Population Studies, 2013
Vol. 67, No. 1, 61–81, http://dx.doi.org/10.1080/00324728.2012.724696

Trends, patterns, and determinants of regional mortality in Belarus, 1990–2007

Pavel Grigoriev[1], Gabriele Doblhammer-Reiter[1,2] and Vladimir Shkolnikov[1,3]
[1]Max Planck Institute for Demographic Research; [2]University of Rostock; [3]New Economic School (Russia)

We report analyses of regional trends in overall and cause-specific mortality in Belarus for the period 1990–2007. We explore the respective spatial patterns and attempt to determine the factors responsible for the regional mortality variation. The results show that inter-regional mortality differentials tend to rise, mainly because of the growing advantage of the capital over other regions. The increasing variation is associated with diverging trends in mortality from external causes of death. Mortality tends to be higher in the eastern part of the country. Regional data show that changes in mortality are largely explained by alcohol and socio-economic conditions, as measured by unemployment and poverty rates. Cardiovascular and external-cause mortality are strongly associated with alcohol and unemployment, while poverty is an important predictor of suicide and homicide mortality. Clusters of elevated mortality from certain cancers located in the contaminated zone point to the possible impact of the Chernobyl accident.

Keywords: Belarus; regional mortality; causes of death; spatial distribution of mortality; mortality determinants

[Submitted March 2011; Final version accepted February 2012]

Introduction

The unprecedented increase in mortality that took place in the countries of the former Soviet Union (FSU) in the early 1990s has been extensively documented (Bobadilla and Costello 1997; Shkolnikov et al. 2004). The literature suggests that a complex interplay of a number of factors, rather than a single determinant, was responsible for this sharp rise. There are thought to be three main determinants: the increase in alcohol consumption; the consequences of the socio-economic crisis, including psychological stress; and the deterioration of the health care system (Bobak et al. 1998, 2000; Brainerd 1998; McKee and Britton 1998; Cornia and Paniccià 2000; McKee 2001; Brainerd and Cutler 2005; Cockerham et al. 2006). It has also been pointed out that the acute health crisis of the 1990s came on the top of a long-standing crisis that had been observed in the region since the mid-1960s (Eberstadt 1981; Feshbach 1984; McKee 2006). For more than four decades, overall mortality had been rising owing to adverse trends in mortality from cardiovascular diseases and external causes of death at working ages (Shkolnikov et al. 1996). During the Soviet era, these negative mortality dynamics were interrupted between 1985 and 1988 only, because of the anti-alcohol campaign launched by the Soviet government in 1985. The short-term improvement was quickly followed by the subsequent deterioration. It is believed that the effect of the anti-alcohol campaign had a significant influence on mortality trends in the early 1990s (Shkolnikov and Nemtsov 1997).

Compared to the substantial evidence from studies of national populations, little is known about regional mortality trends and patterns in the FSU. A few studies of the geographical diversity of mortality were conducted for Russia. Most of them, however, examined either the pre-transition period or the early 1990s. Andreev (1979), and later Shkolnikov (1987), detected a south-west/north-east mortality gradient within Russia in periods around the population censuses of 1970 and 1979. Vallin et al. (2005) identified significant differences between the south-west and the north-east of Russia in both overall mortality and cause-of-death patterns. Walberg et al. (1998) found that the decline in life expectancy in the early 1990s did not affect all Russian regions equally. The fact that the greatest mortality increments were observed even in some of the wealthiest regions suggested the insufficiency of the 'impoverishment' explanation. Factors reflecting the severe effects of poorly conducted economic reforms—such as labour force turnover, social cohesion, and income inequality—were found to be associated with larger mortality increases.

Several studies of regional mortality trends were conducted in the Baltic countries. Kalediene and Petrauskiene (2000) analysed mortality data in 55 administrative regions of Lithuania during the period 1988–96. Major towns were found to have lower mortality. Regional differences in cardiovascular mortality and mortality from external causes were mostly responsible for overall regional mortality variation. The regional differences in levels of urbanization, education, and marital status were associated with regional mortality differences, whereas no associations were observed with the distribution of health care resources, unemployment, and certain other aspects of well-being. Kalediene and Petrauskiene (2004) reported growing inequalities in mortality between the urban and rural populations of Lithuania during the period of socio-economic transformation. The main factors proposed as responsible for the increased urban–rural mortality differential were greater social and psychological stress affecting the rural population, unhealthy lifestyles, inequalities in the accessibility of health care, and the lack of preventive programmes in rural areas. Krumins et al. (2009) explored changes in regional differences in health and mortality in Estonia, Latvia, and Lithuania. They found that, during the transition period, geographical variation increased, particularly from diseases of the circulatory system. The authors argued that the observed geographical patterns in the three Baltic countries appeared to be influenced more by socio-economic and cultural factors specific to the geographic area (and related to the historical influences of neighbouring countries) than by the fact that this area belonged to a particular national territory.

A number of regional studies were conducted in the countries of Central and Eastern Europe, including Hungary and Poland (Józan and Forster 1999; Józan and Prokhorskas 1999; Kolodziej and Lopuszańska 2010). The case of the Czech Republic is particularly interesting, because, in contrast to what occurred in many other transition countries, there was actually an increase in life expectancy in the early 1990s. Within the Czech Republic, the mortality changes were found to be highly regionally differentiated, and the regional pattern of the mortality decline was associated with changes in mortality from diseases of the circulatory system, cancer, and external causes of death (Blažek and Dzúrová 2000; Dzúrová 2000; Spijker 2009).

Although there are many similarities between Belarus and its neighbouring countries, it should not be assumed that evidence obtained elsewhere (e.g., Russia) is applicable to Belarus. Among the countries of the former USSR, Belarus is distinctive in its socio-economic and demographic development. After the disintegration of the Soviet Union in 1991, the political and economic changes in the country were much less radical than they were in the neighbouring post-Soviet countries. This has influenced mortality trends in a particular way. As in the other Soviet republics, there was a considerable mortality increase in Belarus immediately after the dissolution of the USSR, but the magnitude of the crisis was less dramatic than elsewhere. The policy of gradualism chosen by Belarusian authorities seems to have lessened social pressure, and slowed down the increasing mortality in the early 1990s. However, the long-term deterioration in health has continued. In contrast to the Baltic countries, Belarus still has not overcome the health crisis which began during the Soviet era (Grigoriev et al. 2010).

The study reported in this paper was the first systematic analysis of regional mortality patterns in Belarus over the two decades following the transition in 1990. Our report contributes to the existing literature on health and mortality in the countries of the former USSR in three respects. First, it provides new evidence on the geographical diversity of overall and cause-specific mortality in Belarus. In contrast to previous studies, we examined the dynamics of regional mortality in Belarus in order to identify both the temporal changes and the cross-sectional differences in overall and cause-specific mortality over this period. Second, thanks to the availability of detailed cause-of-death mortality data, we were able to compare areas contaminated as a result of the Chernobyl accident with the rest of the country. The results of this analysis contribute to the debate on the impact of the Chernobyl accident on mortality. Finally, by performing a statistical analysis, we linked mortality to socio-economic indicators across regions, and tested the validity of various proposed mortality determinants.

Data and methods

Our analysis was based on official data from the National Committee of Statistics of Belarus

(Belstat). These data included original unpublished detailed files on causes of death and mid-year population (exposure) by age, sex, type of residential area, and region. Detailed mortality data by large regions ('oblast' level) were available to us for the period 1997–2007. Similar data by lower-level territorial units, or cities and towns ('rayon' level), were available for the period 2003–07. In order to extend the analysis to the period before 1997, we had to rely on the limited set of officially published general mortality indicators. Data on socio-economic indicators used for the explanatory analysis of regional mortality variation were also taken from the official statistical publications.

A few remarks about the quality and reliability of data are also worth making. In general, mortality data in the countries of the European part of the former USSR, including Belarus, are considered to be reliable. Anderson and Silver (1997, p. 130) have noted that the recent mortality data in these countries 'are generally trustworthy, especially at the working ages'. On the basis of data quality indicators—such as the timeliness, completeness, and coverage of death registration, and the proportion of deaths assigned to ill-defined causes (1981–2001)—the WHO ranks Belarus as a country with mortality data of medium quality (Mathers et al. 2005).

The analysis was performed at two territorial levels: the regional, or 'oblast' level; and the district, or 'rayon' level. At the regional level, there were seven units: six oblasts plus the capital, Minsk, which is treated as a separate region (Figure 1). On average, each oblast consists of about 20 rayons. At the rayon level, there are 118 rayons and 13 cities. The remaining small towns are included in their respective districts. While the administrative borders of districts have remained unchanged over time, there have been some minor changes: some cities that had been treated as separate units early in the period were later merged with their districts. To ensure data comparability, we had to go back and merge these cities with their corresponding districts.

Before the analysis could be conducted, some rearrangement of the original data was necessary.

Figure 1 Territorial division of Belarus: regions (oblast), districts (rayons), and cities
Source: www.diva-gis.org (base maps).

First, the initial cause-specific mortality data were aggregated into a few groups of the principal causes of death in accordance with the two different classifications used in the statistical practices of Belarus during the analysed period—the Soviet classification of 1988 (1988–2001) and the abridged version of the ICD-10 (since 2002). The analysed items were aggregated in such a way that the transition to the ICD-10 in 2002 could not cause a notable distortion of time trends. The list of causes of death used in the further analysis is presented in Appendix A. To ensure greater robustness of age-specific and cause-specific mortality, the rates were calculated for a 5-year period (2003–07) at the rayon level and for a 3-year period (2005–07) at the oblast level. Information about the absolute number of deaths at the rayon level (selected causes) is provided in Appendix B. The rates obtained were then age-standardized using the European population standard (Waterhouse et al. 1976). Throughout the paper, these rates are referred to as the standardized death rates (SDRs). We also used an alternative mortality indicator, life expectancy at birth (official estimates), to explore general mortality trends.

To produce mortality maps, we used shape files for Belarus that were freely available on the DIVA-GIS website (DIVA-GIS 2010). These shapes were modified through a re-projection using ArcGIS 9.3™ (World Miller Cylindrical projection). In addition, 13 circles of different sizes representing Belarusian cities were added, with the capital, the regional centres, and the other towns treated as separate units in the use of vital statistics (see Figure 1).

