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Research Article

Lung cancer mortality in historical context: How stable are spatial patterns of smoking over time?

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Lung cancer mortality in historical context: How stable are spatial patterns of smoking over time?

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Abstract

BACKGROUND
The lands of the Recovered Territories were acquired by Poland in 1945 and populated by almost 5 million Polish settlers mostly from central provinces in the country and from ex-Polish territories in the east. Transgenerational persistence of informal institutions provides a context for the study.

OBJECTIVE
Persistence of the spatial variation of age-adjusted lung cancer mortality and their causes were evaluated. The high smoking prevalence in the Recovered Territories was hypothesised to be related to the age of the local communities and persistence of informal institutions.

METHODS
A spatial scan statistic was used to detect clusters of elevated lung cancer mortality. A two stages least squares regression model with heteroscedasticity and autocorrelation consistent standard errors was fitted to identify determinants of a spatial clustering of lung cancer mortality.

RESULTS
A strong west-to-east trend of lung cancer mortality is consistent with spatial patterns of tobacco use in interwar, post-war, and current Poland. Age-adjusted lung cancer mortality was contrastingly high in 1980–1984 in Masuria, West Pomerania, and Silesia. Tobacco prevalence and unbalanced dietary patterns were found to be associated with a spatial clustering of lung cancer mortality in the country.

CONCLUSIONS
Migrant communities of the Recovered Territories were more likely to take up and continue smoking. This effect was enhanced by the young age of communities and population, as well as by high urbanisation and availability of employment outside

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agriculture in the Recovered Territories. The identified spatial pattern is consistent with elevated frequency of other socially condemned behaviours in the Recovered Territories, including crime, nonmarital births, and divorce.

CONTRIBUTION
Phantom borders reflecting different historical legacies can structure health-related behaviours. Spatial distribution of lung cancer mortality is persistent over time, particularly in women.

1. Introduction

In 2014, 23,200 new deaths due to lung cancer were registered in Poland, which is nearly twice as many as in 1980. The purpose of this paper is to illustrate and better understand spatial distribution of mortality due to lung cancer, which is the leading cancer cause of death in Poland and a cancer with the strongest spatial autocorrelation of mortality in the country. Determinants of spatial variation in lung cancer mortality and its historical context are examined as well.

Previous studies have documented the persistence of informal institutions, such as cultural traits and preference parameters, transmitted from generation to generation (Bisin and Verdier 2000). They were referred to as "rootedness" by Jasiewicz (2009). In this article, spatial patterns in smoking and lung cancer mortality are discussed and compared between regions defined by history. Poland regained their national independence in 1918 after 123 years of partition by Prussia, Russia, and Austria. Only in 1945 Poland acquired territories which for centuries had been under German domination and were called in the post-war Poland the Recovered Territories or now more frequently the Western Territories, which is more ideologically neutral. Since the 18th century, Pomerania and Silesia have spent most of their time within the sphere of German culture.

The lands acquired by Poland in 1945 have been populated by almost 5 million Polish settlers in a process parallel to the flight and expulsion of Germans. In 1950, only 1.2 million of the native population was living in the Recovered Territories. According to the 1950 census, 38% of the native population of the Recovered Territories was living in Opole Province (provinces are known in Poland as 'voivodships'). In 1950, the share of the native population in Opole Province was 54%, while in the entire Recovered Territories this percentage did not exceed 20%. The proportion of the native population was the lowest in Szczecin and Zielona Góra Provinces (3%). Previously, the relationship between regions defined by the Polish history and contemporary voting behaviour was discussed in multiple articles, finding a conservatism–liberalism cleavage between the central parts of the country and the Recovered Territories (Zarycki 2002; Bartkowski 2003; Jasiewicz 2009; Jańczak 2015).

In some European studies, smoking prevalence was found to be higher among migrants (Nierkens, de Vries, and Stronks 2006; Kabir et al. 2008; Urban et al. 2015). However, most of the studies included external migrants from countries of high smoking prevalence. An inverse relationship was seen in the United States: smoking prevalence in the migrant population was found to be lower than both the country of origin and the US levels (Bosdriesz et al. 2013). Westphal (2016) finds the association between smoking and internal migration in Germany inconclusive; nonetheless, the results show that female smokers were less likely to migrate than women who did not smoke. The probability value for the same relationship in male population was near the significance threshold.

In this article, it is discussed whether smoking tends to be more frequent in newly formed communities. Spatial patterns of age-adjusted lung cancer mortality and smoking prevalence in Poland are examined in a historical context. Persistence of spatial clusters of lung cancer mortality between 1980–1984 and 2010–2014 is discussed. Factors associated with spatial variation in lung cancer mortality in 2010–2014 are investigated. Lung cancer mortality patterns are discussed in parallel with spatial variation in smoking, since in populations with prolonged cigarette use, 90% of lung cancer cases are attributable to cigarette smoking (IARC 2004).

