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Regional analysis of mortality by causes of death in Russia

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Mortality indicators may be a valuable characteristic of examining different aspects of a population's well-being: its economic and social development, quality of health care services, personal values in health and safety, etc. Mortality decline and life expectancy growth are an essential goal for Russia. The Presidential Order of May 7, 2018 lists the increase of life expectancy to 78 years[1] as one of the priorities of national development (in the year 2015, life expectancy at birth in Russia was 71.4 years for both sexes).

High mortality in Russia attracts much attention, yet most studies devoted to this topic use the mortality indicators calculated for the country as a whole. Not many studies perform mortality analyses at the subnational level. However, mortality indicators for the total Russian population comprise a considerable variability of indicators calculated for various territories within Russia. In 2015, at the regional level, life expectancy at birth in Russia deviated from 63.1 years in the Tuva Republic to 80.1 years in the Ingushetia Republic[2]; a gap of 17 years. Standard deviation (not weighted by population size of the regions) was 2.4 years. To compare, standard deviation across the regions of the European Union countries (NUTS2 level)[3] is the same 2.4 years, while the gap between the minimum and the maximum life expectancies (73.5 years in North-West region of Bulgaria and 84.5 years in Madrid autonomous community) was just 11.0 years. While some level of mortality inequality is inevitable, extremely high inequality indicates that there is an unequal distribution of some resources essential for the health and safety of a population.

To reach the goal of life expectancy growth set for Russia in the most effective way, it would be best to shrink mortality inequality at the regional level following the

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[1] The Presidential Order of May 7, 2018 «On National Goals and Strategic Objectives of the Russian Federation through to 2024».

[2] These estimates were officially published by the Federal Statistics Service of the Russian Federation. However it is worth to mention that the accuracy of these estimates for certain regions including the Ingush Republic is questionable (Andreev E. On the accuracy of Russian Censuses // Voprosy Statistiki. 2006. №11. P. 21-35; Bogoyavlensky D. Were all Russian nationalities calculated correctly? // Демоскоп Weekly. – 2008. – № 319-320).

[3] URL: http://ec.europa.eu/eurostat/web/products-datasets/product?code=tgs00101

decline of mortality at the national level, allowing those regions lagging behind in life expectancy to catch up with the leaders. To understand how to reduce interregional inequality in life expectancy, and what interventions should be organized for it, a complex analysis of regional patterns of mortality by age and causes of death is needed. This paper presents such an analysis.

Mortality analysis at the subnational level is essential for identifying regional peculiarities in mortality and for planning territory-oriented programs for its decline. Such analyses allow us to identify and systematize the most effective programs aimed at mortality reductions in different territories, which in turn can lead to implementation of programs at the Federal level and assessment of the results of these programs.

Previous studies on this topic

Demographic and epidemiological studies rely on the analysis of mortality patterns and trends by age and causes of death and a theoretical understanding thereof. Concepts which build a theoretical framework for the current study were presented in the papers of B.Ault, J Bourgeois-Pichat, T.Frejka, J.Frenk, R.Hackenberg, R.Lozano, A.Olshansky, A.Omran, R.Rogers, F.Mesle, and J.Vallin. The works of these authors linked the evolution of cause-specific mortality structure with the change of all-cause mortality level and life expectancy. In the Russian literature, theoretical interpretation of the evolution of mortality patterns was presented in the studies of A.G.Vishnevsky.

The analysis of life expectancy trends in Russia during the Soviet era was performed by E.M.Andreev, M.S.Bedny, R.N.Biryukova, V.A.Bystrova, A.G.Vishnevsky, R.M.Dmitrieva, V.K.Ovcharov, B.C.Urlanis, K.Yu.Shaburov, V.M.Shkolnikov, and others. However, until the late 1980s these researchers had only limited access to the demographic data. It was even prohibited to publish some

indicators. Consequently, the number of studies devoted to mortality analysis under the Soviet regime was low, and the studies themselves were not well detailed[4].

In "Glasnost" period of the late 1980s mortality data became more readily available for researchers. During the joint project of the Center of Human Demography and Ecology (Moscow) and the National Institute of Demographic Studies (Paris) data on death counts by causes of death in Russia during the Soviet period that were held in Goskomstat, Ministry of Healthcare of the Russian Federation, and the Russian State Archive were collected, verified, and digitalized. This laborious process, coupled with work on the reconstruction of continuous mortality trends by causes of death performed by F.Meslé, V.M.Shkolnikov, J.Vallin, V.Ertrish and E.M.Andreev, allowed mortality trends in Russia (also by causes of death) to be analyzed for a longer time period. Newly opened access to this mortality data highlighted the unfavorable trends in Russian mortality.

