THE DEVELOPMENT OF REGIONAL MORTALITY DISPARITIES IN THE CZECH REPUBLIC IN THE PERIOD 1991–2015

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ABSTRACT

Convergence analysis represents a distinct stream of research in demography and its findings have both theoretical and practical implications. This article focuses on an analysis of mortality convergence of Czech districts over the years between 1991 and 2015. Selected methods that can be used in this kind of analysis are introduced. The results mainly point to the significant influence of age (especially in relation to the differences in mortality in the oldest age groups) on the process of mortality convergence and the effect of specific regional factors (e.g. some districts lag behind others in mortality).

Keywords: mortality, convergence, divergence, Gini coefficient, districts, Czech Republic

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1. INTRODUCTION

The study of mortality convergence (and divergence) is a developing branch of research in demography today. It focuses mainly on the international level, although many studies also stress the importance of observing developments on the regional level (*Burcin – Kučera*, 2008; *Janssen et al.*, 2016; *Vallin*, 2013). Analysis of mortality convergence between regions provides a deeper insight into changes observed on the national level (*Odoi – Busingye*, 2014), but above all it can contribute to the discussion of the theoretical and practical issues connected with regional disparities in demographic processes, their practical significance, and their trends over time.

First of all, a regional analysis of convergence can be used to verify the assumption included in some theoretical concepts – that mortality conditions are converging (e.g. the demographic revolution, the epidemiological transition, the health transition, etc.; *Kibele – Klüsener – Scholz*, 2015; *Vallin – Meslé*, 2004).

Governments also seek (explicitly or implicitly) not just to improve mortality in the population (*Coleman*, 2002) but also to reduce (regional and other) differences in the level of mortality within the state. Inequality in death is viewed by society as 'more inequitable than other' (*Vallin*, 2013: 139) inequalities in human well-being. As *Vallin* (2013) has pointed out, while it is probably impossible to achieve total mortality equity, it is still the aim to reduce inequalities as much as possible. Understanding regional differences in mortality and their development may thus also

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determine how financial resources in the state budget are distributed in selected regions in an effort to reduce these inequalities (*Janssen et al.*, 2016).

Last but not least, it is possible to note that there is often an assumption in population forecasts about the future convergence of regions in terms of intensity of mortality, both at the international level (see, e.g., *European Commission, Economic Policy Committee*, 2014) and at the regional level (see, e.g., *Bleha – Šprocha – Vaňo*, 2014; *Czech Statistical Office*, 2014; *Fiala – Langhamrová – Hulík*, 2009). To verify such assumptions, first it is necessary to learn more about past mortality trends.

Janssen et al. (2016) note that the results of studies focusing on regional mortality convergence and divergence differ from the viewpoint of the various trends observed, even when the attention is solely devoted to the total level of mortality in advanced countries. If we are concerned only with European states and regions, there is a relatively large body of literature devoted to regional mortality differences (overall or by causes of death) that offers examples of countries and regions in which current trends indicate convergence, while stagnation or even growing differences have also been recorded. While some studies have been pointing to regional convergence in mortality in France since the 1950s (*Vallin*, 2013), in Germany since the 1990s (*Kibele*, 2012), or in the European Union since the start of the new millennium (*Jaworska*, 2014), no change in mortality conditions was observed in 1988–2009 in the Netherlands (*Janssen et al.* 2016), and a tendency towards mortality divergence has been observed between regions in, for example, Belarus since the early 1990s (*Grigoriev – Doblhammer-Reiter – Shkolnikov*, 2013) and in Scotland between 1981 and 2001 (*Boyle – Exeter – Flowerdew*, 2004). Although there are some studies that have also looked at mortality trends in regions in the Czech Republic (see e.g. *Burcin – Kučera,* 2000; *Burcin – Kučera*, 2008; *Dzúrová*, 2000), none of them focused primarily on analysing convergence tendencies. Therefore, with a view to the questions noted above, the main goal of this article is to analyse mortality convergence at the regional level in the Czech Republic since 1990.

2. DATA AND METHODS

The indicators used in this study were constructed from data drawn from the standard records of population change maintained and processed by the Czech Statistical Office (*Czech Statistical Office*, 2017). Our analysis looks at mortality trends on the level of districts within the Czech Republic (76 district units + the Capital of Prague), analysing them separately for men and women, using selected indicators characterising intensity of mortality over the course of life and at age intervals that reflect the specific character of mortality. We divided the total age interval into three age groups (defined as the ranges of exact age 0–50, 50–70 and 70 years and over), which represent age groups in which level of mortality and the possible trend in mortality are relatively distinct from each other. The 0–50 age group is characterised by generally low mortality with already small potential for its further decrease. Conversely, the oldest age group, 70 and over, is currently characterised by a significant decrease in mortality but also by its still high level. The middle age interval, aged 50–70 years, represents a kind of transition between low and high mortality, with large differences between sexes. To express the level of mortality we used the temporary life expectancy in the first two age groups, and we used life expectancy at the exact age 70 for the 70+ age group.