2. Material and methods

Kulldorff's spatial scan test was used to detect primary (or most likely) and secondary clusters of elevated age-adjusted lung cancer mortality in 1980–1984 and 2010–2014 (Kulldorff and Nagarwalla 1995). The null hypothesis of Kulldorff's test is no clustering occurred, i.e., the number of deaths is an inhomogeneous Poisson process with its average proportional to the size of the population at risk in the location. Since the distribution of the test statistic is not determined, a Monte Carlo simulation was used to perform the hypothesis test ($N_{rep} = 9{,}999$ replicates). Under the alternative hypothesis, it is assumed the number of deaths within the window Z exceeds that which is expected. The size of the window is allowed to vary and in the current study the predefined size of the window was limited to 10% of the population at risk. The upper limit of 10% was also applied in some previous investigations (Norström, Pfeiffer, and Jarp 2000; Sheehan et al. 2000). The window size is much higher than the value corresponding to the most populous county in the study area. The primary cluster Z^* is the window which attains the maximum likelihood value:

$$\lambda = sup_Z \left(\frac{n(Z)}{e(Z)}\right)^{n(Z)} \left(\frac{n-n(Z)}{n-e(Z)}\right)^{n-n(Z)} I\left(\frac{n(Z)}{e(Z)} > \frac{n-n(Z)}{n-e(Z)}\right), \tag{1}$$

where Z indicates a selected elliptic scanning window, $n(Z)$ and $e(Z)$ are the observed and the expected numbers of deaths within the window, and I is the indicator function. Secondary clusters have a significantly large likelihood ratio (here $\alpha = 0.001$) but less than the primary one. Both primary and secondary clusters are not allowed to overlap. The rank of the likelihood ratio among all randomisation tests determines the P-value.

In the second part of the analysis, factors associated with spatial variation in lung cancer mortality are analysed based on consumption data collected in a countrywide survey in 2001–2007 (Target Group Index). A semirandom sampling approach was employed for the sample selection: quota-sampling with age, gender, and place of residence quota controls. A total number of 251,700 participants of the survey (122,600 men and 129,100 women), who were 15–75 years old, constituted a sample of the population of the entire Poland (divided into 380 counties). A mixed-mode design was used, where respondents were approached by paper-based personal interviewing, computer-assisted personal interviewing, and computer-assisted web interviewing. A different group of individuals was sampled each month. Consumption behaviour during the previous three months was reported by individuals.

Several forms of the tobacco smoking variable, which is crucial in the current study, were constructed and tested, including intensity of smoking (heavy, medium, and light smoking and nonsmoking) and smoking status (daily smoking versus nonsmoking). The food records from this survey were also used to calculate monthly intakes of protein, carbohydrates, and sucrose based on Poland's food composition tables (Kunachowicz et al. 2012). Based on information criteria, the latter (binary) form of the covariate was chosen. In addition to survey data, information on emission of particulate matter into the atmosphere per sq. km (2001–2007) and socioeconomic controls such as number of health outpatient departments per 10,000 population (2001–2007), average gross wages and salaries (2002–2007), and the rate of unemployment registered at labour offices (2004–2007) was derived from the local data bank of the Poland's Central Statistical Office. All data was aggregated to produce county (LAU 1) estimates.

Highly spatially autocorrelated data of lung cancer mortality in Poland (demonstrated by global Moran's index $I = 0.543$ in the male population and $I = 0.657$ in the female population) violates the independence assumption required for most statistical tests and regression techniques. To deal with the spatial autocorrelation in the data, the spatial regression model was estimated. The spatial lag model takes into account the spatial dependence of the explained variable (Anselin 1988):

$$y = \rho \boldsymbol{W} y + \boldsymbol{X} \beta + \varepsilon, \quad |\rho| < 1, \tag{2}$$

where y is a vector of dependent variable (here: age-adjusted lung cancer mortality rate), ρ is the autoregressive parameter determining the importance of spatial lag, $\boldsymbol{W}$ is a spatial weights matrix, $\boldsymbol{X}$ is an observation matrix, β is a parameter vector related to $\boldsymbol{X}$, and ε is a stochastic error term vector. Matrix $\boldsymbol{X} = [1 \;\; x_{*,1} \;\; x_{*,2} \;\; x_{*,3}]$ of the epidemiological model discussed in the next section includes variables of $x_{*,1}$, the proportion of daily smokers; $x_{*,2}$, the average monthly fish consumption per capita; and $x_{*,3}$, the average monthly sucrose intake per capita.

Spatial units differ in important characteristics, including population size, which for Polish counties varies from 1,754,000 in the city of Warsaw to 20,000 in Sejny County. Heteroscedasticity was confirmed with the Breusch–Pagan test ($P < 0.001$). This problem was solved by using a spatial version of the nonparametric heteroscedasticity-autocorrelation consistent (HAC) estimator (Kelejian and Prucha 2007). The error vector in this estimation is assumed to be generated by the following process:

$$\varepsilon = \boldsymbol{R}\xi, \tag{3}$$

where ξ is a vector of innovations and $\boldsymbol{R}$ is a nonsingular and nonstochastic matrix, which is not assumed to be known and is not parametrised. A spatial HAC estimator assumes that each observation is a realisation of a random stationary process (Conley 1999). This nonparametric estimator is robust against heteroscedasticity and spatial autocorrelation. Since the HAC estimator has been rarely used so far, estimates for a classical spatial lag model fitted using maximum likelihood are reported for reference in Table 1.