This data availability as well as the unique mortality trends observed in Russia attracted much interest on the part of demographers, epidemiologists, and other researchers who were pursuing the analysis of different aspects of Russian mortality. A large contribution to the mortality analysis in this period was made by E.M.Andreev, O.I.Antonova, D.D.Bogoyavlensky, A.G.Vishnevsky, L.A.Gavrilov, N.S.Gavrilova, E.V.Dubrovina, A.E.Ivanova, E.A.Kvasha, A.V.Nemtsov, T.P.Sabgayda, V.G.Semenova, T.L.Kharkova, V.M.Shkolnikov, D.Leon, M.McKee, F.Mesle, W.Pridemore, J.Vallin, and others. Their papers extensively described the dynamics and structure of Russian mortality. The hypotheses of the factors affecting mortality levels in Russia were also set out in these papers.

The Russian mortality crisis of the mid-1960s – early 2000s has been studied quite explicitly. In particular, the studies of A.V.Nemtsov and V.M.Shkolnikov

[4] Vishnevsky A.G., Shkolnikov V., Vassin S. A. Epidemiological Transition and Regional Contrasts. // Genus (Roma). 1991. V. XVLII. № 3-4. P. 79-100; Meslé, F., Shkolnikov, V. M., Hertrich, V., & Vallin, J. (1996). Tendances récentes de la mortalité par cause en Russie 1965-1994. Série: Données statistiques No 2. Paris: INED.

highlighted a clear link between alcohol consumption and mortality fluctuations in Russia. The Izhevsk Family Studies held in the city of Izhevsk[5] helped prove that alcohol consumption in Russia influences not only mortality from alcohol-related causes and external causes of death, but also it influences mortality from circulatory diseases. Analyses of the influence of other factors – including smoking, social and psychological stress, and underdevelopment of healthcare services – were performed by G.Cornia, W.Cockerham, M.Field, D.Holmes, D.Leon, R.Paniccia, K.Danishevsky, V.M.Shkolnikov, and others.

Much has been written about the unfinished epidemiological transition in Russia (A.G.Vishnevsky, V.M.Shkolnikov). There was even an opinion of a reverse epidemiological transition in Russia, which aimed to highlight the regressive character of mortality trends in Russia (V.Semenova).

After almost half a century of negative tendencies in mortality, a sustained vector of growing life expectancy was eventually established in Russia starting in the middle of the first decade of the 21st century. In recent years studies devoted to the current period of mortality decline and life expectancy growth have been published in Russia (E.M.Andreev, A.G.Vishnevsky, E.A.Kvasha, T.L.Kharkova, V.M.Shkolnikov, P.Grigoriev, D.Leon, and others). These authors highlight that life expectancy growth in Russia still has a recovering character to a great extent, compensating for the earlier decline. However, some of these studies also show that the favorable tendencies of the recent period of life expectancy growth in Russia are also related to a large extent to the mortality decline stemming from circulatory diseases among the elderly. The latter is a new tendency for Russia, one which may indicate that Russia is moving towards a new stage of epidemiological transition. This new stage is known as the cardiovascular

[5] URL: http://www.ifsmetadata.info/

revolution[6], as mortality reductions from circulatory diseases among the elderly are contributing the most to the further growth of life expectancy.

Mortality trends and patterns in Russia are studied at the national level quite explicitly. Although there is some research on subnational mortality in Russia, these patterns are still understudied. Spatial mortality peculiarities have been examined by E.M.Andreev, S.A.Vassin, E.A.Kvasha, T.L.Kharkova, V.M.Shkolnikov, H.Vallin, G.Cornia, and others. A North-West mortality gradient, manifested through the growing mortality levels while moving from the south to north and from the west to east, has been identified and described. Spatial analyses of mortality from specific groups of causes of death: external causes, neoplasms, circulatory diseases, have been performed in the studies of E.M.Andreev, O.I.Antonova, A.G.Vishnevsky, S.V.Kondrichin, Yu.V.Razvodovsky, and S.A. Timonin.

