attributable mortality at the national level, with the Northern European countries being ahead of the Southern European countries.⁴ This pattern is consistent with our finding of a North–South gradient within Germany, as well as with a study of smoking-attributable mortality across the 16 German Federal States.⁴⁰ In this regard, it is also relevant to note that the northern part of Western Germany, which was hit strongest by the smoking epidemic, borders with two countries that were also severely hit by this epidemic: the Netherlands and Denmark.²⁸ Thus, the German regional differences in smoking patterns could form part of a larger-scale pattern that stretches across national borders. Studying this with a pan-European perspective might further improve our understanding of the determinants and drivers of the smoking epidemic including aspects of spatial diffusion.

STUDY LIMITATIONS

PGW method

We used an indirect approach (the PGW method) to estimate smoking-attributable mortality via lung cancer mortality. Germany was not among the countries used to generate the regression coefficients linking lung cancer and all-cause mortality, due to the data availability constraints. The inclusion of Germany in the model would be only possible after the 1990 reunification. However, there are no reasons to think that the link between lung cancer and all-cause mortality should differ from the other 20 industrialised countries used in the model. The link between cohort smoking histories and lung cancer has also been shown to be remarkably similar in Eastern and Western Germany compared with the USA.¹³

During the transition period, Eastern Germany experienced mortality fluctuation, including a changing cause-of-death composition, which was followed by a rapid mortality decline in the 1990s.⁴¹ These changes question the appropriateness of using the PGW regression coefficients linking lung cancer and all-cause mortality in the Eastern German population. As a robustness check, we replaced the PGW regression coefficients by those estimated (for women only) in Eastern and Western Germany over the 1991–2003 period by Vogt *et al.*¹³ The Vogt *et al* model avoided the transitional mortality fluctuation but captured the sharp Eastern German mortality decline. Both levels and regional differentials in smoking-attributable fractions were largely unaffected by this change. This is presumably because trends in lung cancer mortality were comparatively stable (figure 2), and smoking-attributable mortality is more highly concentrated at older ages where the PGW and Vogt *et al* regression coefficients were similar.

The proportion of lung cancer cases attributable to smoking may differ by sex and period.⁴² This could question the validity of lung cancer as a proxy for female smoking behaviour. However, Vogt *et al* showed that PGW-style cohort smoking coefficients aligned remarkably well with cohort smoking histories for women from survey data, in both Eastern and Western Germany. Thus, we assume that any bias introduced from this method would have a larger impact on the levels compared with the age cohort trends and regional differentials.

A larger concern of the PGW method is that it implicitly assumes that lags between smoking and mortality are the same for all smoking-related causes of death. However, it is known that smokers experience a younger excess mortality from cardiovascular diseases compared with lung diseases.¹⁷ Nevertheless, it is reassuring that studies which have incorporated cause-specific lag structures into a Peto-Lopez methodology found estimates of smoking-attributable mortality that differed by less than 2% from those who did not.⁴³

Overall, there is a trade-off between these biases from indirect approaches, and the well-known biases from direct approaches which measure smoking-attributable mortality from survey data, which include survival biases,

improper adjustments for confounding, and imperfect self-reported data on the intensity and history of smoking uptake and cessation.² Indirect approaches are also less demanding in terms of data requirements, and statistically powered survey data for regional analyses are rarely available. Despite these differences, it is remarkable how similar recent estimates of smoking-attributable deaths in the USA have been using direct and indirect approaches.⁴⁴

Comparability of mortality data for East Germany prior to reunification

For the reasons explained in the Methods section, we did not include Berlin in our analysis. In the context of the present analysis, it would be inappropriate to include the whole city in the East also because more than 60% of the total population of Berlin constituted West Berlin. On the other hand, the hypothetical inclusion of East Berlin into East Germany would be possible only until 2001. Historical mortality data available to us for the period 1990–1997 suggest that male mortality from lung cancer was comparable between East Berlin and East Germany, whereas corresponding female mortality was considerably higher in East Berlin. Nevertheless, this difference would only result in a marginal increase in mortality rates in East Germany because East Berlin accounted only about 8% of the total population and about 6% of the total number of deaths of East Germany.

Another factor which could affect the comparability of mortality trends of the East with the other macro-regions is the difference in coding practices, which existed prior to German reunification. Generally, compared with many other cancer localisations, reporting lung cancer has been considered to be highly reliable. Nevertheless, there is evidence of systematic under-reporting of cancer mortality including lung cancer in the former GDR.²⁵ This implies that our estimates of the smoking-attributable fraction, and consequently the impact of past smoking behaviour on life expectancy in East Germany during the period before 1990 should be treated with caution.

CONCLUSION

The North–South gradient in smoking histories and its effect on lung cancer mortality are the main determinant of current male regional mortality disparities in Germany, despite the number of smoking-attributable deaths declining overall. Among women, smoking has become a key determinant of regional differences in recent decades, and its relevance can be expected to further gain importance in the decades to come. While our outcomes are very consistent for explaining differences across our four Western German regions, the region East constitutes an exception both among men and women. This exceptional role seems to be related to the divided past of Germany, though the factors that contributed to the exceptional position of the East seem to vary for men and women. Future research based on more detailed data

might make use of this quasi-natural experiment to get a better understanding of causal mechanisms at play.

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