A two stages least squares model with heteroscedasticity and autocorrelation consistent standard errors was estimated using *SpHet* R package. The *SpatialEpi* R package was used to identify clusters of elevated lung cancer mortality. Age-adjusted cancer mortality rates were presented in choropleth maps. Intervals in legends were selected based on the Jenks natural breaks classification method. The location of historic borders of Poland was defined based on delimitation by the Institute of Geography and Spatial Organisation of the Polish Academy of Sciences (Bański 2016). Lung cancer mortality data for 1980–1984 and 2010–2014 comes from the Polish National Cancer Registry which processes information from death certificates collected by Poland’s Central Statistical Office (ICD-10: C33–C34, ICD-9: 162). Age-adjustment of death rates was achieved by direct standardisation and is based on the 1980–1984 and 2010–2014 total resident population using 5-year age groups.

3. Results

3.1 Spatial patterns of smoking and age-adjusted lung cancer mortality

A west-to-east pattern of lung cancer mortality in 1980–1984 was similar in men and women (Figure 1). In 1980–1984, age-adjusted lung cancer mortality was higher in urban than rural areas in both genders. In 2010–2014, the gender gap in age-adjusted lung cancer mortality was low in urban areas, which is particularly noticeable in city-counties, being the largest urban centres in their respective regions. In 2010–2014, age-adjusted lung cancer mortality in men was lower in urban areas and in women it was higher in urban areas than in rural ones.

Figure 1: Lung cancer age-adjusted mortality per 100,000 population in Poland in 1980–1984

a) Men

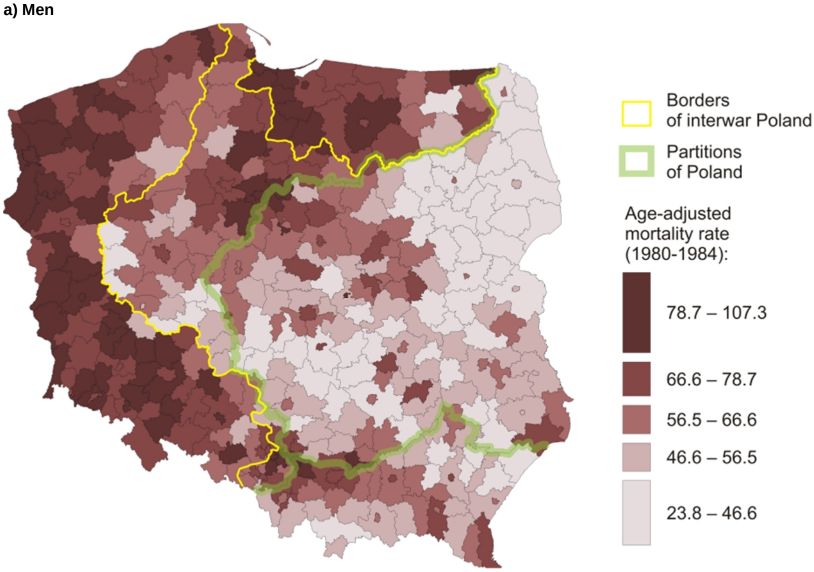
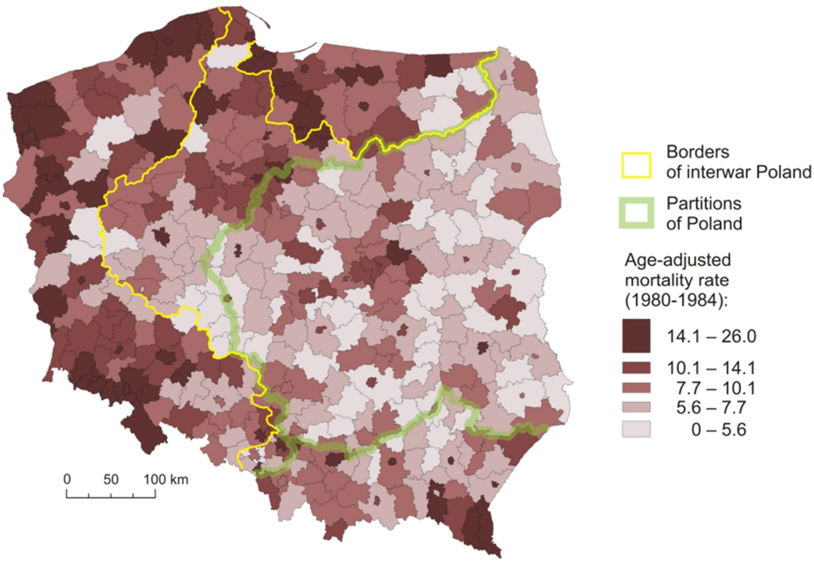


Figure 1: (Continued)

b) Women

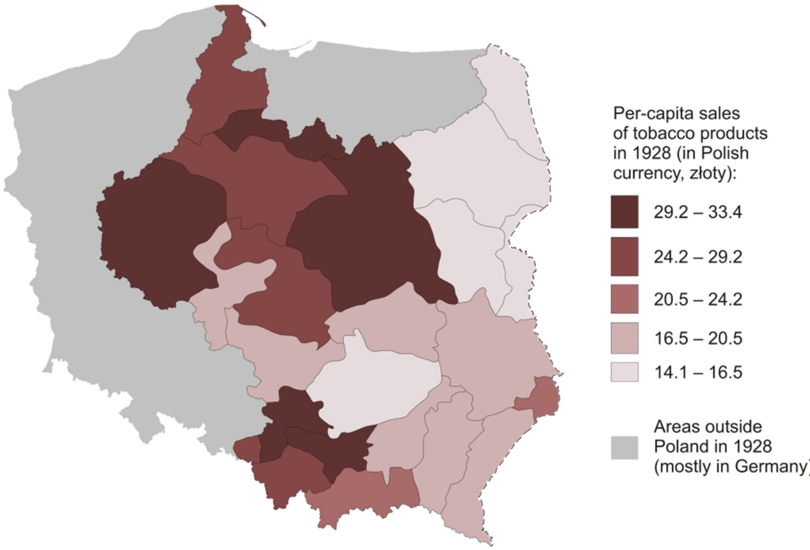


Source: Own elaboration based on National Cancer Registry data.