The Institute of Demography of HSE regularly addresses issues of regional inequality in mortality and life expectancy. In its annual demographic reports "Population of Russia", a special section in the Chapter "Mortality and life expectancy" is devoted to the regional differences in mortality.

Studies devoted to the regional analysis of mortality are still quite fragmentary and tend to reduce the analysis to the description of the statistical data. The interrelation between mortality differences in life expectancy and mortality differences in mortality levels from specific causes of death as well as the interrelation between national and subnational mortality indicators are still understudied. In addition, the studies which are conducted do not pay enough attention to the issue of quality and comparability of cause-specific mortality data gathered by the regions. The latter is necessary to assure reliable and correct results. These considerations motivated the direction of our study to focus on the regional peculiarities of mortality in Russia.

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[6] Meslé F., Vallin J. Mortality in Europe: The divergence between East and West // Population (English edition). 2002. №57 (1). P. 157–197.

The objective of the study: use statistics on the regional mortality by causes of death to evaluate the inequality of the progress of regions in the epidemiological transition and to estimate the components of persisting large regional disparity in life expectancy.

To reach this goal the following tasks had to be completed:

1. Evaluate the quality and comparability of the statistical data on mortality gathered by the regions (all-cause and cause-specific) in Russia at the regional level;
2. Track how changes in life expectancy at the regional level followed the changes in life expectancy at the national level. Determine which regions experienced the changes in life expectancy significantly higher or lower of those observed for Russia as a whole;
3. Analyze the changes in interregional life expectancy inequality and its interrelation with the changes in life expectancy at the national level in Russia;
4. Estimate the contribution of single age groups and causes of death to interregional life expectancy inequality in Russia and to the changes of the inequality over time;
5. Determine spatial characteristics of mortality differentiation for single age groups and causes of death and estimate the interregional inequality.

Theoretical background of the study

- The concept of the epidemiologic transition of A.Omran;
- The concept of health transition of J.Frenk et al., who rethought and developed the concept of epidemiologic transition;
- Theoretical views on the processes of divergence and convergence of demographic processes during the demographic transition and health transition in particular.

Data and methods

1. Data provided by the Federal State Statistics Service of the Russian Federation (the Rosstat). We used population estimates and death counts for the period 1989-2015 by age (5-year age groups), sex, regions, and causes of death. The data for Russia as a whole is available for the period 1965-2015;

2. Data from the Russian Fertility and Mortality Database of the Center for Demographic Research of the New Economic School. Mortality rates and population estimates by age (1-year age groups), sex, and region for the period 1989-2015 were used, as were regional mortality data for the around-census periods 1969-1970 and 1979-1980;

3. To compare mortality levels across countries, the data from the Human Mortality Database (a joint project of Max-Planck Institute for Demographic Research and University of Berkley, California) were used;

4. To decompose the gap in life expectancy between the groups of Russian regions and Poland, the data of the Human Cause-of-Death Database (a joint project of Max-Planck Institute for Demographic Research and the French Institute for Demographic Studies of INED) were used;

5. The data on the causes of death in the departments of France were provided by the French Institute for Demographic Studies (INED).

6. To plot the data on the maps, an open dataset of spatial objects was downloaded from the GIS-Lab.

The following methods were used in the study:

- The methods of demographic analysis of mortality (including the methods of standardization of mortality rates, constructing life tables)

- The method of step-wise replacement decomposition of life expectancy by age and causes of death[7];
- Statistical methods for analyzing distributions;
- The methods of spatial analysis (mapping, estimating indices of spatial autocorrelation).

The novelty of this study

1. A complex analysis of the quality and comparability of the mortality data gathered at the regional level in the Russian Federation was performed. The leading problems with the data were systematized: lowered mortality rates at very old ages, incomparability of regional approaches to the selecting of the underlying cause of death, the influence of "Senility" on the mortality rates from the other causes of death at ages over 80. In the study, a list of causes of death was proposed which made it possible to perform regional mortality analysis by causes under the circumstances of different approaches to certification and coding of the underlying cause.
2. Regional trajectories of the changes in the life expectancy from the late 1960s to 2015 were traced. We defined the regions where the trends of the changes in life expectancy were unique and distinguishing from those observed for Russia as a whole. We identified the diverging contribution of the cities of Moscow and Saint-Petersburg to the change of inter-regional inequality in life expectancy.
3. We analyze the changes of the inter-regional inequality in life expectancy over time and identify the components (by age and causes of death) of this inequality from the late 1960s through the present day. It is shown that today the decrease in mortality from external causes at young and middle ages and the circulatory diseases at middle ages is contributing the most to the decrease of inter-regional inequality in life

[7] Andreev E. M., Shkolnikov V. M. Begun A. Z. Algorithm for decomposition of differences between aggregate demographic measures and its application to life expectancies, healthy life expectancies, parity-progression ratios and total fertility rates // Demographic Research. 2002. № 7(14). P. 499-522.

expectancy. This is a contrast to the decrease of mortality from circulatory diseases at older ages, which is leading to the growing diversity across regions.