We calculated the temporary life expectancy between exact ages x and $x+i$ (expressed as ${}_ie_x$) according to the Arriaga (1984) as:

$$ {}_ie_x = \frac{T_x - T_{x+i}}{l_x} $$

where T_x and T_{x+i} are the total number of person-years lived after reaching the exact age x, or $x+i$ (i is the length of the age interval) and l_x is the life table survival function (i.e. number of survivors to the exact age x).

In order to calculate these indicators, we used the DeRaS software application (*Burcin – Hulíková Tesárková – Kománek*, 2017) producing detailed life tables, which are smoothed in older age, using the Kannisto model. Based on the Akaike information criterion, this model was evaluated as the most suitable one for the used data of all mortality models (Gompertz, Gompertz-Makeham, Coale-Kisker, Heligman-Pollard, Thatcher and Kannisto) offered by the application DeRaS. The model parameters were estimated using the nonlinear regression method by minimising the weighted least squares. To reduce random fluctuations resulting from the small number of events, we constructed the tables and subsequently the indicators defined above for five-year periods – 1991–1995, 1996–2000, 2001–2005, 2006–2010 and 2011–2015 – representing the time frame of our analysis.

There is an array of analytical approaches in demography and other fields of study that can be used to study changes in regional disparities (see, e.g. *Cowell*, 2011).[4] This broad range of options using different indicators and including different hierarchical levels undermines the comparability of studies focusing on regional convergence (*Janssen et al.*, 2016; *Netrdová – Nosek*, 2009; *Novotný*, 2007).

One way of differentiating between approaches to the analysis of (regional) inequalities is the distinction of beta convergence and sigma convergence (*Barro – Sala-i-Martin*, 1992; *Janssen et al.*, 2016). Beta convergence is based on regression models and is used primarily to determine whether in regions where the situation is less favourable in terms of mortality, its improvement (mortality decrease) is faster than in 'more advanced' regions. However, this method of measuring convergence does not answer the question of whether inequalities are decreasing over time within the given group of regions as a whole. This question is addressed by the second approach, sigma convergence (Novotný, 2010; Rey – Janikas, 2005).[5] Considering the aim of our analysis, attention is devoted to the analytical tools that are used in the study of sigma convergence. It can be explored more deeply using numerous indicators, most often the Gini coefficient and the Theil index (*Netrdová – Nosek*, 2009; *Novotný*, 2010), but also using basic statistical characteristics of variability such as standard deviation (*Coleman*, 2002; *Janssen et al.*, 2016). The advantages of the Gini coefficient and the Theil index compared to the majority of these basic characteristics are their independence from the average, their non-dimensionality, and their explanatory nature (*Netrdová – Nosek*, 2009; *Novotný*, 2010).

We used cartograms to create an initial idea of the regional trends in mortality differentiation in the Czech Republic, and to evaluate regional convergence tendencies we used the Gini coefficient in its unweighted form and in a form weighted for the population size of the districts.[6] The unweighted Gini coefficients reflect the inter-regional differences in the phenomenon under observation (each region has the same weight in the formula; *Firebaugh*, 1999). They are also easier to interpret than the results obtained using the weighted formula (*Janssen et al.*, 2016). On the other hand, the weighted formula reflects the differences between individuals (each individual is assigned the same weight; *Firebaugh*, 1999), which in our analysis makes it possible to observe the trends in mortality inequalities between inhabitants of the Czech Republic.

The Gini coefficient (marked as G in its unweighted form and G_w in the form weighted for population size), which is derived from the Lorenz curve (particularly used in economics, for instance, to illustrate the inequalities in the distribution of wealth or income in the population), was calculated according to *Novotný – Nosek – Jelínek* (2014) as:

$$G = \frac{1}{k^2}\frac{1}{2y}\sum_{i=1}^{k}\sum_{j=1}^{k}(|y_i - y_j|)$$

$$G_w = \frac{1}{2y}\sum_{i=1}^{k}\sum_{j=1}^{k}\left(\frac{n_i}{n}\frac{n_j}{n}|y_i - y_j|\right)$$

where k is the number of districts, y indicates the mean of the values of (overall or temporary) life expectancy (in the case of the weighted form the weighted average is used), y_i and y_j indicate the levels of (overall or temporary) life expectancy in district

4) It is also possible to encounter the opinion that 'there is no one ideal measure of inequality due to its multidimensionality' (*Novotný*, 2004: 57).

5) It might at first glance seem that when beta convergence occurs then sigma convergence also automatically occurs, but this is not the case. It has been shown that even when beta convergence is observed it is possible for the differences between the defined population units or groups to grow (*Barro – Sala-i-Martin*, 1992; *Young – Higgins – Levy*, 2008).