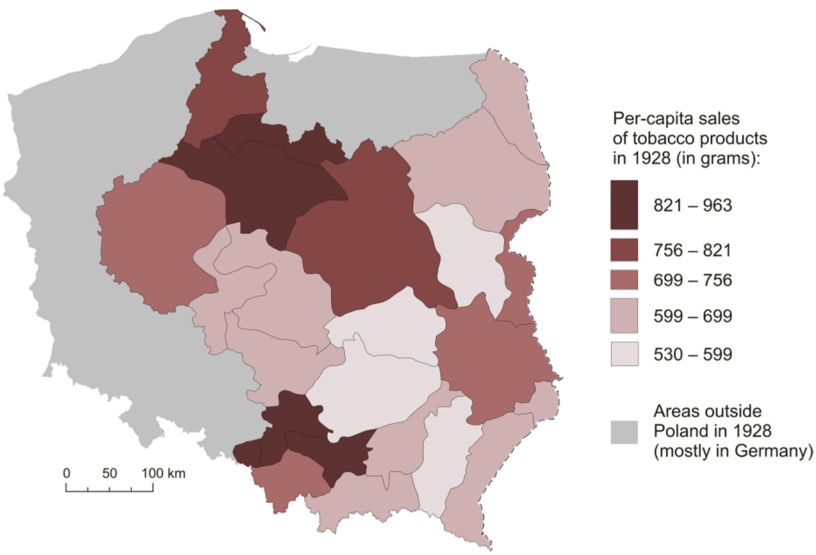
Age-adjusted lung cancer mortality in 1980–1984 was moderately elevated in the central-northern parts of the country. This is consistent with spatial patterns of registered per-capita sales of tobacco products in interwar Poland (Figure 2). During 1980–1984, age-adjusted lung cancer mortality was particularly low in eastern Poland, i.e., the areas of the former Russian partition of Poland.

Figure 2: Sales of tobacco products in selling areas in 1928 (interwar Poland)

a) In expenditure terms



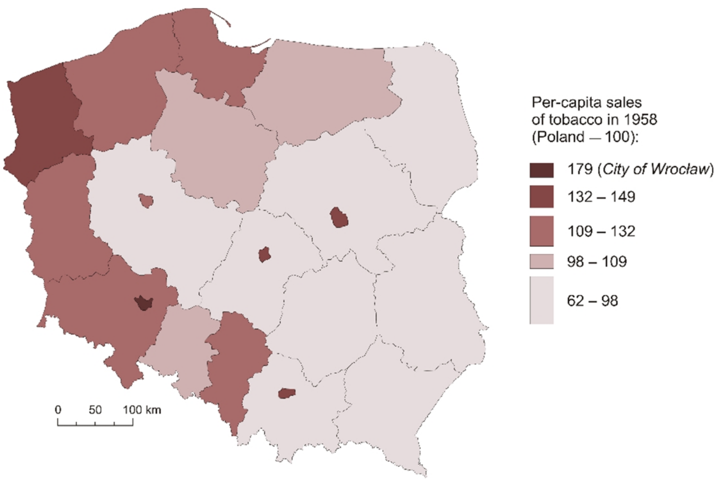
b) In volume terms



Source: Own elaboration based on General National Exhibition (1929), Dzierżyński (1930).

Age-adjusted lung cancer mortality in 1980–1984 was much higher in the Recovered Territories. In 1980–1984, Pomerania, Lubusz Land, and Silesia were homogenous spatial areas of elevated age-adjusted lung cancer mortality in men, according to Kulldorff's spatial scan test. The same pattern could be observed in per-capita sales of tobacco products in post-war Poland (Figure 3). In 1958 in the Recovered Territories, only in Opole Province were per-capita sales of tobacco products somewhat below the country's average. Tobacco consumption was also high in city-voivodeships (cities granted voivodeship status), particularly in Wrocław, the largest city of the Recovered Territories.

Figure 3: Sales of tobacco products by province in 1958 (post-war Poland)

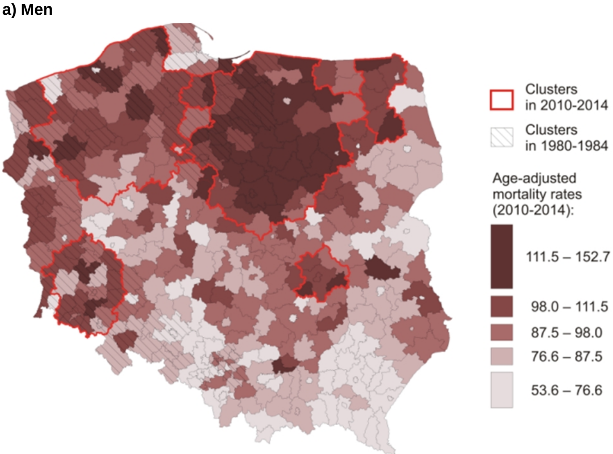


Source: Own elaboration based on registry data of tobacco trade and manufacturing structures (Didkowska, Wojciechowska, and Zatoński 1996).