4. Using the methods of spatial analysis, we estimated spatial dependence in how mortality indicators (all-cause and cause-specific) are spread across the territory of Russia and how this dependence tends to change over time. We show that there is significant spatial autocorrelation in mortality within Russia: regional with lower mortality levels tend to be found adjacent to the regions in which mortality levels are also lower.

Results of the study

Quality and comparability of the mortality data gathered in Russia at the subnational level

The reliability and accuracy of a cause-specific mortality analysis relies on the quality of the data. The checks for the data quality performed in the current study showed that there are systematic problems with the quality and comparability of mortality data gathered at the regional level in Russia. Insufficient quality of the data posed a severe limitation for the analysis.

Demographic analysis at the subnational level is more complicated than at the national level, with possible biases caused by migration across territories. In Russia, a death is statistically assigned to that region where the Civil registration office (ZAGS) registered it[8]. According to the Federal law "On the registering acts of civil status", death registration can be performed "according to the most recent address of the deceased, place of death, place of body discovering…" and some other stipulations listed[9]. Consequently, the death counts assigned to the particular region in the statistics

[8] Surinov A.E. The Rosstat data as input information for actuarial calculations in insurance. Completeness and reliability. The presentation on the XIth International Insurance Conference. Moscow, 5-6 June, 2013.

[9] Federal Law of 29 December, 2017 N 472-FZ «On introducing changes to the Federal Law of 15 November, 1997 N 143-FZ «On the Acts of Civil Status» (with changes and additions)

may include deaths of residents of other regions, in those instances where their deaths were registered in that particular region. By the same token, the death counts may not include the deaths of all of the region's residents, should these deaths have been registered elsewhere. It is obvious that such a system can cause some numerator-denominator bias in the mortality rates estimation. This problem can be especially crucial for the federal cities and surrounding regions.

Death registration, either by the place of residence or by the place of death, may also result in a so-called statistically "immortal population", which happens when the death of a region's resident was registered outside the region, but he/she is still being counted in the population. At young ages the death probability is rather low, i.e., the low number of deaths corresponds to a large number of population, and these problems cannot bias the demographic indicators significantly. However, if the proportion of "immortal population" accumulates while moving to the older ages, the mortality rates may be substantially biased.

While comparing regional mortality levels for cause-specific mortality, it is essential to take into account the comparability of regional approaches to selecting the underlying cause of death. In the current study, we rely solely on the secondary data, i.e., on data processed and published by the statistical offices. Consequently, no additional data other than death counts by regions, sex, age, and causes of death were available. The conclusions on the comparability of regional approaches to selecting the underlying cause could be made only using the indirect statistical methods. For 42 groups of causes of death, we calculated the coefficient of variation and the ratio between the 3rd maximum and the 3rd minimum for the share of these causes in the cause-specific mortality structures of regions for the period 2013-2015. For comparison, we calculated the similar indicators for the departments of France.

The analysis showed that mortality levels from neoplasms have the highest consistency across all Russian regions. High cross-regional consistency was also found

for the large groups included in the ICD-chapter of circulatory diseases (ischemic heart disease and cerebrovascular diseases), diseases of the digestive system, and transport accidents. For some of the other causes of death the dispersion in mortality levels was so vast that it is hard to fathom that such a variation is even possible within a single country. Instead it seems that regional differences in mortality from these causes reflect the different regional approaches to the selection of the underlying cause of death.

To perform the mortality analysis, we aggregated some groups of causes of death into a larger category, as the studies show that misclassification within ICD-chapters is more common than between chapters[10]. Some causes (e.g., endocrine disorders, disorders of the nervous system) had to be excluded from the analysis because these causes could not be combined with any others, and the cross-regional dispersion for these causes was too high. In the end a list of 23 groups of causes of death was proposed for further analysis. This list covers 85.2% of the age-standardized death rate in Russia in 2013-2015, and 90% of the death rate for age interval 0-79 years.