The *quintile method* of classification was used to produce mortality maps. In the analysis of mortality patterns in the contaminated areas, we relied on the local indicators of spatial association (LISA) (see Anselin 1995, 2005). The LISA is often used to identify statistically significant clusters (or 'hot-spots'). The most useful representation of the LISA is the so-called LISA cluster map, in which there are five categories coded in accordance with the type of spatial autocorrelation. The *high–high* (high rates: high neighbours) and *low–low* (low rates: low neighbours) locations represent local spatial clusters. According to Anselin (2005, p. 145), '. . . the cluster is classified as such when the value at the location (either high or low) is more similar to its neighbours . . . than would be the case under spatial randomness. Any location for which this is the case is labelled on the cluster map.' *High–low* and *low–high* locations are spatial outliers. Statistically not-significant spatial autocorrelation is labelled as *not significant*. To obtain LISA, it was first necessary to decide on the spatial neighbourhood structure. Here, we relied on *the first-order queen* structure, which is widely used in spatial analyses. This structure assumes that the districts that share a common border are neighbours.

Because we could not obtain data for suitable explanatory variables at the district level, the analysis of mortality determinants was conducted at the regional level. For this purpose, we relied on a one-way fixed-effects panel regression model (for the general specification of the model, see Wooldridge 2002). As a result, predictors' net effects were estimated. The model was applied separately for males and females, with the SDR for selected causes of death set as the dependent variables. Because the data we used in the regression analysis were not a typical 'large N small T' panel data set, greater caution was needed to ensure that the standard errors produced were robust to various disturbances. With this in mind, all of the models were adjusted for the presence of cross-sectional dependence, autocorrelation, and heteroscedasticity.

Results

Regional mortality trends and patterns

This section presents the analysis of mortality by the large regions, or oblasts, of Belarus. First, we explore the major inter-regional differences in overall mortality and how they change over time. Second, we report the analyses of cause-of-death mortality patterns, undertaken in order to identify the causes of death responsible for the inter-regional mortality variation.

Changes in all-cause mortality. At the beginning of the 1990s, Belarus experienced a significant reduction in life expectancy at birth, which was associated with the economic and political changes that came about with the dissolution of the USSR (Grigoriev et al. 2010). Between 1990 and 1995, mortality increased in all of the regions of Belarus, but the magnitude of this increase varied. For example, in the Brest oblast, the life expectancy of males declined by about 3 years, while in the capital, Minsk, the decrease was about 5 years (Table 1).

It seems that the population of Minsk (and, presumably, of other big Belarusian cities) was more vulnerable than other areas to the challenges of the early transition years, such as economic

Table 1 Life expectancy (years) at birth by sex and its changes by region, Belarus 1990–2007

	Life expectancy				Changes in life expectancy			
Region	1990	1995	2001	2007	1990–95	1995–2001	2001–07	1990–2007
Males								
Brest	67.3	64.4	63.9	65.6	−2.9	−0.5	1.7	−1.7
Vitebsk	65.7	62.1	62.2	64.0	−3.6	0.1	1.8	−1.7
Gomel	66.5	62.8	61.8	63.5	−3.7	−1.0	1.7	−3.0
Grodno	67.0	62.8	62.4	64.1	−4.2	−0.4	1.7	−2.9
Minsk-city	68.6	63.9	65.8	67.4	−4.7	1.9	1.6	−1.2
Minsk	65.2	61.4	61.1	62.8	−3.8	−0.3	1.7	−2.4
Mogilev	66.0	62.8	61.9	63.8	−3.2	−0.9	1.9	−2.2
Belarus	**66.3**	**62.9**	**62.8**	**64.5**	**−3.4**	**−0.1**	**1.7**	**−1.8**
Females								
Brest	76.3	74.9	75.2	76.5	−1.4	0.3	1.3	0.2
Vitebsk	75.8	74.0	74.1	75.7	−1.8	0.1	1.6	−0.1
Gomel	76.2	74.0	74.2	75.8	−2.2	0.2	1.6	−0.4
Grodno	76.3	74.2	74.5	76.4	−2.1	0.3	1.9	0.1
Minsk-city	76.3	75.1	76.1	77.8	−1.2	1.0	1.7	1.5
Minsk	76.0	73.9	73.5	75.0	−2.1	−0.4	1.5	−1.0
Mogilev	76.0	74.2	73.7	75.5	−1.8	−0.5	1.8	−0.5
Belarus	**75.6**	**74.3**	**74.5**	**76.2**	**−1.3**	**0.2**	**1.7**	**0.6**

Source: Belstat 2009a.

instability, hyperinflation, and falling standards of living. This observation is consistent with findings for Russia: in the first half of the 1990s, the steepest mortality increase was seen in two metropolitan cities, Moscow and St Petersburg (Shkolnikov et al. 1998). In the late 1990s, as the socio-economic situation stabilized, mortality trends in the capital recovered faster than elsewhere. Today, Minsk has the highest life expectancy among all of the regions, and the Brest oblast is in second place. The levels of and trends in mortality in the other Belarusian regions have been similar, with the possible exception of the Minsk oblast, which stands out as having the lowest life expectancy.

The differences in mortality between the Belarusian regions have grown in recent years. These differences are especially apparent for females, since their life expectancy was about the same in all of the regions in 1990. By 2007, the gap between the leader (Minsk) and the region with the lowest level of life expectancy (the Minsk oblast) had grown to about 3 years. In contrast, there have always been marked regional differences in life expectancy for men. Despite some improvements in recent years, the mortality of males in all of the regions still remains higher today than it was in pre-transitional Belarus. For females, on the other hand, life expectancy had returned to the 1990 level by 2007 in almost all of the regions; in the capital, it even exceeded the 1990 level by 1.5 years.

Changes in cause-specific mortality. The regional trends by principal classes of causes of death are presented in Figure 2.

The three main causes of death in Belarus and its regions are cardiovascular diseases (CVD), external causes, and cancers. Until the early 2000s, CVD mortality was growing in all of the regions of Belarus. This growth was somewhat less steep in Minsk-city, and from the mid-1990s, the gap between the capital and the other regions began to widen. In the most recent years, however, it has narrowed again following a notable mortality decline, which has been taking place in all of the regions. It is too early to say whether the latter change is a temporary fluctuation or a new long-term trend.

Apart from deaths caused by CVD, mortality from external causes has played an important role in shaping regional mortality patterns. This cause of death underwent an especially steep increase, coinciding with the increase in the regional mortality differential. Over the 1990s, mortality that was the result of violence rose sharply in the Vitebsk oblast, as well as in the capital. At the same time the increase was far less steep in, for example, the Brest oblast. Like CVD mortality, mortality from external causes has been declining over the last few years. In Minsk the improvement began in 1999, earlier than elsewhere. Today the two Belarusian regions that differ the most from the rest of the country in

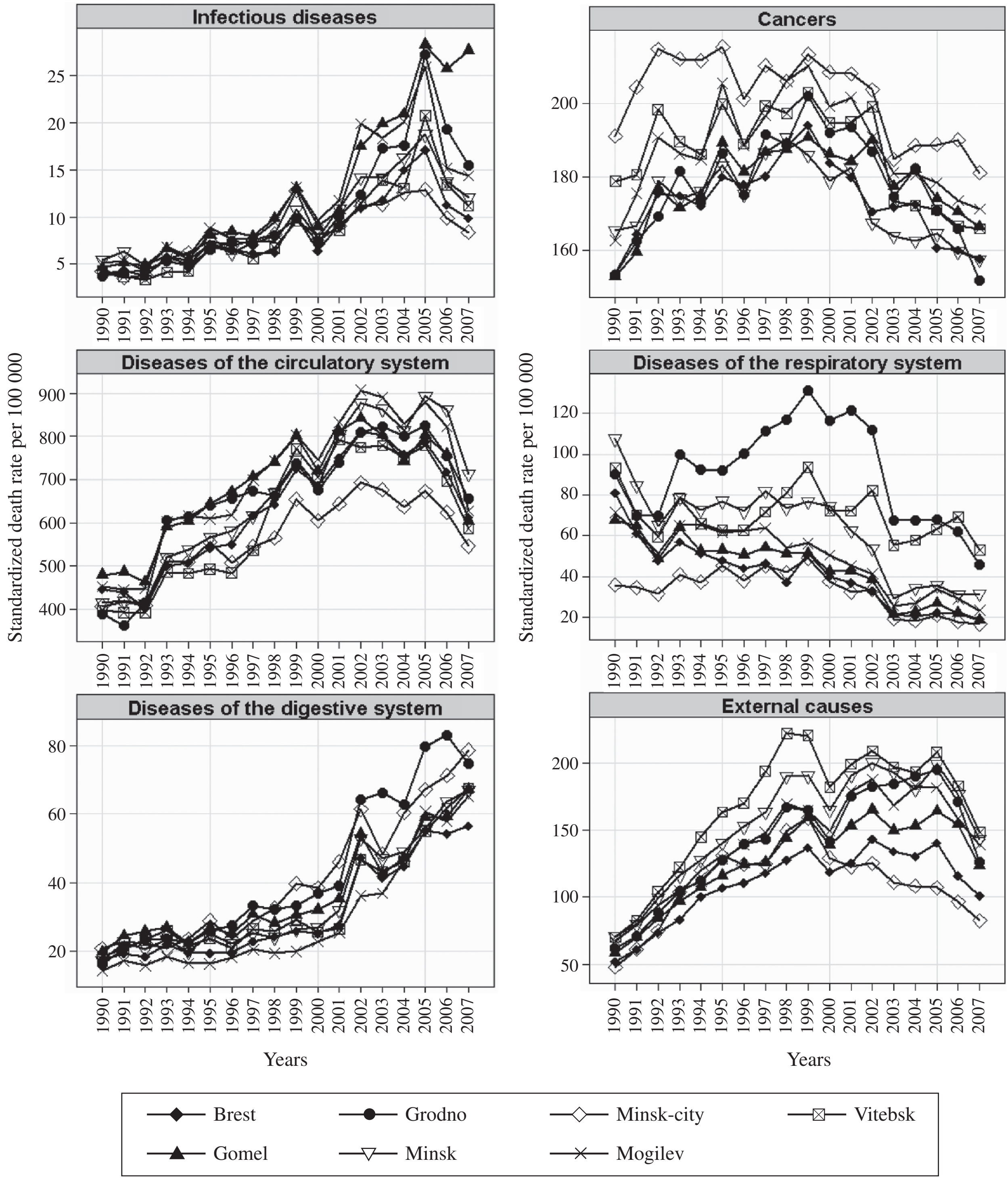

Figure 2 Age-standardized death rates (per 100,000 population) from main causes of death, both sexes by region, Belarus 1990–2007
Note: Death rates were standardized using the indirect method of standardization.
Source: Belstat 2009a.

experiencing lower mortality from external causes are the capital and the Brest oblast.