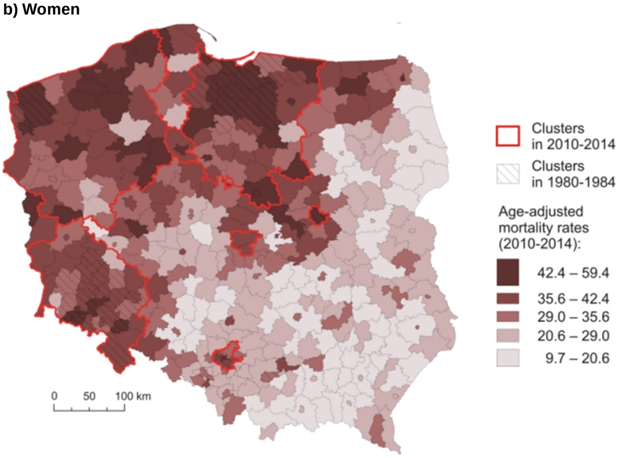
A west-to-east trend of lung cancer mortality was still present in 2010–2014 in both men and women; however, in the last three decades, a strong spatial diffusion of lung cancer mortality in men can be observed. Figure 4 shows age-adjusted lung cancer mortality in 2010–2014 and results of cluster detection using Kulldorff's spatial scan statistic. The primary cluster of lung cancer mortality in men was placed in central-northern Poland (log likelihood ratio in men: $log\lambda = 330.4,\ P = 0.001$). The number of male deaths due to lung cancer in this cluster in the 2010–2014 period was equal to 9,562, while the expected number amounted to 7,372. This means it is extremely unlikely that elevated mortality in the specified area is a result of random processes. Five secondary clusters for male mortality due to lung cancer were identified, most of them are situated in northern Poland. The large difference between primary and secondary clusters is reflected in the likelihood ratio values, i.e., the corresponding value of the likelihood ratio for secondary clusters does not exceed $log\lambda^{*} = 40$. Lung cancer mortality clusters for men and women are placed close together, which means that spatial distribution of risk factors is similar for both genders.

Figure 4: Lung cancer age-adjusted mortality per 100,000 population in Poland in 2010–2014 and clusters identified by Kulldorff's scan statistic

a) Men



b) Women



Source: Own elaboration based on National Cancer Registry data.

Despite their heterogeneity, clusters of elevated lung cancer mortality were situated similarly in the 1980–1984 and 2010–2014 periods. This applies particularly to the female population. In 2010–2014, female lung cancer mortality was still much lower in eastern Poland. Similarly to the male population, the primary cluster of female mortality due to lung cancer in 2010–2014 was detected in central-northern Poland ($log\lambda = 158.1$, $P = 0.001$). Six secondary clusters of female mortality of lung cancer were identified, most of them centred in western Poland. One of the secondary clusters stands out from others. The value of the likelihood ratio is particularly high for the Warsaw cluster of female mortality ($log\lambda = 125.6$, $P = 0.001$). The probability value of $P = 0.001$ for detected spatial clusters means that the observed rank of λ from the computation is 1 in 1,000 Monte Carlo simulations.

Figure 5: Tobacco smoking prevalence in the Polish population aged 15–75 in 2001–2007

a) Men

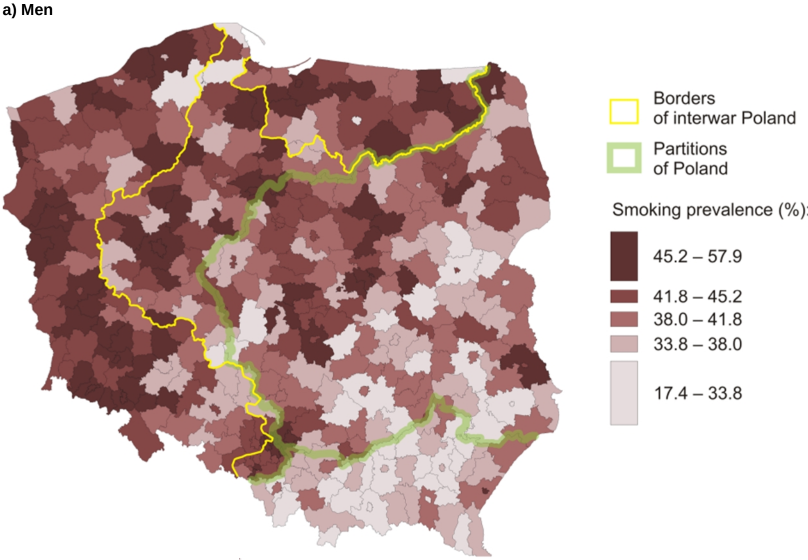
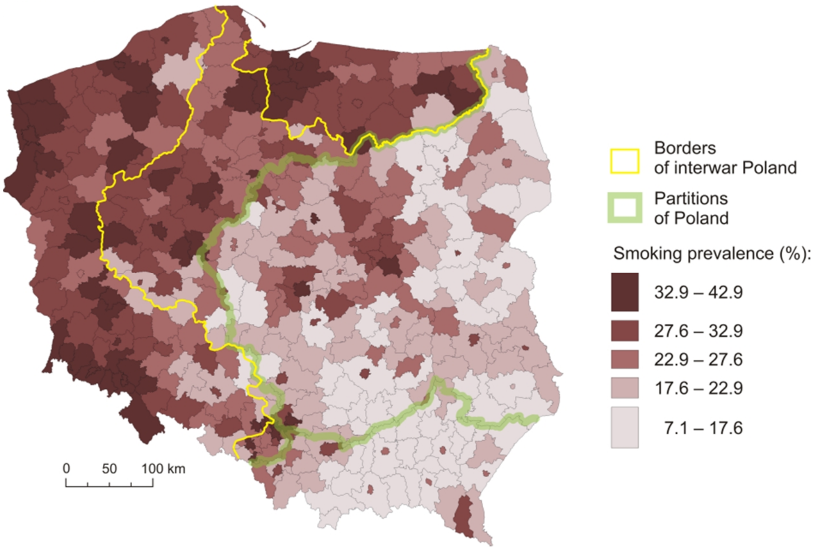