We also had to exclude ages 80 and over from the analysis by causes of death. At these ages, 18.6% of deaths in Russia in 2014-2015 were coded under "Senility" (ICD-10 code R54) and this share is wildly different from region to region. In 8 regions fewer than 1% of all deaths were coded under Senility, whereas in Rostov oblast this code was used for 55% of deaths at age 80 and older, and this number increased to 57.5% in rep. Bashkortostan and Smolensk Oblast. The prevalence of senility in cause-of-death mortality structure also fluctuated significantly in Russia over time. Before 1989, the deaths of older people were rarely coded as being caused by senility. For the entire period of 1965-1989 there were 3.8 times fewer deaths coded as "Senility" than in the single year 2015. This increase in the share of deaths coded under "Senility" started after 1989, when a special Decree of the Soviet Minister of Health was issued,

[10] Harteloh P. The reliability of cause-of-death coding in Netherlands // European Journal of Epidemiology. 2010. Vol.25. № 8. P. 531-538; Winkler V. Reliability of coding causes causes of death with ICD-10 in Germany// Int J Public Health. 2010. Vol. 55. № 1. P. 43-48.

prescribing all deaths of those aged 80 and over to be coded as caused by senility unless there was evidence of an external cause of death or unless the medical records indicated any other cause.

Because the prevalence of senility in cause-of-death mortality structure changes substantially both across territories and over time, it is not possible to perform the correct cause-specific mortality analysis after age 80.

Regional trajectories of changes in mortality and life expectancy and their reflection in inter-regional mortality inequality

Regional trajectories of mortality changes between the turn of the 1960s and 1970s and today are examined. We also compared these with the trend for Russia as a whole and analyzed how the discrepancies in regional trends affected the values of interregional inequality.

To define whether various regional trends were consistent with the national one, we estimated the changes in life expectancy at the regional level between the following time points: 1969/1970-1978/1979; 1978/1979-1989; 1989-2003; and 2003-2015. These four time periods reflect the key milestones of changes in Russian mortality after the 1960s: slow deterioration in life expectancy after mid-1960s (which was more of a stagnation in females), rapid increase of life expectancy during the anti-alcohol campaign, life expectancy fluctuations of the 1990s-early 2000s, and the current period of life expectancy growth after the year 2003. The analysis of changes in life expectancy at the regional level showed that, even though in the vast majority of regions the trends of life expectancy coincided with the national one in time, the regions display enormous differences in the values of life expectancy gains and losses in different time periods. This indicates that the regions do not share equal successes and failures in mortality and life expectancy changes.

In 2015, the value of life expectancy at birth in Russia was the highest in the historical perspective when calculated for the country as a whole. However, this is not true for all regions. In 2015, life expectancy was lower in 23 regions for males and 3 regions for females than in 1989. In 2 regions for males, life expectancy was lower than in 1969/1970 (in Kemerovo and Bryansk oblasts)[11].

Most of the regions do follow the national mortality trends when analyzed by age groups. Compared to 1969-1970 and 1989, infant and child mortality decreased substantially by the year 2015 in all the regions. This is in contrast to mortality at young and middle ages, which increased in most of the regions. Compared to the rest of the regions, the city of Moscow and the North Caucasus republics seem to be more favorable – in these regions, the changes in mortality at young and middle ages were rather positive. Mortality in the elderly declined in the vast majority of the regions. The decline in the cities of Moscow and Saint-Petersburg was especially pronounced. Meanwhile, in Amur, Belgorod, Bryansk, Smolensk, Kursk and Orenburg oblasts, the mortality of senior men still hasn't reached its lowest level. There is a significant increase in mortality at advanced ages in the republics of North Caucasus. The latter, however, probably reflects the improvement in the quality of mortality statistics in these regions.

The analysis of the changes in life expectancy at the regional level showed that the cities of Moscow and Saint-Petersburg and the republics of North Caucasus are quite different from the other regions of Russia, especially in male mortality. However, while the republics of North Caucasus were always somehow peculiar regarding mortality levels: life expectancy in these regions has always been rather high, the favorable position of Moscow and Saint-Petersburg is a recent achievement which came in force in the second half of the 1990s. The gain in life expectancy between 2003 and

[11] The comparison with life expectancy values for years 1965 and 1987 – the years of the maximum life expectancy in Russia - would probably show that there are even more regions that still haven't reached the maximum levels of life expectancy. However, the data for those years were not available for this study.