The regional variation in cancer mortality has not been very pronounced, and in the most recent years, it has been diminishing. Generally, since 1999 cancer mortality has tended to decline in all regions. In the capital it has been slightly higher than elsewhere. Mortality trends from diseases of the respiratory system have varied considerably among the regions. In two regions, the Vitebsk and Grodno oblasts, it has been much higher than in the other oblasts. Mortality from diseases of the digestive system has been increasing in all of the regions, and this increase has been particularly noticeable in the Grodno oblast and Minsk-city.

A detailed profile of cause-specific regional mortality in Belarus is provided in Appendix C. The crucial role of CVD mortality is apparent: it is responsible for more than half of all deaths in Belarus. Within this category, the majority of deaths are attributed to heart disease. The lowest SDR by heart disease is observed in the capital: 558 deaths for men and 269 deaths for women per 100,000 population. At the same time, the highest SDR by cerebrovascular diseases is also observed in the capital.

Mortality from external causes contributes substantially to these regional variations, but it is much more important for males than for females. The SDR of males from external causes of death varies from 183 (Minsk-city) to 318 (Vitebsk) deaths per 100,000 population. Three causes of death account for the majority of deaths within this category: accidental poisonings by alcohol, suicide, and other accidents.

Among all of the causes of death, mortality from cancers exhibits the lowest degree of regional variation. The inter-regional difference is more pronounced among females. The SDR from all cancers in Minsk-city is considerably higher than in the other regions of Belarus, while among males, it is just slightly above the national average. With respect to the composition of cancer mortality, there are no large differences between the regions. The leading causes of cancer mortality among men are cancers of the larynx, trachea, bronchus, and lungs, as well as stomach and prostate cancers. For women, the leading causes of cancer mortality are breast, uterine, and stomach cancers.

Although respiratory diseases are not among the main causes of mortality for males, they have a surprisingly large influence on inter-regional mortality differences. The impact of these diseases is certainly more pronounced than that of cancer mortality, and it is comparable to the influence of mortality from external causes of death. The regional variation in mortality from tuberculosis (TB) (especially among males) is also worth noting here. The data further suggest that, in all of the regions, mortality from diseases of the digestive system is determined by mortality from cirrhosis and fibrosis of the liver. Thus, this cause of death appears to be responsible for the increasing mortality trends for the whole category of digestive diseases (see Figure 2).

Small-area variation

This section is devoted to the analysis of mortality variation at the district level. First, we explore the spatial distribution of overall and cause-specific mortality. Second, we examine mortality patterns in the contaminated areas of Belarus.

Spatial distribution of overall and cause-specific mortality. The spatial distribution of overall mortality in Belarus has two distinctive features. First, mortality in the eastern part of the country tends to be higher than in the western part, and this pattern is slightly more pronounced for women (Figure 3).

To support this observation statistically, we made an arbitrary division of the districts according to their geographical location (either east or west). The west was defined as all districts of the Brest and Grodno oblasts, as well as the western half of the Minsk oblast. Statistically, being located in the eastern part of Belarus is associated with an increase in SDR by 141 deaths (standard error = 39) among males and 78 deaths (standard error = 18) among females, or by 7 and 8.5 per cent of the average mortality level, respectively.

Second, regardless of sex, there are significant variations in mortality across the country. In the period 2003–07, overall SDR within Belarus by area varies from about 1,500 to 3,000 deaths per 100,000 for men, and from 700 to 1,500 deaths per 100,000 for women. The mortality of females is roughly half that of men, and the sex mortality ratio does not vary much by area (mean = 2.19, minimum = 1.90, maximum = 2.51, standard deviation = 0.12).

Belarusian cities and towns (the circles on the map) exhibit lower mortality than the other areas. In many cases, including that of the capital, mortality in the areas surrounding major cities is double that of the cities. This difference does not, however, always persist in the spatial distribution of cause-specific mortality (Figure 4).

The main causes of death responsible for the city/non-city mortality gap are CVD mortality and mortality from external causes of death. However, for some causes, such as cancers and diseases of the digestive system, mortality in cities is higher. Some of this difference can probably be explained by better diagnosis and registration of causes of death in the cities. For this reason, the patterns of regional differences in cause-specific mortality should be interpreted with caution.

For CVD mortality, higher mortality is found in central and eastern Belarus than in other places.

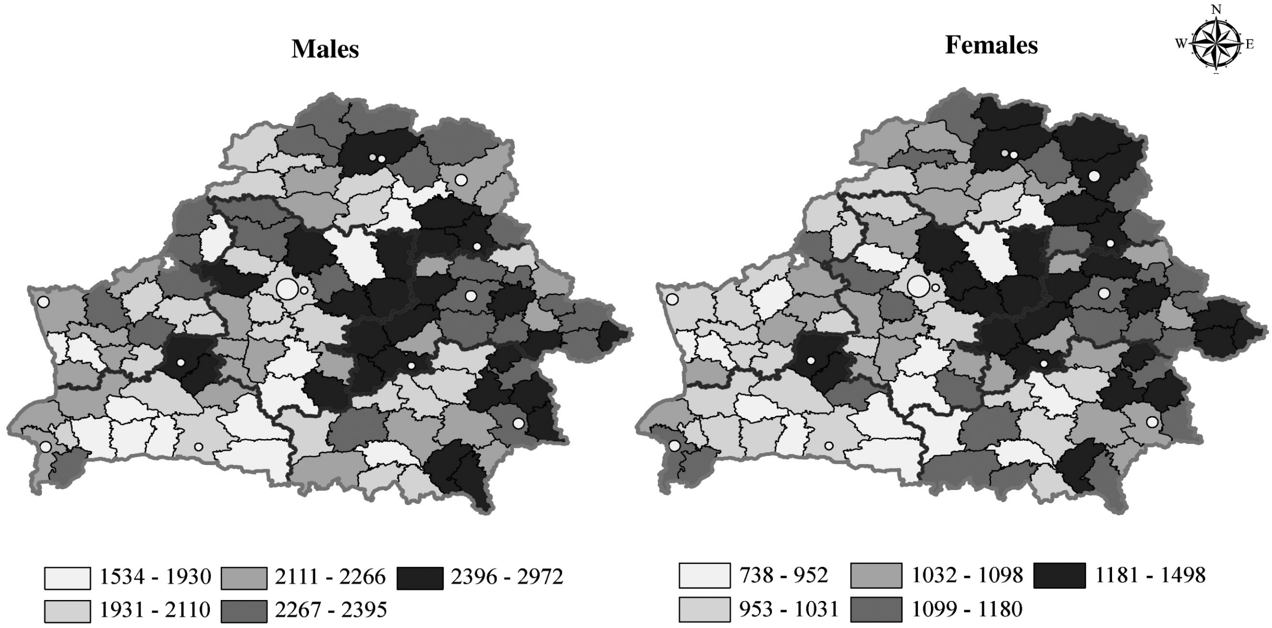

Figure 3 Age-standardized death rates (per 100,000 population) from all causes of death by sex, Belarus 2003–07

Note: Quintile method of classification was used to produce these and the following maps.
Source: Belstat official unpublished data.

Districts of the Mogilev oblast, together with neighbouring districts of the Minsk oblast, form a cluster of high-CVD mortality. SDR from external causes tends to be higher in the east than in the west, with the lowest mortality observed in districts of the Brest oblast. The mortality experience of the Vitebsk oblast is poorer than that of other regions: mortality from external causes in most of its districts is in either the highest or second-highest category.

An apparent cluster of high mortality from respiratory diseases is located in the northern part of the country. Like Vitebsk in the north, the Grodno oblast in the west exhibits high mortality from this cause of death. This region also has the highest mortality from diseases of the digestive system. The patterns of spatial distribution of mortality from cancers and infectious diseases appear to share some features. For both groups of causes, the spatial distribution is rather dispersed, with the districts with higher mortality predominately located in the east.

Mortality in contaminated areas. For a number of reasons, it is very difficult, if not impossible, to assess mortality attributable to the radiological impact of the Chernobyl disaster. First, there is a lack of reliable longitudinal data suitable for use by carefully designed epidemiological studies. Second, even if these data were available, it would be necessary to control for other risk factors, such as smoking and diet. So far, no studies of this kind have been conducted.

The fact that the Chernobyl accident, the anti-alcohol campaign, and the socio-economic crisis of the early 1990s closely coincided in time complicates studies based on population-level mortality data. The huge impact of the two later events on mortality overwhelms the much smaller impact of Chernobyl, and makes it hardly detectable. Finally, after the accident, many people who had been exposed to radiation migrated to other regions of Belarus and beyond. Nevertheless, the analysis of regional mortality in Belarus would be incomplete without addressing the potential mortality effects of the Chernobyl accident since the country was severely affected by its aftermath. Within the country, two regions suffered most: the Gomel and Mogilev oblasts (Figure 5). The Gomel oblast suffered more: 20 out of 21 districts in this region were either fully or partially contaminated (UNDP 2005).