Figure 5: (Continued)

b) Women



Source: Own elaboration based on questionnaire study of 251,700 participants.

3.2 Determinants of spatial clustering of age-adjusted lung cancer mortality

Factors associated with spatial variation of lung cancer mortality in 2010–2014 after adjustment for age were examined using spatial regression. Three explanatory variables in the model were found to be statistically significant: smoking prevalence, per-capita fish consumption, and per-capita sucrose intake (Table 1). The variables of county-level emission of particulate matter into the atmosphere per sq. km ($P = 0.411$), per-capita red meat consumption ($P = 0.617$), per-capita protein intake ($P = 0.594$), and per-capita carbohydrate intake ($P = 0.246$) failed to achieve statistical significance. The lowest probability value is reported for the binary covariate for smoking status ($P < 0.001$). Results indicate that high fish consumption is significantly spatially associated with a decreased risk of lung cancer after adjustment for smoking prevalence. Calculated total sucrose intake is probably positively related to lung cancer mortality. The inclusion of socioeconomic controls increases the type I error rates for sucrose and fish consumption variables, but both probability values remain below 0.05. Among socioeconomic controls, the unemployment rate showed the highest significance, which is, among others, related to high labour market imbalances in rural areas of northern Poland where state farms previously dominated.

Table 1: Spatial lag model of age-adjusted lung cancer mortality in 2010–2014: [A] an epidemiological model and [B] an epidemiological–economic model (with the inclusion of socioeconomic controls). Estimation results for 380 counties

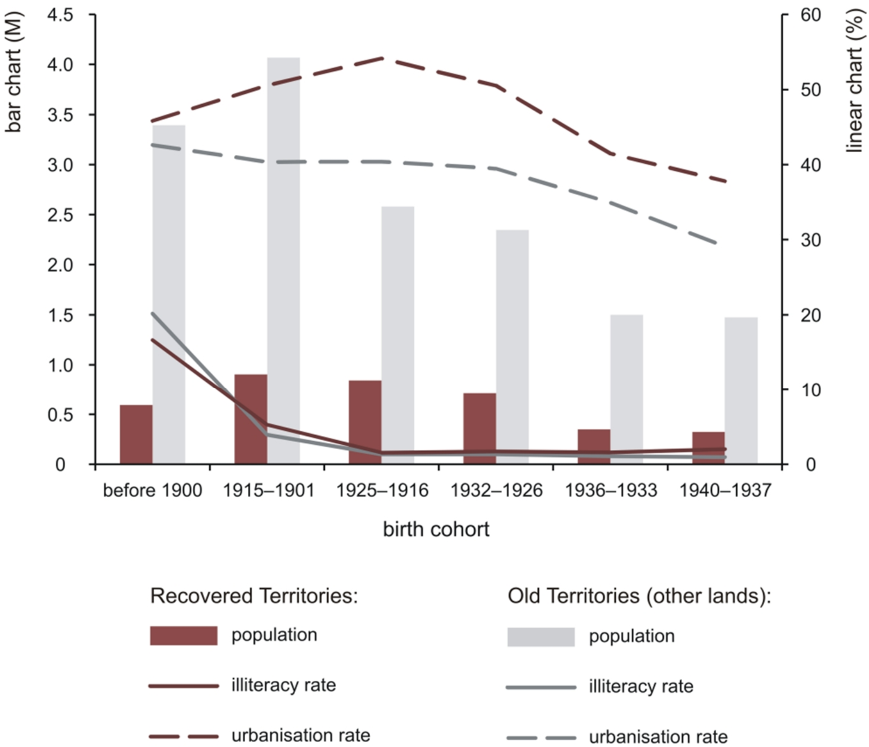
Covariate	Maximum likelihood estimation				Two stages least squares with HAC standard errors			
	[A]		[B]		[A]		[B]	
	estimate (β)	*P*-value	estimate (β)	*P*-value	estimate (β)	*P*-value	estimate (β)	*P*-value
Intercept	–0.0002	0.1934	–0.0004	0.0763	–0.0003	0.1834	–0.0004	0.1174
Spatial lag (ρ)	0.6066	<0.0001	0.5462	<0.0001	0.6837	<0.0001	0.6555	<0.0001
Share of daily smokers (%)	0.0023	<0.0001	0.0021	<0.0001	0.0020	<0.0001	0.0019	<0.0001
Average monthly fish consumption (Kg per capita)	–0.0009	0.0079	–0.0009	0.0160	–0.0008	0.0214	–0.0007	0.0391
Average monthly sucrose intake (kg per capita)	0.0008	<0.0001	0.0008	0.0001	0.0007	0.0068	0.0006	0.0107
Average monthly gross wages and salaries (PLN)	*	*	<0.0001	0.5661	*	*	<0.0001	0.6949
Registered unemployment rate (%)	*	*	<0.0001	<0.0001	*	*	<0.0001	0.0005
Outpatient departments (number per 10,000 population)	*	*	<0.0001	0.1230	*	*	<0.0001	0.0067