2015 – the current period of mortality improvements in Russia – was also among the highest in these two cities; although in 2003 life expectancy there was already quite high compared to the other regions of Russia. Because the two cities are largely populated, the deviation of these two regions from the general trend influences the values of weighted by population indicators of mortality inequality significantly.

As the tempo and sometimes even the directions of the changes in life expectancy for specific regions were often different, the changes in inter-regional inequality followed the changes in life expectancy at the national level. In the current study, two measures of inter-regional disparity in life expectancy were examined: standard deviation (weighted and non-weighted by population size) and the gap in life expectancy at birth between the two 15% groups of the Russian population inhabiting the regions with the largest and the lowest life expectancy. In 2015, the standard deviation in life expectancy across regions in Russia was 3.3 years in males and 1.8 and females (weighted by the population size of the regions). The gap in life expectancy between the two 15% groups of the population was 9.2 years in males and 5.1 years in females.

The trends of both measures during the period under study are similar. Before 2007, the changes in inter-regional inequality negatively correlated with the changes in life expectancy for Russia as a whole. A growth of life expectancy was usually followed by a decline in inter-regional inequality, a reduction in life expectancy – by a growth of inequality. Since 2007 this correlation has been broken: the continuing increase in life expectancy is no longer followed by the decline in inter-regional disparities. In general, the analysis of trends in inter-regional inequality for the last 50 years shows that the problem of inequality in life expectancy at the subnational level is much more crucial for Russia today than it was during the Soviet era. Moreover, it is even more crucial than it was in the 1990s – the period of mortality crisis in Russia.

Using a stepwise replacement decomposition technique[12], we decomposed the difference in life expectancy between the two 15% groups of the population by ages and causes of death. This analysis was performed for five broad groups of causes of death: "Infectious and parasitic diseases," "Neoplasms," "Circulatory diseases," "External causes," and "All other."

The decomposition showed that the largest contribution to the gap in life expectancy between the two 15% groups is made by the same components which are responsible for the Russian lagging position in life expectancy compared to the other developed countries. First of all, these are external causes in young and middle ages and circulatory diseases which make the most substantial contributions at middle and older ages. The contribution of young and middle ages to the life expectancy decrease determined the life expectancy fluctuations in Russia in the 1990s – beginning of the 2000s – to a large extent. In the recent decade, the contribution of young and middle ages to the inter-regional inequality declines. However, this decline is compensated for by the growing contribution of the older ages, primarily due to growing inequality in mortality from circulatory diseases.

We can conclude that the main tendencies of the current period of life expectancy increase in Russia affect the processes of divergence and convergence differently at the regional level. Those processes which are attributed to the recovery growth of life expectancy in Russia –the decline in "crisis" component of Russian mortality as reflected through the exceptionally high premature mortality in young and middle ages – lead to the convergence in life expectancy at the regional level. On the other hand, those processes in which the researchers tend to see the possible beginning of the cardiovascular revolution in Russia – mortality decline from the circulatory diseases in the elderly – lead to the regional divergence in life expectancy. These two tendencies

[12] Andreev E. M., Shkolnikov V. M., Begun A. Z. Algorithm for decomposition of differences between aggregate demographic measures and its application to life expectancies, healthy life expectancies, parity-progression ratios and total fertility rates // Demographic Research. 2002. № 7(14). P. 499-522.

compensate for each other, resulting in a stable inter-regional inequality in Russia during the recent years.

To understand how the difference between the top and the bottom 15% groups of regions looks not only when the groups are compared to one other but also compared to other countries, we decomposed the difference in life expectancy between Poland and the two selected groups of regions. We chose Poland because like Russia this country has experienced unfavorable mortality trends since the mid-1960s. However, after the fall of the Iron Curtain, Poland and Russia took different paths. Poland entered the cardiovascular revolution[13], while Russia experienced crisis mortality fluctuations over the subsequent 15 years.