It might be expected that, if there had been a pronounced long-term effect of the accident, it would still be noticeable in the contaminated areas. The availability of the detailed cause-specific mortality data allowed us to compare cause-specific mortality patterns in contaminated areas with those in the rest of the country by each individual cause of death. However, for our further analysis, we selected only those causes of death for which an association with morbidity and mortality was well documented:

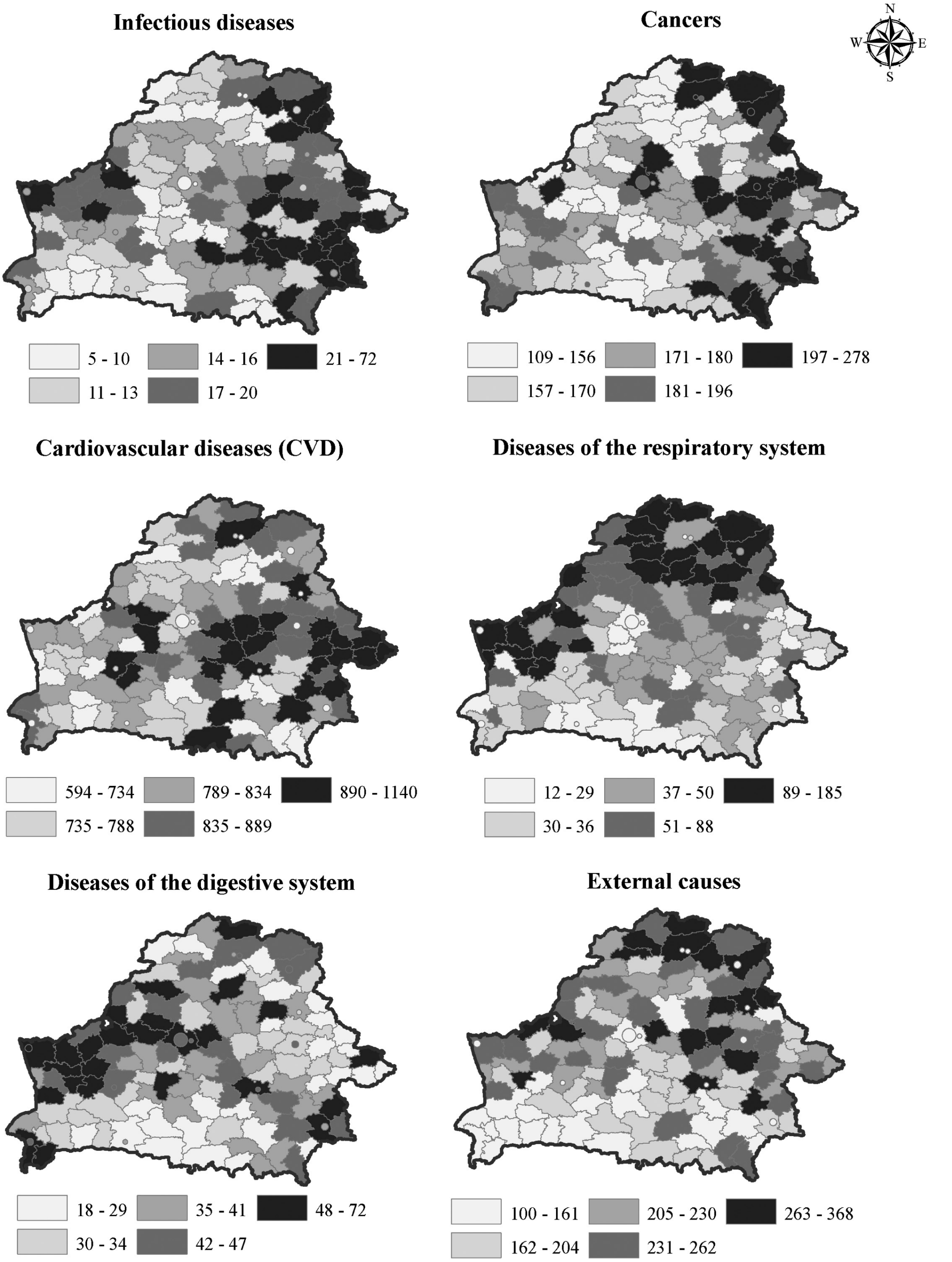

Figure 4 Age-standardized death rates (per 100,000 population) from main causes of death, both sexes, Belarus 2003–07
Source: As for Figure 3.

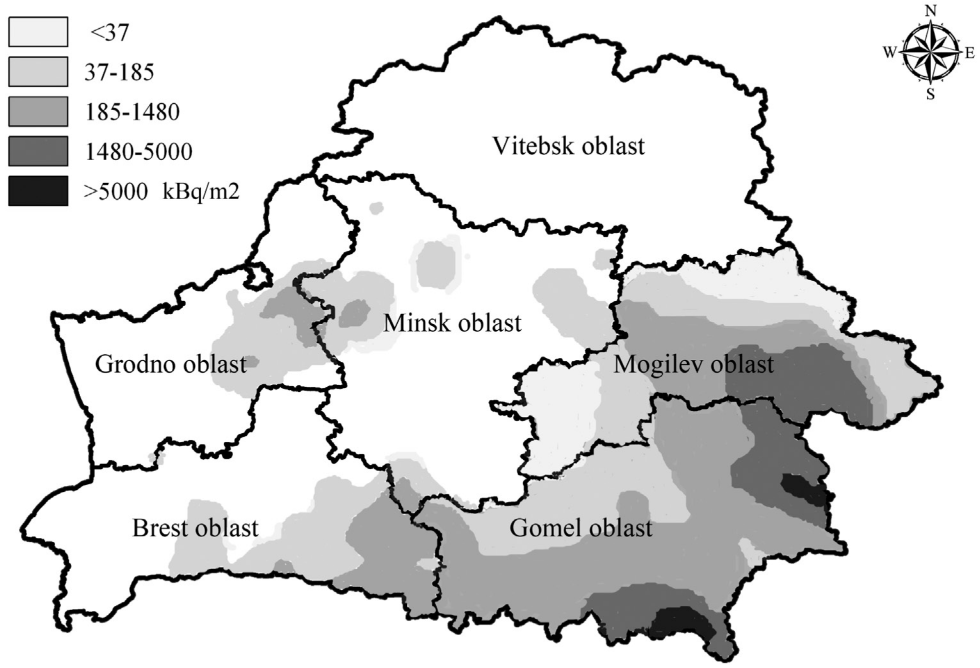

Figure 5 Areas of Belarus contaminated with radionuclides Te-132 and I-132 in April–May 1986
Source: Zuravkov and Mironov 2005, cited in Yablokov et al. 2007.

cancer of the thyroid gland, leukaemia, lung cancer, and certain conditions originating in the perinatal period. Thyroid cancer caused by iodine fallout is considered to be one of the main health effects of the accident (Chernobyl Forum 2006). Leukaemia has been also linked to ionizing radiation (Preston et al. 1994), but there has been no clear evidence of such an effect in the populations affected by the Chernobyl accident (Sumner 2007). The relative risk of lung cancer among Chernobyl 'liquidators' (clean-up workers who were highly exposed to radiation) was found to be significantly higher than among the population not exposed to radiation (Okeanov et al. 2004). Higher mortality from conditions originating in the perinatal period in the contaminated zone might also be expected. Women who were of reproductive age over the past two decades were exposed to radiation as infants and children in 1986. Thus, they might be more predisposed to adverse birth outcomes and delivery complications.

Do mortality patterns in the contaminated areas of Belarus deviate from the rest of the country today, over two decades after the Chernobyl accident? To answer this question, we produced mortality maps for the various causes of death, and compared them with the pattern of the contamination with radionuclides Te-132 and I-132 presented in Figure 5 (the patterns of the contamination with other important radionuclides such as I-131 and Cs-137 look similar). The results, LISA cluster maps, are presented in Figure 6. Here, we are particularly interested in the geographical location of *high–high* clusters, areas where the local mean is significantly higher than the global mean.

All of the clusters of highest mortality from selected causes of death are located either in the Mogilev or the Gomel oblasts, the areas of Belarus most affected by the Chernobyl accident. This is unlikely to be a coincidence. The geographical proximity of the clusters of highest mortality to the contaminated zone may be related to the impact of ionizing radiation. Nevertheless, this impact does not appear to be very pronounced or conclusively established. On the one hand, we can observe a cluster of high mortality from all cancers, including lung cancer and leukaemia in the Mogilev oblast. On the other hand, no similar cluster is found in the Gomel oblast, except for a small cluster of mortality from lung cancer in the western part and a cluster of thyroid cancer mortality in the south. In addition, a cluster of high mortality from perinatal causes can be observed in the Gomel oblast, while in the contaminated Mogilev oblast, no similar cluster can be seen (and there is even a cluster of the lowest mortality).

Analysis of factors associated with mortality

We now report an analysis that sought to determine the factors responsible for changes in mortality at the oblast level. Unfortunately, the choice of explanatory variables was limited owing to a lack of regional data on socio-economic indicators for

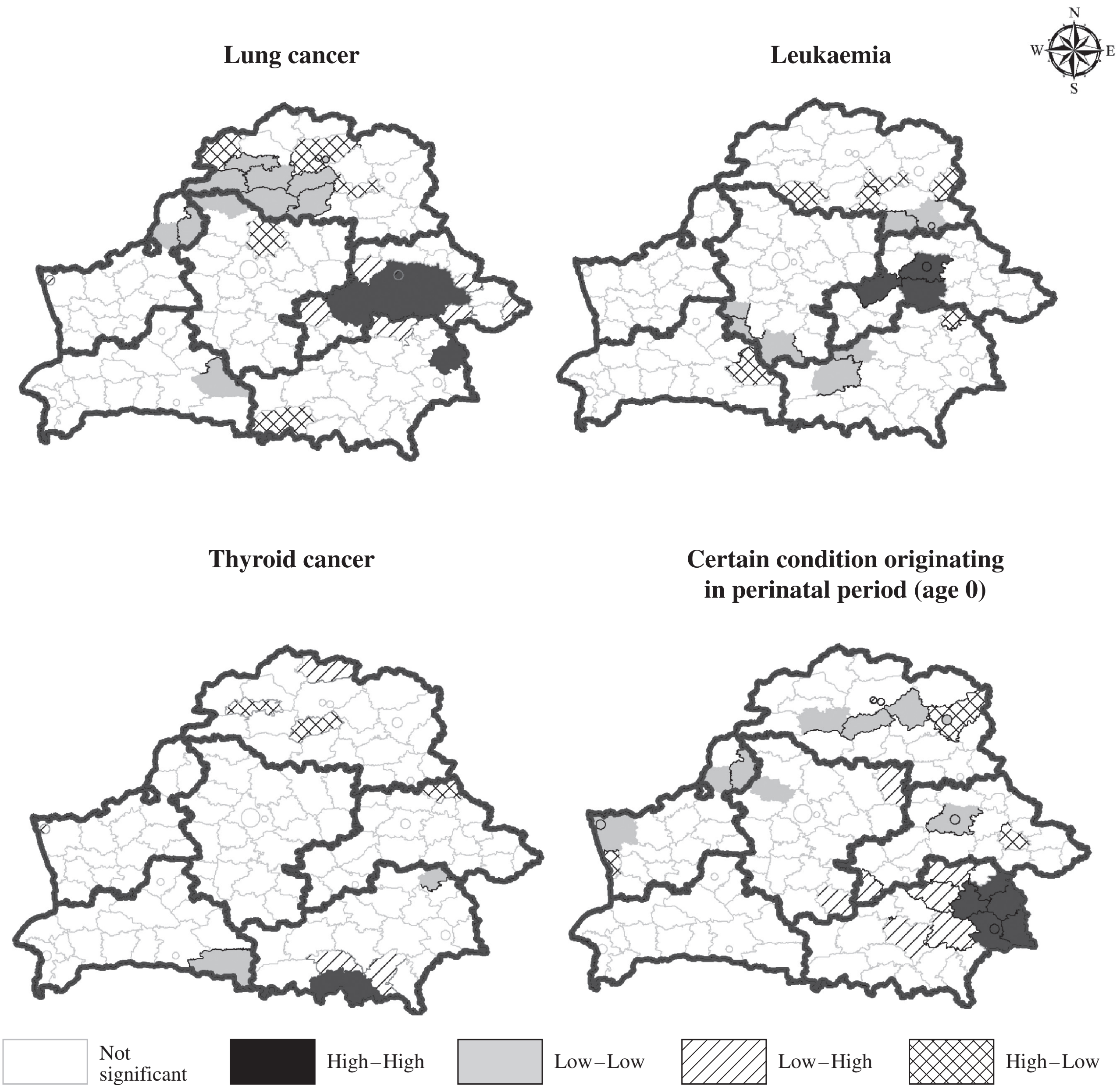

Figure 6 LISA cluster maps of mortality from selected causes of death, both sexes, Belarus 2003–07
Note: Calculations were performed using GeoDa™; $p = 0.05$, 9,999 permutations.
Source: As for Figure 3.