Source: Own elaboration.

4. Discussion

Tobacco use in Poland was spatially polarised in 1928, 1958, and 2001–2007 (Figures 2, 3, and 5). Current variance of smoking prevalence by region (NUTS 2) in Poland is substantially higher than in the geographically larger Germany and comparable but higher than in Ukraine (Pötschke-Langer et al. 2015; State Statistics Service of Ukraine 2017). During 1980–1984, age-adjusted lung cancer mortality was much higher in the Recovered Territories, which refer to newly formed communities. The phantom borders of interwar Poland largely coincide with spatial discontinuities in age-adjusted lung cancer mortality in 1980–1984 in men and women. Since smoking behaviours are largely translated into lung-cancer risk (IARC 2004), in the study, spatial patterns of both variables are analysed jointly.

Figure 6: Demographic parameters of the population living in the provinces of Recovered and Old Territories of Poland in 1950



Source: Own elaboration based on the 1950 National Census of Poland.

Low school attainment is a well-known risk factor for smoking and this was also the case in pre-war Poland, according to school survey data (Jaxa-Bykowski 1918). According to the national censuses of 1950 and 1960, there were no major differences in the educational structure of the population of the Recovered Territories and the rest of the country (Figure 6). In 1960, the proportion of the population aged 7 and older with primary and incomplete primary education in the Recovered Territories was 27% and 48%, respectively, compared to 24% and 50% in the rest of the country.

In 1950, the urbanisation rate in the Recovered Territories was higher than in the rest of the country (Figure 6), which was a consequence of settlement patterns in interwar Germany. However, the rural population was well-represented in the settlers. According to estimates of registry- and survey-based research by Turnau (1960), in 1948, 25% of the inhabitants of Wrocław, the largest city of the Recovered Territories, came from rural areas and 16% from cities with under 100,000 inhabitant population. According to the 1950 census, 38% of the population of the Recovered Territories lived off agriculture, while 50% did in the rest of the country. In the post-war period, high urbanisation and availability of employment outside agriculture were two of the reasons for a high smoking prevalence in the Recovered Territories.

A two-wave survey study by Miklaszewski (1912, 1914) investigated that a smoking prevalence was slightly higher among the lower-class urban population than the upper-class population. However, low tobacco use in the former Russian territory of interwar Poland, depicted in Figure 2, was being explained mainly by low economic development, including high employment in agriculture and high ruralisation (Dzierżyński 1930). In some rural areas and small towns in central Poland, tobacco smoking was prohibited due to fire hazards (Grabowski 1886). This is in line with the results of the first large-sample survey on smoking habits and attitudes in post-war Poland (Staszewski and Wiśniewski 1960), which was carried out in Upper Silesia on a nonprobabilistic sample of 2,725 patients. The study confirmed that regardless of gender, smoking prevalence in post-war Poland was higher in individuals employed outside agriculture and those living in urban areas.

Further hypotheses about spatial discontinuities in age-adjusted lung cancer mortality in 1980–1984 can be made. Migration patterns have created considerable differences in the age structure (Figure 6). One proposes two hypotheses which are not mutually exclusive: a possible self-selection of settlers and the protective effects of family ties or expectations. Mahabee-Gittens et al. (2012) found protective effects of family bonding against smoking among all racial and ethnic groups in the United States. The protective effects of family ties and expectations were observed also against substance and alcohol use (Gil, Wagner, and Vega 2000). The effect of age of communities could be further enhanced in the Recovered Territories by a high smoking prevalence in the former German citizens who were allowed to stay in the Recovered Territories after WWII.

In pre-war Poland, smoking tobacco, especially among youth, was considered socially and religiously undesirable (Grabowski 1886; Kuznowicz 1921; Jasiński 1929). Differences in socially condemned or nonconservative behaviours between the Recovered and Old Territories are not limited to smoking habits. In 1960, the share of nonmarital births in the provinces of the Recovered Territories was higher by 113% compared to the rest of the country (7.0% versus 3.3%).[2] The difference is only partly influenced by a higher urbanisation rate in the Recovered Territories. In 1960, the share

[2] Not all census data is available for Recovered and Old Territories of Poland separately. In the postwar period, Poland's Central Statistical Office provided most data at the regional level only. According to the classification of Poland's Central Statistical Office, the regions of the Recovered Territories were Olsztyn, Gdańsk, Koszalin, Szczecin, Zielona Góra, Wrocław, and Opole Provinces, as well as the city of Wrocław. However, Olsztyn and Gdańsk Provinces encompassed both Recovered and Old Territories.