Life expectancy calculated for the 15% of the Russian population which lives in the regions of the highest life expectancy was only 2.0 years lower in males and 2.5 years lower in females compared to Poland in 2014. The gap in life expectancy between Russian leading regions and Poland is mostly attributable to the excess mortality in young and middle ages. It is only due to higher mortality at age interval 25-49 years male life expectancy, calculated for the top 15% of the Russian population, that mortality is 1.7 years lower than that estimated for Poland. The difference in female life expectancy between the top 15% group of the Russian population and Poland is mainly due to excess mortality at the older ages in Russia, although excess mortality in young ages also contributes to this gap. Meanwhile, mortality from neoplasms in the top 15% group of the Russian population is lower than in Poland for both in males and females.

The gap in life expectancy between the bottom 15% group of the Russian population and Poland is much larger: 11.7 and 7.1 years for males and females respectively. At ages 25-79 years in males and 30-79 years in females, each 5-year age interval contributes at least 0.5 years to the difference in life expectancy between this group of regions and Poland. At ages 30-49 years this contribution accounts for more

[13] Fihel A., Pechholdová M. Between 'Pioneers' of the Cardiovascular Revolution and Its 'Late Followers': Mortality Changes in the Czech Republic and Poland Since 1968 // European Journal of Population. 2017. Vol.33. №5. P. 651-678

than 1 year for each 5-year age interval. In males, the contribution of external causes and circulatory diseases is nearly equal: 4.0 and 4.1 years respectively (calculated for ages before 80). The contribution of excess mortality from external causes is generally manifested at young and middle ages, whereas at middle and senior ages it is from circulatory diseases. In females circulatory diseases contribute the most to the gap in life expectancy between the bottom 15% group in Russia and Poland, 3.0 years, while external causes contribute the other 1.4 years.

Thus, the "lagging" regions in Russia are experiencing the double burden of disease today. The "crisis" component of mortality – primarily, premature mortality from external causes and circulatory diseases – is very high in these regions and still is an important factor of low life expectancy. However, mortality decline in the elderly – the process which researchers claim to be a sign of the beginning of the cardiovascular revolution in Russia – has affected these regions only slightly.

Spatial patterns of mortality distribution in Russia

To determine whether there is any spatial dependence of mortality distribution within Russia, we calculated Moran's indices of spatial correlation[14]. Moran's index shows whether the values of some indicator (in our case, mortality) are closer to one other in the neighboring territories. In the study, several ways of neighborhood determination (neighborhood matrices) between regions were tested:

- the matrix of common borders – the regions are defined as neighbors if they share a border;
- the matrix of "five nearest neighbors" defined by the distance between the centroids – region j is a neighbor for region i, if region j is among five closest regions for region i, where the closeness is determined by the geographical distance between the centroids of regions;

[14] Moran P.A.P. Notes on Continuous Stochastic Phenomena // Biometrika. 1950. № 37 (1). P. 17–23.

- the matrix of “five nearest neighbors” defined by the distance between the most populated cities – this matrix is similar to the previous one, but the closeness is determined according to the shortest distance by car between the most populated cities of the regions;
- the matrix of the inverse distances between the most populated cities. The closeness was also determined according to the shortest distance by car between the most populated cities of regions. When the most populated cities of the two regions are located less than 1000 km by car from each other the regions are identified as neighbors. Unlike the previous matrices which were binary (the neighborhood either exists or not), in this matrix the weight of neighborhood for each pair of regions was defined depending on the distance between the two regions;
- the matrix of migration flows between regions. The neighborhood between regions was defined based on the data of cross-regional migration during the period 2009-2012.

For all matrices, Moran’s indices for life expectancy of birth were positive during the entire period of observation. It means that regions neighboring the regions with lower life expectancy tend to have a lower life expectancy as well. And in turn, neighbors of those regions with higher life expectancy are more likely to also have higher values of life expectancy. During most of the observation period, the highest values of Moran’s index were found for the matrix of common boundaries. The other matrices do not explain spatial variation in mortality within Russia so well. The lowest estimates of Moran’s index were found for the matrix of migration flows.

The change of Moran’s index of spatial autocorrelation over time is negatively correlated with the change in life expectancy at the national level and positively correlated with the change in inter-regional inequality. It means that the periods of life expectancy increase in Russia which were followed by the decline in inter-regional disparities also resulted in the increasing patchiness of mortality map.