the early 1990s. For this reason, we restricted our analysis to the period from 1997. We were, however, still left with a very limited list of covariates. To select variables for the final model, we took the following steps. First, from the whole set of available indicators, we selected only those for which an association with mortality was supported by the literature. We were looking for covariates which could capture the impact of alcohol consumption, psychological stress, the economic situation and the provision of health care. These factors are believed to be the main mortality determinants in the FSU (Cornia and Paniccià 2000; Brainerd and Cutler 2005). The initial set of explanatory variables included the following: urbanization (percentage of urban population); the real (adjusted for inflation) growth of industrial output (a global measure of economic performance analogous to the GDP at the national level); the ratio of the regional average salary to the country average and the crude divorce rate (as a measure capturing the psychosocial context). We then examined the pair-wise associations between each of these candidate variables and mortality (measured by SDR) by looking at the strength and significance of bivariate correlations. Variables having no or very weak associations with the dependent variable, as well as those causing severe multicollinearity, were

Table 2 Description and summary statistics of variables predicting mortality at the oblast level, Belarus 1997–2007

Variables	Description	Mean (SD)
Unemployment	Unemployment rate (per cent). The official level of unemployment (only those officially registered as being unemployed are counted)	2.2 (0.9)
Poverty	Poverty rate (per cent). The proportion of people with income below the poverty line. Based on the data from the Income and Expenditure of Households Sample Survey	26.7 (13.9)
Alcohol	SDR from accidental poisonings by alcohol (per 100,000). A proxy measure reflecting hazardous alcohol consumption	27.9 (9.4)
Physicians	Number of physicians per 10,000 residents. A crude indicator of the availability of health care resources	42.1 (11.8)

Source: Belstat 1997–2007, 2009b; Belstat official unpublished data.

eliminated from the analysis. As a result, only four predictors were used in the final model: *unemployment*, *poverty*, *alcohol*, and *physicians per head* (Table 2). Clearly, a number of socio-economic, environmental, and other factors still remained unobserved. In this case, applying the panel regression model with fixed effects was a reasonable solution, as it allowed us to control for unobserved heterogeneity. Furthermore, although we could not disentangle ethnic and cultural factors (our descriptive analysis suggested their possible relevance), the model still allowed us to control for differences in these time-invariant, region-specific contextual characteristics.

Because our independent variables were expected to be primarily related to the working-age population, and also because of the lower quality of death registration at older ages, the model was applied to adult ages (15–64) only. As response variables, we chose the SDR by all causes of death, and also the SDR by the two leading causes of death, which were diseases of the circulatory system and external causes of death. The choice of causes of death was also based on the assumption that they respond to changes in

Table 3 Multivariate analysis of factors associated with mortality from selected causes of death at ages 15–64 for males and females at the regional level, Belarus 1997–2007. (Panel regression model with fixed effects)

	Dependent variable (SDR per 100,000 population)						
		Diseases of the circulatory system			External causes		
Independent variables	All causes	All	Heart diseases	Cerebrovascular diseases	All	Suicide	Homicide
				Males			
Unemployment	25.8** (9.1)	14.2** (4.1)	9.7** (3.4)	4.1*** (0.7)	4.6 (3.0)	2.8** (0.8)	0.9 (0.5)
Poverty	0.4 (0.4)	−0.3 (0.2)	−0.4 (0.2)	0.1* (0.1)	0.7*** (0.2)	0.3*** (0.0)	0.1*** (0.0)
Alcohol	5.0*** (0.7)	1.6** (0.4)	1.3** (0.4)	0.2** (0.1)	2.3*** (0.2)	0.3*** (0.1)	0.1** (0.0)
Physicians	−1.8 (1.8)	−1.0 (1.0)	−0.7 (0.8)	−0.3 (0.2)	X	X	X
Constant	687.8	284.4	216.2	63.1	145.2	28.1	3.7
F	103.73	29.84	38.54	198.53	133.83	24.84	49.04
Prob > F	0.0000	0.0004	0.0002	0.0000	0.0000	0.0009	0.0001
Within R^2	0.5701	0.4063	0.3661	0.5553	0.5031	0.5664	0.5360
				Females			
Unemployment	9.4*** (2.0)	6.8*** (1.3)	4.0*** (1.0)	2.6*** (0.6)	1.4** (0.5)	0.4 (0.2)	0.4 (0.3)
Poverty	0.4** (0.1)	0.3** (0.1)	0.1** (0.0)	0.2*** (0.0)	0.1*** (0.0)	0.03** (0.0)	0.1*** (0.0)
Alcohol	1.5*** (0.2)	0.6*** (0.1)	0.5*** (0.1)	0.1 (0.0)	0.7*** (0.1)	0.05* (0.0)	0.1*** (0.0)
Physicians	−0.2 (0.4)	−0.2 (0.3)	−0.1 (0.2)	−0.1 (0.1)	X	X	X
Constant	189.6	70.2	41.2	25.2	22.9	3.8	0.8
F	20.69	27.42	24.19	78.78	38.50	16.99	46.83
Prob > F	0.0012	0.0005	0.0008	0.0000	0.0003	0.0025	0.0001
Within R^2	0.6212	0.7112	0.5878	0.6096	0.5951	0.1762	0.4638

Note: Figures in the table are regression β coefficients; as an independent variable varies over time by one unit, a dependent variable increases or decreases by β units. Standard errors are presented in parentheses ***$p < 0.01$; **$p < 0.05$; *$p < 0.1$. Number of observations $N \times T = 7$ regions $\times$ 11 years = 77.
Source: As for Table 2.

explanatory variables rather promptly. Thus, even though they were among the leading causes of death, cancers were not included in the analysis. The development of cancer is clearly driven by the accumulation of risk over a long period of time, and thus the contemporary factors studied here would not be expected to have an impact on cancer mortality.

The results of the multivariate analysis after controlling for fixed effects are presented in Table 3. They indicate that the covariates included in the model explain about 60 per cent of the variation in overall mortality of males.

It appears that *alcohol* has a direct association with the overall mortality of males, and with mortality from all other selected causes of death. *Unemployment* is associated with all-cause mortality and CVD mortality, but its association with mortality from external causes (except suicide) is not statistically significant. *Poverty* is strongly associated with mortality from external causes of death, including suicide and homicide, but not with all-cause mortality and mortality from CVD. Finally, for all selected causes of death, the mortality effects of the variable *physicians* are not statistically significant.

In terms of the directions and the significance of the associations, the results obtained for females look very similar. All of the explanatory variables except for *physicians* are strongly associated with the mortality of females from all causes of death. An increase in the measure of alcohol abuse (accidental poisoning by alcohol) results in a statistically significant increase in mortality from all selected causes, but not from cerebrovascular diseases. The association between *poverty* and mortality from external causes is also in the expected direction; that is, it is direct and statistically significant.

Discussion

Study limitations

Before discussing the results, some issues of data quality and limitations of the study should be considered. One issue of data quality is the possibility of regional variations in the diagnosis and coding of causes of death. Coding practices and the interpretation of medical rules might vary across the country (especially in the period immediately following the adoption of the ICD-10 in 2002). However, this should not be an issue at the level of the broad groups of causes of death we used in the analysis.

One of the limitations of this study is that it relied on a relatively short time series. Unfortunately, we could not perform a detailed analysis of regional (oblast-level) mortality trends because no detailed, cause-specific series of mortality before the mid-1990s were available to us. The extension of regional mortality trends backwards is desirable since many important changes happened during the early transition years. In exploring mortality trends during these years, we had no alternative to using the highly aggregated official data. The extent of our analysis was also restricted by the availability of regional data on socio-economic indicators. It was very difficult to find trustworthy explanatory variables for the early 1990s, mainly because the national statistical system of Belarus at that time was in the process of development in these first years of independence.

Principal findings

In this study, we analysed regional trends of all-cause and cause-specific mortality, explored the spatial patterns of mortality and assessed the factors associated with mortality fluctuations in the regions of Belarus.

The analysis of overall mortality trends suggests that the inter-regional mortality differences in Belarus are not very pronounced, but that they have been increasing in recent years. This pattern can be seen in the growing mortality difference between the capital and the rest of the country. Apart from the capital, the Brest oblast has the highest life expectancy. In both regions, mortality from external causes of death is substantially lower than elsewhere in Belarus. The increasing regional mortality differentials are also predominatly explained by the diverging mortality rates from external causes of death. The leading cause of death, CVD mortality, explains a substantial part of the mortality gap between the capital and the rest of the country, but not between oblasts. Regional differences in cancer mortality are clearly not the cause of inter-regional mortality variation. In fact, they tend to diminish following the steady mortality decreases from these diseases in all of the regions of Belarus.