of nonmarital births in the urban population was 77% higher in the provinces of the Recovered Territories compared to the rest of the country (7.2% versus 4.1%). Kozak and Marczewski (1986) discussed the problem of elevated criminality in the Recovered Territories. In 1960, the crime rate was 30% higher in the provinces of the Recovered Territories than in the rest of the country (202.8 versus 156.1 per 10,000 population aged 16–59). According to the 1960 census, the refined divorce rate was 39% higher in the provinces of the Recovered Territories compared to the rest of the country (14.4 versus 10.4 divorces per 10,000 married population). The above-mentioned percentages become larger by over one-fifth if Opole and Gdańsk Provinces were excluded from the comparison due to a relatively high share of the native population.

Previously, the strong persistence of a conservatism–liberalism cleavage between the central parts of Poland and the Recovered Territories was shown in the example of political preferences (Zarycki 2002; Bartkowski 2003; Jasiewicz 2009; Jańczak 2015). It was hypothesised that ideological or identity factors may be related to the age of local communities. The old communities in central and eastern Poland would be well integrated and more conservative while the young communities in the Recovered Territories would be less integrated and their attachment to the traditional values would be weaker. Previously, in the structural equation approach, social conservatism was found to be correlated with lower levels of cigarette use (Castro, Stein, and Bentler 2009). Rejection of conventional values and acceptance of deviance was shown to contribute to smoking in high school seniors (Waldron and Lye 1990).

In the current study, the geographical patterns of age-adjusted lung cancer mortality and smoking prevalence were found to be more stable over time in women than in men. The spatial diffusion of smoking prevalence in men in the recent decades and high spatial persistence of smoking behaviours in women can be hypothesised to be related to differences in perceived acceptability of male and female smoking. Female smoking has been more repressed by social norms than male smoking (Grabowski 1886; Grech and Zawada 2005) and therefore spatial diffusion of smoking behaviours in women might be less likely.

Few studies have been published on smoking prevalence in the Polish migrant populations. According to the 2016 census, the Polish minority constitutes approximately 3% of Ireland's population. Previously, smoking prevalence in Ireland residents of Polish origin was found to be higher than in the Irish counterparts (Kabir et al. 2008) and in the overall Polish population. Smoking rates and the levels of consumption of cigarettes are particularly high in the Polish migrants who have lived in Ireland for more than two years (Kabir et al. 2008).

In summary of the spatiotemporal analysis, observed currently age-adjusted lung cancer mortality and smoking prevalence in women remain substantially lower in the eastern parts of the country. However, age-adjusted lung cancer mortality and smoking prevalence in men are largely spatially similar over the regions. It may be concluded that in the recent decades significant spatial diffusion of tobacco use in Polish men could be observed. However, the primary cluster of lung cancer mortality in men (and women) in 2010–2014 includes areas of high smoking prevalence in interwar Poland, i.e., central-northern Poland. A current strong west-to-east trend of lung cancer mortality is hypothesised to be related to the age of the local communities and persistence of informal institutions.

As regards to the regression part of the analysis, in the 1940s, smoking tobacco was found to be an explanation for the rise of lung cancer mortality (Müller 1940; Schairer and Schöniger 1944). However, the effect of smoking on lung disease was hypothesised by then and also in Poland (Grabowski 1886; Kuznowicz 1921; Jasiński 1929). In this paper, the results of the modelling demonstrate a possible protective role of fish consumption in lung cancer, which is consistent with previous estimates (Song et al. 2014). The same refers to the variable of sucrose intake, which is associated with an increased risk of lung cancer. High sucrose intake was found to be a risk factor in lung carcinogenesis (De Stefani et al. 1998). Sucrose was found to be responsible for facilitating lung metastasis (Jiang et al. 2016).

Some limitations of the performed ecological regression should be noted. Analysed data on consumption is not available for the period prior to the 2000s. The data is retrospective and self-reported. Answers to multiple choice questions on consumption are less precise than reporting binary smoking status. No registry data on tobacco use in the country is available for the market economy period, which was the case for tobacco sales in interwar and post-war Poland.

5. Conclusions

The spatial differences in tobacco use between western and eastern Poland can be explained by cultural and historical factors. Lung cancer mortality in 1980–1984 notably reveals the existence of phantom borders, reflecting population replacement and partition legacies. This is manifested by high age-adjusted lung cancer mortality in 1980–1984 in Masuria, West Pomerania, and Silesia. The primary cluster of age-adjusted lung cancer mortality in 2010–2014 is centred in the region of high tobacco use in interwar Poland. However, the spatial diffusion of tobacco use in men could be observed in recent decades. The spatial patterns of age-adjusted lung cancer mortality were found to be more persistent in women than in men. Urban–rural differences in health of men and women were identified in the study: The gender gap in lung cancer mortality is much lower in large cities. However, this could not be observed in 1980–1984 when age-adjusted lung cancer mortality in the urban population was high in both men and women. The identification of high-risk areas of lung cancer mortality was followed by examining the underlying causal mechanisms using a spatial regression model. This study reveals that daily smoking and unbalanced dietary patterns explain most of the total variance of the spatial distribution of lung cancer mortality.

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