For the 23 groups of causes of death mentioned above, the mapping of mortality indicators was applied. It allowed visual inspection of mortality levels from these causes across the Russian Federation. Mortality rates for years 2013-2015 were calculated for four age intervals: 0-19 years, 20-39 years, 40-64 years, and 65-79 years. Also, for the analyzed mortality components (combinations of age groups and causes of death) we compared cross-regional distributions (weighted by population size) between the period 2013-2015 and 1989-1991. This allowed an analysis of how the proportion of population inhabiting the territories with lower/higher levels of mortality has changed in the last quarter of a century.

The analysis performed showed that the mortality components are different both by their time trends and by the changes in inter-regional inequality. The comparison of distributions between 1989-1991 and 2013-2015 showed that even though mortality in 2013-2015 was lower, it was not the same for all causes of death. The negative trends were especially pronounced in mortality changes form HIV, digestive diseases and also for some neoplasms. The increase in mortality from these causes also resulted in a significant rise in inter-regional inequality, i.e., regions were unequally affected by unfavorable mortality trends.

For most mortality components analyzed (by ages and causes of death), mortality levels in 2013-2015 are lower than in 2013-2015. However, inter-regional mortality inequality often remains higher than in the turn of the 1980s and 1990s. It means that successes in mortality decline also affected the regions unevenly.

Looking at the maps, it can be concluded that spatial regularities of mortality distribution across the territory of Russia which were described in the 1970s and 1980s still persist[15]. Mortality increases while moving from the south to north and from the west to east. It is true both for total mortality and for its components (by ages and

[15] Andreev E.M. Life expectancy in the USSR: differential analysis / eds. Andreev E., Vishnevski A. // Length of life: Analysis and modelling. – Moscow: Statistika, 1979; Shkolnikov V.M. Geographical factors of length of life// Izvestiya AN SSSR. Geographical Series. 1987. Vol.3. № 12. P. 35–44.

causes of death) which were analyzed in the current study. Lower mortality levels are observed in the southern regions of Russia, while higher mortality is found in the regions of East Siberia and the Far East.

Conclusions

1. After 2007, the growth of life expectancy in Russia no longer followed the decline in inter-regional mortality inequality, as had been the case with the previous periods of life expectancy increase in Russia. This is a result of compensating processes of divergence and convergence at the regional level in Russia. Mortality decline from external causes at young and middle ages and circulatory diseases at middle ages pushes regions to a convergence in their life expectancy. Mortality decline in the elderly, primarily due to the decrease in cardiovascular mortality, results in their divergence.

2. The regions of Russia are at different steps on their path of epidemiological transition. It is expressed both through regional differences in the overall mortality levels and through differences in age profiles of mortality and cause-specific mortality structures. Some regions of Russia are coping quite successfully with declining excess mortality at working ages, and it seems that some of them are entering the path to the cardiovascular revolution. Meanwhile, some other regions are experiencing the double burden of diseases: premature mortality at young and middle ages is still very high in these regions, and the progress in declining mortality among the elderly is still not prominent.

3. The cities of Moscow and Saint-Petersburg contribute notably to the divergence in life expectancy across regions. Since the mid-1990s these two cities have had an accruing advantage in mortality and life expectancy levels compared to most of the rest of Russian regions. Today these two regions, together with the North Caucasus republics, constitute a cluster that stays quite apart from the other regions of Russia in terms of life expectancy.

4. Frameworks and strategies seeking to increase life expectancy in Russia should take the differences in regional epidemiological models into account. The decline in inter-regional mortality and life expectancy inequality, the increase of life expectancy in the regions which lag behind is today no less an important task for Russia than is the rise of life expectancy in the country per se.

5. There is a significant spatial autocorrelation in mortality distribution across the territory of Russia: regions with similar indicators of mortality and life expectancy tend to be clustered on the map.

6. Problems with the quality of mortality data and its comparability across regions pose a severe limitation for mortality analysis by causes of death, especially at older ages. It was possible to perform cause-specific mortality analysis only for the aggregated groups of causes of death and only for ages before 80. There is an urgent need for the improvement of quality and comparability of mortality data gathered by Russian regions.

7. The methodology of the current study can be used for monitoring and analysis of regional differences in mortality and the further examination of the factors underlying these differences.

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Publications

The author has published 6 academic papers on the subject of the dissertation research, 7.15 author sheets in total (personal contribution of the author is 3.93 author sheets). Among them 3 papers were published in academic journals indexed in Scopus (1 is published in the journal indexed in Web of Science), 1 paper was published in the journal included into the list of academic journals recommended by the National Research Institute Higher School of Economics.

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