The analysis of spatial patterns of mortality yielded several interesting observations. First, overall mortality tends to be higher in the eastern part of Belarus. This east–west divide might have historical and cultural roots. On the one hand, the fact that until 1939 the entire territory of the Grodno oblast and the greater part of the modern Brest oblast belonged to Poland could have had an impact on recent demographic developments in western Belarus. This region may have its own peculiar cultural norms and behavioural patterns. On the other hand, elevated mortality in the eastern part of Belarus might be linked to its geographical proximity to Russia, the country of highest mortality in the region.

Second, in terms of observed cause-of-death mortality patterns, some Belarusian regions are unique. For example, how can the very high mortality from diseases of the digestive system in the Grodno oblast be explained? The analysis of specific causes of death belonging to this category of causes showed that mortality from cirrhosis and fibrosis of the liver is the major contributor to the phenomenon. Since this disease is clearly associated with alcohol, it is reasonable to suppose that drinking patterns (in particular, the type of alcohol consumed) in the Grodno oblast deviate from those in the rest of Belarus. Previous studies have linked the high incidence of liver cirrhosis in Hungary and Slovakia to the widespread consumption of home-made alcoholic beverages derived from plums, apricots, and peaches (Bosetti et al. 2007).

Another interesting observation is that there is a north–south mortality gradient in mortality from diseases of the respiratory system. This could be related to the specific climate conditions of northern Belarus or the proximity to highly polluted industrial centres (i.e., the petrochemical corporation 'Polimir' in Vitebsk oblast and the fertilizer company 'Azot' in Grodno). Other possible explanations include variations in the diagnosis of the causes of death.

Mortality from external causes definitely deserves particular attention since it largely determines the regional variation in all-cause mortality. The large cluster of low mortality from external causes located in the Brest region is unique for Belarus. So is the Brest region itself: the greater part of this oblast belongs to the area known as western 'Polesia', which is populated by people referred to as the western 'Polishuki'. According to some researchers, these people are a Slavic ethnic group who differ from other Belarusians in that they speak their own dialect and possess specific anthropological features (Tserashkovich 2004). The peculiarities of the Brest region's culture, norms, traditions, and behavioural patterns might help explain specific mortality patterns found there.

An examination of the causes of death related to the radiological impact of the Chernobyl accident did not provide a clear picture. The fact that the majority of mortality 'hotspots' for cancers are located in the Mogilev and Gomel oblasts might have some significance. Further, the location of the cluster of high mortality from thyroid cancer in the most contaminated area in the southern part of the Gomel oblast is unlikely to be a coincidence. Yet the observed patterns are not sufficient to allow us to conclude that Chernobyl had a significant impact on recent mortality in the contaminated areas. First, the number of deaths from the causes involved is too small to make statistical inferences reliable. Second, a pronounced impact would have been reflected in a deviating pattern of overall and cause-specific mortality (especially mortality from cancers) in the contaminated districts, and it also would have influenced mortality patterns in the whole Mogilev and Gomel oblasts in a certain way. Yet the results of the analysis of the aggregated mortality data did not show such a deviating pattern. It would not be possible to obtain an accurate assessment of the health effects of the Chernobyl accident without detailed micro-level data that could link histories of exposure with individuals' risks of disease and death. The lack of such data is probably a reason why no consensus has so far been reached about the extent to which the accident has affected population health (see Chernobyl Forum 2006; Yablokov et al. 2007).

The analysis of factors associated with mortality suggests the importance of three factors in explaining the mortality variation for males and females within oblasts: alcohol, unemployment, and poverty. It is not surprising that, of these factors, alcohol, acting as both an immediate and an intermediate mortality determinant, appears to be the most prominent. Excessive alcohol consumption has proven to be the most obvious mortality determinant in the FSU. For decades, it has had a strong impact on mortality trends (Meslé et al. 1992; Shkolnikov and Nemtsov 1997; Razvodovsky 2003). Recent epidemiological case–control studies have shown that mortality among the working-age population is strongly associated with alcohol consumption in Russia (Leon et al. 2007; Zaridze et al. 2009). Both in Russia and in Belarus, alcohol is known to be directly associated not only with mortality from external causes, but also with CVD mortality (McKee and Britton 1998; Malyutina et al. 2002; Razvodovsky 2009). The Belarusian regional data show that there is a direct relationship between alcohol and CVD mortality. The significant association between alcohol and suicide mortality is not surprising: alcohol dependency is known to be associated with depression and self-destructive behaviours, and these psychological characteristics predispose individuals to commit suicide (Kendall 1983).

Unlike the association between alcohol and mortality, the relationships between unemployment and mortality and between poverty and mortality in the FSU have been investigated less extensively. The available literature suggests that unemployment is an important determinant of mortality for adult males in the transition countries (Stuckler et al. 2009), and of suicide mortality in particular (Brainerd 2001). Belarusian regional data suggest that unemployment is directly related to overall mortality, CVD mortality, and suicide among males. Although the explanation of the relationship between unemployment and mortality may seem intuitively obvious, the causal links of this association are not straightforward because a number of confounding factors need to be taken into account. The effect of unemployment on mortality can be mediated through alcohol consumption, psychological stress, and material deprivation (Tomkins et al. 2007). The health-related selection effects (when poor health causes unemployment) complicate the relationship further (Lundin et al. 2010).

A strong association between the level of poverty and mortality caused by violence was observed for both men and women. While poverty was found to be strongly associated with overall and CVD mortality among women, no such association was seen among men. This might be explained by that fact that the socio-economic situation (which we measured by the poverty rate) might be of greater importance for the health status of females. However, the lack of consistency of the poverty–mortality association between the sexes might also indicate that the measure of poverty used in our analysis was not accurate enough. The same can be said about the variable *physicians*. In all models, this variable is inversely related to mortality, which suggests the relevance of health care. However, the fact that the association fails to reach statistical significance points to the need to search for better measures of the quality of health care.

The results of the regression analysis suggest that certain factors known to be associated with mortality in the FSU are also important in Belarus. Our findings are also consistent with the results of individual-level studies conducted in Russia. However, our quantitative relationships cannot be projected automatically to the individual level because of the potential ecological fallacy (Morgenstern 1995).

Further research on regional mortality in Belarus can be enriched by extending the period of observation backwards through the collection of regional mortality data from the archives. It would also be useful to expand and improve the set of explanatory variables by incorporating into the model predictors reflecting, for example, ethnicity and inequality in income distribution. Comparative regional studies across neighbouring countries that have common historical and cultural backgrounds (e.g., Belarus vs. Poland, Lithuania, Russia, and the Ukraine) could be also useful for helping us to better understand recent demographic processes.

Notes

1 Pavel Grigoriev is at the Max Planck Institute for Demographic Research, Konrad-Zuse-Straße 1, 18057 Rostock, Germany. E-mail: grigoriev@demogr.mpg.de. Gabriele Doblhammer-Reiter is at the Max Planck Institute for Demographic Research and the University of Rostock. Vladimir Shkolnikov is at the Max Planck Institute for Demographic Research and the New Economics School, Russia.

2 This study was conducted within the framework of the joint ANR-DFG project ‘European Divergence and Convergence in Causes of Death’. We are very grateful to the three anonymous reviewers for their constructive comments and suggestions.

References

Anderson, Barbara A. and Brian D. Silver. 1997. Issues of data quality in assessing mortality trends and levels in the New Independent States, in J. L. Bobadilla, C. Costello, and F. Mitchell (eds.), *Premature Death in the New Independent States*. Washington, DC: National Academy Press, pp. 120–155.

Andreev, Evgueni M. 1979. Prodolzhitel’nost’ zhizni v SSSR: differentsialniy analiz [Length of life in the USSR: a differential analysis], in Evgueni Andreev and Anatoli Vishnevski (eds.), *Prodolzhitel’nost’ Zhizni: Analiz i Modelirovaniye* [*Length of Life: Analysis and Modelling*]. Moskwa: Statistika, p. 136.

Anselin, Luc. 1995. Local indicators of spatial association—LISA, *Geographical Analysis* 27(2): 93–115.

Anselin, Luc. 2005. *Exploring Spatial Data with GeoDa™: A Workbook*, Revised Version, 6 March 2005. Santa Barbara, CA: Center for Spatially Integrated Social Science. Available: http://www.csiss.org/ (accessed: 21 May 2010).

Belstat. 1997–2007. *Raschody i Dochody Naseliniya Respubliki Belarus* [*Expenditures and Income of the Population of Belarus*]. *Annual Statistical Publications.*

Minsk: National Committee of Statistics of Belarus (Belstat).

Belstat. 2009a. *Population of the Republic of Belarus. Statistical Yearbook*. Minsk: National Committee of Statistics of Belarus, 436 pp.

Belstat. 2009b. *Regiony Respubliki Belarus* [*The Regions of the Republic of Belarus*]. *Statistical Yearbook*. Minsk: National Committee of Statistics of Belarus, 870 pp.

Blažek, Jiri and Dagmar Dzúrová. 2000. The decline of mortality in the Czech Republic during the transition period: a counterfactual case study, in G. A. Cornia and R. Paniccià (eds.), *The Mortality Crisis in Transitional Economies*. Oxford: Oxford University Press, pp. 303–327.

Bobadilla, José L. and Christine A. Costello. 1997. Premature death in the Independent States: overview, in J. L. Bobadilla, C. Costello, and F. Mitchell (eds.), *Premature Death in the New Independent States*. Washington, DC: National Academy Press, pp. 1–33.

Bobak, Martin, Hynek Pikhart, and Michael Marmot. 1998. Socioeconomic factors, perceived control and self-reported health in Russia. A cross-sectional survey, *Social Science and Medicine* 47(2): 269–279.

Bobak, Martin, Hynek Pikhart, Richard Rose, Clyde Herzman, and Michael Marmot. 2000. Socioeconomic factors, material inequalities, and perceived control in self-rated health: cross-sectional data from seven post-communist countries, *Social Science and Medicine* 51(9): 1343–1350.

Bosetti, Cristina, Fabio Levi, Franca Lucchini, Witold A. Zatonski, Eva Negri, and Carlo La Vecchia. 2007. Worldwide mortality from cirrhosis: an update to 2002, *Journal of Hepatology* 46(5): 827–839.

Brainerd, Elizabeth. 1998. Market reform and mortality in transition economies, *World Development* 26(11): 2013–2027.

Brainerd, Elizabeth. 2001. Economic reform and mortality in the former Soviet Union: a study of the suicide epidemic in the 1990s, *European Economic Review* 45(2001): 1007–1019.

Brainerd, Elizabeth and David M. Cutler. 2005. Autopsy on an empire: understanding mortality in Russia and the Former Soviet Union, *Journal of Economic Perspectives* 19(1): 107–130.

Chernobyl Forum. 2006. *Chernobyl's Legacy: Health, Environmental and Socio-economic Impacts and Recommendations to the Governments of Belarus, the Russian Federation and Ukraine*, Chernobyl Forum: 2003–2005, Second Revised Version. Vienna: IAEA. Available: http://www.iaea.org (accessed: 26 October 2009).

Cockerham, William C., Brian P. Hinotea, and Pamela Abbott. 2006. Psychological distress, gender, and health lifestyles in Belarus, Kazakhstan, Russia, and Ukraine, *Social Science and Medicine* 63(9): 2381–2394.

Cornia, Giovanni A. and Renato Paniccià. 2000. The transition mortality crisis: evidence, interpretation, and policy responses, in G. A. Cornia and R. Paniccià (eds.), *The Mortality Crisis in Transitional Economies*. Oxford: Oxford University Press, pp. 3–37.

DIVA-GIS. 2010. Portal containing free spatial data. Available: http://www.diva-gis.org/ (accessed: 10 June 2010).

Dzúrová, Dagmar. 2000. Mortality differentials in the Czech Republic during the post-1989 socio-political transformation, *Health & Place* 6(4): 351–362.

Eberstadt, Nick. 1981. The health crisis in the USSR, *The New York Review of Books*, 19 February: 23–31 (reprinted in *International Journal of Epidemiology* 35(1): 384–394, 2006).

Feshbach, Murray. 1984. Soviet health problems, *Proceedings of the Academy of Political Science* 35(3): 81–97.

Grigoriev, Pavel, Vladimir Shkolnikov, Evgueni Andreev, Domantas Jasilionis, Dmitri Jdanov, France Meslé, and Jacques Vallin. 2010. Mortality in Belarus, Lithuania, and Russia: divergence in recent trends and possible explanations, *European Journal of Population* 26(3): 245–274.

Józan, P. and D. P. Forster. 1999. Social inequalities and health: ecological study of mortality in Budapest, 1980–3 and 1990–3, *British Medical Journal* 318(7188): 914–915.

Józan, Péter and Remigijus Prokhorskas. 1999. *Atlas of Leading and 'Avoidable' Causes of Death in Countries of Central and Eastern Europe*. Budapest: Hungarian Central Statistical Office.

Kalediene, Ramune and Jadvyga Petrauskiene. 2000. Regional life expectancy patterns in Lithuania, *European Journal of Public Health* 10(2): 101–104.

Kalediene, Ramune and Jadvyga Petrauskiene. 2004. Socio-economic transition, inequality, and mortality in Lithuania, *Economics and Human Biology* 2(1): 87–95.

Kendall, R. E. 1983. Alcohol and suicide, *Substance and Alcohol Actions/Misuse* 4(2/3): 121–127.

Kolodziej, H. and M. Lopuszańska. 2010. Regional differences in premature mortality in Poland [in Polish], *Przeglad Epidemiologiczny* 64(4): 543–550.

Krumins, Juris, Domantas Jasilionis, Mall Leinsalu, and Vlada Stankuniene. 2009. Changes of geographical mortality differences in the three Baltic countries during the period of socio-economic transformation. Paper presented at the IUSSP 26th International Population Conference, Marrakech.

Leon, David A., Lyudmila Saburova, Susannah Tomkins, Evgueny Andreev, Nikolay Kiryanov, Martin McKee, and Vladimir M. Shkolnikov. 2007. Hazardous alcohol drinking and premature mortality in Russia: a population based case–control study, *Lancet* 369(9578): 2001–2009.

Lundin, A., I. Lundberg, L. Hallsten, J. Ottosson, and T. Hemmingsson. 2010. Unemployment and mortality—a longitudinal prospective study on selection and causation in 49321 Swedish middle-aged men, *Journal of Epidemiology and Community Health* 64(1): 22–28.

Malyutina, Sofia, Martin Bobak, Svetlana Kurilovitch, Valery Gafarov, Galina Simonova, Yuri Nikitin, and Michael Marmot. 2002. Relation between heavy and binge drinking and all-cause and cardiovascular mortality in Novosibirsk, Russia: a prospective cohort study, *Lancet* 360(9344): 1448–1454.

Mathers, Colin D., Doris Ma Fat, Mie Inoue, Chalapati Rao, and Alan D. Lopez. 2005. Counting the dead and what they died from: an assessment of the global status of cause of death data, *Bulletin of the World Health Organization* 83(3): 161–240.

McKee, Martin and Annie Britton. 1998. The positive relationship between alcohol and heart disease in Eastern Europe: potential physiological mechanisms, *Journal of the Royal Society of Medicine* 91(8): 402–407.

McKee, Martin. 2001. The health effects of the collapse of the Soviet Union, in D. Leon and G. Walt (eds.), *Poverty and Inequality in Health*. Oxford: Oxford University Press, pp. 17–36.

McKee, Martin. 2006. Commentary: The health crisis in the USSR: looking behind the facade, *International Journal of Epidemiology* 35(6): 1398–1399.

Meslé, France, Vladimir Shkolnikov, and Jacques Vallin. 1992. Mortality by cause in the USSR population in the 1970–1987: the reconstruction of time series, *European Journal of Population* 8(4): 281–308.

Morgenstern, H. 1995. Ecologic studies in epidemiology: concepts, principles, and methods, *Annual Review of Public Health* 16: 61–81.

Okeanov, A. E., E. Y. Sosnovskaya, and O. P. Priatkina. 2004. A national cancer registry to assess trends after the Chernobyl accident, *Swiss Medical Weekly* 134(43): 645–649.

Preston, Dale L., Shizuyo Kusumi, Masao Tomonaga, Shizue Izumi, Elaine Ron, Atsushi Kuramoto, et al. 1994. Cancer incidence in atomic bomb survivors. Part III: leukemia, lymphoma and multiple myeloma, 1950–1987, *Radiation Research* 137(2 Suppl): 68–97.

Razvodovsky, Yury E. 2003. *Alcohol and Mortality Crisis in Belarus*. Grodno: Medical University Press.

Razvodovsky, Yury E. 2009. Aggregate level beverage specific effect of alcohol sale on myocardial infarction mortality rate, *Adicciones* 21(3): 229–237.

Shkolnikov, Vladimir M. 1987. Geograficheskiye faktori prodoljitelnosti jizni [Geographical factors of length of life], *Izvestiya AN SSSR, Seriya Geograficheskaya* [*Academy of Sciences of the USSR*] 3(12): 35–44.

Shkolnikov, Vladimir, France Meslé, and Jacques Vallin. 1996. Health crisis in Russia. I. Recent trends in life expectancy and causes of death from 1970 to 1993, II. Changes in causes of death: a comparison with France and England and Wales (1970 to 1993), *Population: An English Selection* 8: 123–190.

Shkolnikov, Vladimir M. and Alexander Nemtsov. 1997. The anti-alcohol campaign and variations in Russian mortality, in J. L. Bobadilla, C. Costello, and F. Mitchell (eds.), *Premature Death in the New Independent States*. Washington, DC: National Academy Press, pp. 239–261.

Shkolnikov, Vladimir M., Giovanni A. Cornia, David A. Leon, and France Meslé. 1998. Causes of the Russian mortality crisis: evidence and interpretations, *World Development* 26(11): 1995–2011.

Shkolnikov, Vladimir M., Evgueni M. Andreev, David A. Leon, Martin McKee, France Meslé, and Jacques Vallin. 2004. Mortality reversal in Russia: the story so far, *Hygiea Internationalis: An Interdisciplinary Journal for the History of Public Health* 4(1): 29–80.

Spijker, Jeroen. 2009. Explanations for the age, sex, spatial and temporal structure of Czech mortality for the period 1987–97, *Environment and Planning A* 41(3): 682–702.

Stuckler, David, Lawrence King, and Martin McKee. 2009. Mass privatisation and the post-communist mortality crisis: a cross-national analysis, *Lancet* 373(9661): 399–407.

Sumner, David. 2007. Health effects resulting from the Chernobyl accident, *Medicine, Conflict and Survival* 23(1): 31–45.

Tomkins, S., L. Saburova, N. Kiryanov, E. Andreev, M. McKee, V. Shkolnikov, and D. Leon. 2007. Prevalence and socio-economic distribution of hazardous patterns of alcohol drinking: study of alcohol consumption in men aged 25–54 years in Izhevsk, Russia, *Addiction* 102(4): 544–553.

Tserashkovich, P. V. 2004. *Ethnicheskay Istoriya Belarusi XIX–nachala XX Veka: v Kontexte Centralno-Vostochnoi Evropy* [*Ethnic History of Belarus of the XIXth–Beginning of the XXth Century: In Context of Central-Eastern Europe*]. Minsk: Belarussian State University.

UNDP. 2005. *Belarus: Addressing Imbalances in the Economy*, National Human Development Report 2004/2005. Minsk, Belarus: UNDP.

Vallin, Jacques, Evgeni Andreev, France Meslé, and Vladimir Shkolnikov. 2005. Geographical diversity of cause of death patterns and trends in Russia, *Demographic Research* 12(13): 323–380.

Walberg, Peder, Martin McKee, Vladimir Shkolnikov, Laurent Chenet, and David A. Leon. 1998. Economic change, crime and Russian mortality crisis: a regional analysis, *British Medical Journal* 317(7154): 312–318.

Waterhouse, J. A. H., C. S. Muir, P. Cornea, and J. Powell. 1976. *Cancer Incidence in Five Continents,* Vol. III. Lyon: International Agency for Research on Cancer, pp. 454–459.

Wooldridge, Jeffrey M. 2002. *Econometric Analysis of Cross Section and Panel Data*. Cambridge, MA: MIT Press.

Yablokov, A. V., V. B. Nesterenko, and A. B. Nesterenko. 2007. *Chernobyl': Posledstviya Katastrophy dlya Cheloveka i Prirody* [*Chernobyl: Consequences of the Catastrophe for People and the Environment*]. Sankt-Petersburg: Nauka. Available: http://www.rus-green.ru/publications/fil_yablokov2.pdf (accessed: 23 July 2010).

Zaridze, David, Paul Brennan, Jillian Boreham, Alex Boroda, Rostislav Karpov, Alexander Lazarev, et al. 2009. Alcohol and cause-specific mortality in Russia: a retrospective case–control study of 48 557 adult deaths, *Lancet* 373(9682): 2201–2214.

Zuravkov, V. V. and V. P. Mironov. 2005. Ispol'zovanie GIS-technologii pri ocenke zagryzneniya territorii RB radionuklidami ioda na aktivnoi stadiii [Using GIS technology in the assessment of the contamination of the territory of the Republic of Belarus with radio-nuclides of iodine], *Izvestiya Belorusskoy Ingenernoy Akademyi* 2(20): 187–189.

Appendix A. List of causes of death used in the analysis and their correspondence to the Soviet classification of 1988, abridged list of ICD-10 used in Belarus, and ICD-10

	Abridged version of ICD-10 used in Belarus (2002–)	Soviet classification of 1988 (1988–2001)	ICD-10 (detailed list)
Infectious diseases	**1–58**	**1–44**	**A00–A99, B00–B99**
Tuberculosis	9–17, 57	9–13, 43	A15–A19, B90
Cancers	**59–94**	**45–67**	**C00–C97, D00–D48**
Cancer of lip, oral cavity, and pharynx	59	45	C00–C14
Cancer of oesophagus	60	46	C15
Cancer of stomach	61	47	C16
Cancer of larynx, trachea, bronchial tubes, and lungs	68–69	52, 53	C32–C34
Cancer of the breast	75	57	C50
Cancer of uterus	76–77	58, 59	C53–C55
Cancer of prostate	80	61	C61
Cancer of thyroid gland	86	64	C73
Leukaemia	91,92	65	C91–C95
Diseases of the circulatory system	**124–159, 253**	**84–102, 158**	**I00–I99, R54**
Heart diseases plus senility[1]	124–143,253	84–97, 158	I00–I52, R54
Senility	253	158	R54
Cerebrovascular diseases	144–153	98, 99	I60–I69
Diseases of the respiratory system	**160–177**	**103–114**	**J00–J99**
Diseases of the digestive system	**178–193**	**115–127**	**K00–K93**
Cirrhosis and fibrosis of liver	186–187	122–123	K70, K74
Other causes of death	**Residual**	**Residual**	**Residual**
Certain conditions originating in perinatal period	219–235	151–157	P00–P96
External causes	**256–277**	**160–175**	**V01–Y84**
Motor vehicle transport accidents	256–262	160–162	V01–V89, V98–V99
Accidental poisoning by alcohol	269	163	X45
Suicide	271	173	X60–X84
Homicide	272	174	X85–Y09
Unspecified violent death	273	175	Y10–Y34
Other accidents	263–268, 270, 274–277	164–172	W00–W99, X00–X44, X46–X99, Y40–Y84
All causes	**1–277**	**1–175, 206**	**A00–R99, V01–Y98**

[1]Item ‘senility’ was combined with ‘atherosclerotic cardiosclerosis’ (and consequently with heart diseases) because there were some reasons to suspect an exchange between these items. First, in Belarus an artificial rise of the share of ‘senility’ in the total number of deaths (from 0.07 to 12 per cent between 1988 and 1991) occurred at the expense of cardiovascular diseases, and the increase was related to a special directive of the Ministry of Health of the USSR regarding the registration of senility and CVD mortality at older ages (see Shkolnikov et al. 1996). Also, in the Soviet system of death registration (which is still largely maintained in Belarus), the leading cause of death of a significant proportion of imprecise diagnoses was ‘atherosclerotic cardiosclerosis’ (Vallin et al. 2005), making this well-defined item somewhat ‘ill-defined’.

Appendix B. Summary statistics for the number of deaths by causes; 'rayon' level, 5-year period, Belarus 2003–07

	118 rayons				13 cities			
	Min	Max	Mean	SD	Min	Max	Mean	SD
All causes	1,050	13,362	3,975	2,094	2,711	167,266	23,933	43,586
Males	558	7,114	2,060	1,144	1,605	92,386	13,204	24,065
Females	492	6,248	1,915	956	1,106	74,880	10,728	19,522
Infectious diseases	3	339	36	39	26	1,610	257	419
Cancers	319	1,577	446	291	410	31,296	4,289	8,200
Lung cancer	23	336	108	62	81	5,170	751	1,344
Cancer of thyroid gland	0	7	1	1	2	92	13	24
Leukaemia	1	50	15	10	17	1,172	160	310
Diseases of the circulatory system	611	8,558	2,190	1,260	1,335	89,836	12,950	23,400
Diseases of the respiratory system	16	548	165	115	33	3,978	584	1,036
Diseases of the digestive system	10	479	96	78	109	7,650	1,022	2,009
External causes	111	1,518	445	256	468	19,738	2,875	5,130
Certain conditions originating in perinatal period	0	26	6	5	6	482	61	128

Source: Belstat official unpublished data.

Appendix C. Age-standardized death rates (SDRs) from selected causes of death by region and sex, Belarus 2005–07

	Males								Females							
	Total	Brest	Vitebsk	Gomel	Grodno	Minsk-city	Minsk	Mogilev	Total	Brest	Vitebsk	Gomel	Grodno	Minsk-city	Minsk	Mogilev
All causes	**1,826.1**	**1,746.4**	**1,896.2**	**1,880.0**	**1,914.6**	**1,502.4**	**1,986.3**	**1,935.3**	**854.2**	**827.0**	**887.7**	**867.0**	**876.6**	**709.9**	**917.4**	**918.1**
Infectious diseases	**23.7**	**17.1**	**21.2**	**39.7**	**29.3**	**14.2**	**21.9**	**26.4**	**5.2**	**4.5**	**4.9**	**8.6**	**6.1**	**3.7**	**3.6**	**5.6**
Tuberculosis	16.5	14.6	15.1	20.1	24.4	9.4	16.2	19.9	2.2	2.2	2.1	2.9	2.5	1.3	2.1	2.6
Cancers	**261.7**	**243.4**	**260.4**	**271.3**	**260.8**	**276.5**	**257.7**	**272.3**	**110.6**	**103.6**	**110.1**	**107.1**	**104.7**	**139.0**	**101.0**	**112.0**
Cancer of lip, oral cavity, and pharynx	14.3	9.3	14.5	18.6	16.2	11.0	16.1	15.7	0.9	0.9	0.7	1.0	0.7	1.20	0.8	1.1
Cancer of oesophagus	7.9	7.1	5.6	7.7	8.9	7.6	9.3	9.4	0.5	0.2	0.2	0.9	0.5	0.6	0.6	0.3
Cancer of larynx, trachea, bronchus, and lung	82.2	82.7	81.9	87.4	83.5	70.1	87.8	86.0	5.5	5.6	6.1	4.4	6.0	7.1	4.4	5.5
Cancer of stomach	36.5	34.4	39.4	37.0	32.7	37.2	37.1	38.8	14.1	13.0	14.7	14.5	11.6	14.9	13.8	16.3
Cancer of prostate	18.6	13.8	20.4	18.5	16.8	24.0	18.8	18.0	–	–	–	–	–	–	–	–
Cancer of the breast	0.2	0.2	0.1	0.2	0.3	0.3	0.0	0.0	19.9	18.6	19.3	17.4	20.7	26.2	18.6	18.5
Cancer of the uterus	–	–	–	–	–	–	–	–	10.9	9.6	10.6	11.0	8.9	12.8	11.0	13.0
Diseases of the circulatory system	**1,033.4**	**1,069.7**	**1,001.1**	**1,054.9**	**1,009.5**	**850.6**	**1,141.9**	**1,112.4**	**592.2**	**602.3**	**591.5**	**611.4**	**592.3**	**450.8**	**649.2**	**649.9**
Heart diseases plus senility	802.5	887.9	741.8	851.9	793.2	558.2	902.9	878.0	447.1	489.5	425.6	486.8	455.4	268.6	492.5	502.9
Senility	98.0	157.1	113.2	109.5	67.7	37.4	82.3	115.8	120.4	164.0	142.0	141.4	89.0	51.9	102.1	144.0
Cerebrovascular diseases	170.8	125.6	173.3	157.6	169.7	211.4	182.2	187.4	114.2	80.0	122.7	101.4	114.6	143.0	125.1	123.4
Diseases of the respiratory system	**93.8**	**59.1**	**167.3**	**66.1**	**151.9**	**46.7**	**94.5**	**83.9**	**16.5**	**8.4**	**31.6**	**9.4**	**32.2**	**9.1**	**15.3**	**11.1**
Diseases of the digestive system	**60.0**	**53.1**	**55.5**	**58.1**	**74.0**	**69.6**	**56.8**	**54.9**	**28.9**	**23.7**	**28.9**	**27.4**	**35.5**	**30.9**	**29.9**	**28.5**
Cirrhosis and fibrosis of liver	35.8	33.8	33.9	30.4	48.7	40.2	32.8	32.0	18.6	15.2	20.4	15.9	25.1	17.3	20.0	18.5
Injury and poisoning	**264.4**	**219.1**	**317.9**	**273.7**	**299.6**	**183.4**	**306.8**	**287.8**	**58.8**	**44.1**	**78.4**	**55.6**	**63.4**	**41.8**	**71.4**	**67.5**
Motor vehicle transport accidents	31.4	33.1	32.9	28.8	31.5	22.1	45.0	29.1	8.8	8.2	9.4	7.7	8.8	7.3	12.7	9.0
Accidental poisoning by alcohol	47.8	26.1	69.5	50.5	70.3	33.1	38.1	59.8	12.1	5.6	21.0	11.6	16.7	6.8	11.4	16.1
Suicide	50.3	45.1	67.1	53.3	58.3	20.8	61.5	57.9	7.5	5.8	10.7	7.2	7.2	3.9	9.7	9.7
Homicide	10.7	6.5	15.4	13.6	9.2	5.0	13.3	13.8	4.2	2.8	5.5	5.1	4.5	1.8	5.2	5.7
Unspecified violent death	29.4	29.6	23.5	25.0	14.0	43.8	32.8	32.0	6.6	8.1	6.5	5.1	4.0	8.5	7.0	6.6
Other accidents	94.8	78.7	109.5	102.5	116.5	58.6	116.1	95.2	19.6	13.6	25.3	18.9	22.2	13.5	25.4	20.4
Other causes of death (residual)	**89.1**	**84.9**	**72.8**	**116.2**	**89.5**	**61.4**	**106.7**	**97.6**	**42.0**	**40.4**	**42.3**	**47.5**	**42.4**	**34.6**	**47.0**	**43.5**

Source: Belstat official unpublished data.