6) EasyStat statistical software was used to calculate the Gini coefficients (*Novotný – Nosek – Jelínek*, 2014). As noted above, it is also possible to use other statistics that characterise regional differences, such as the coefficient of variation and the Theil index. However, as these analytical tools revealed similar trends in regional inequalities as the Gini coefficients, only the results of the latter are presented in this article.

i and *j*, *n* represents the total number of inhabitants, and n_i and n_j indicate the number of inhabitants in districts *i* and *j*. The Gini coefficient can reach values from 0 to 1, and the lower the value observed, the lower the inequality of the given indicator (*Baštová – Hubáčková – Frantá*l, 2011).

For above mentioned mortality indicators we also constructed the empirical distribution functions. This graphical representation of data offers an opportunity to examine in-depth mortality convergence tendencies observed on an aggregate level using the Gini coefficient.

The empirical distribution function can be defined for value *r* (that is, at point *r*) as the relative number of values less than or equal to this value (it thus determines the share of observations of values smaller or equal to the value of *r*), that is

$$F(r) = \frac{(number\ of\ y_i \leq r)}{k}$$

where y_i indicates the observations for individual districts ($i = 1, ..., k$) and *k* is the total number of observations (*Hendl*, 2009), i.e. the total number of districts. The distribution function can reach the values from 0 to 1, where the value of 1 reflects a situation in which all observed values are less than or equal to *r* and the value of 0 means none of the observed values is less than or equal to *r*.

3. REGIONAL PATTERNS OF MORTALITY IN THE CZECH REPUBLIC: 1991–2015

Between the 1991–1995 and 2011–2015 periods life expectancy at birth in the Czech Republic rose by 6.2 years for men (from 69.0 to 75.2 years) and by 4.8 years for women (from 76.4 to 81.2 years). Although the decline in mortality in the observed units was a universal process for both men and women, not all of them shared the tempo or increase in life expectancy development, and it is possible to detect significant regional differences (Figure 1).

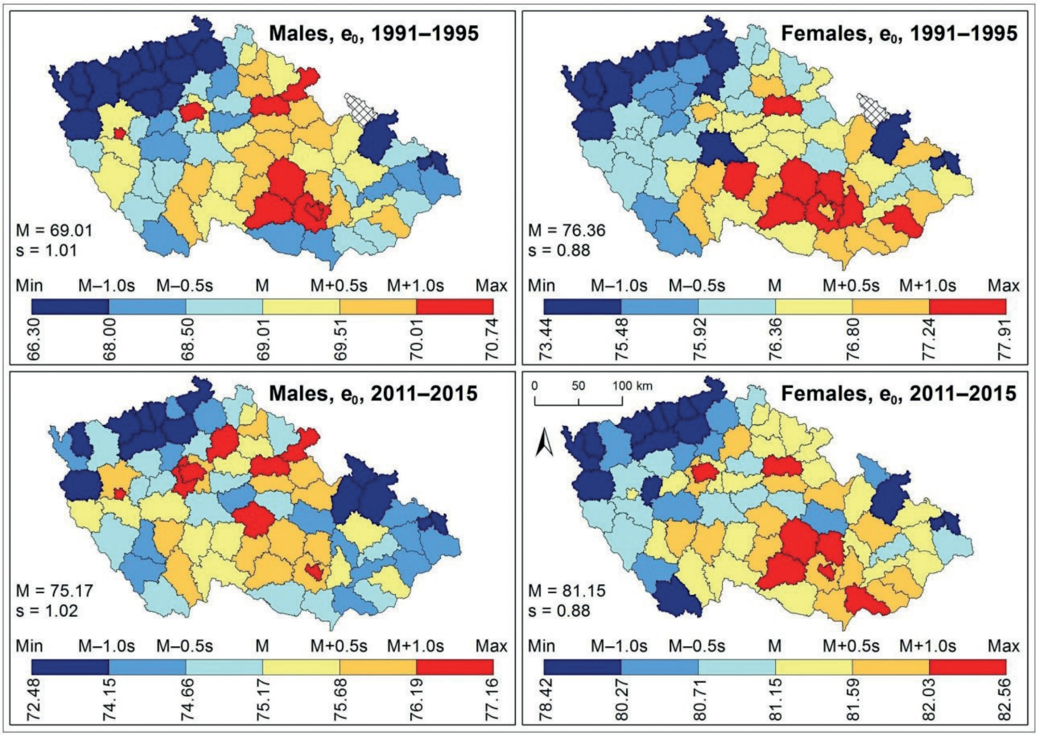
The least favourable mortality conditions across districts for both men and women throughout the analysed period reigned in the northwest of the country (especially districts in the Ústí nad Labem Region and the Karlovy Vary Region)[7)] and mainly in the case of men also in districts in the Moravian-Silesian Region. For example, in the districts of Děčín, Chomutov, Most, Teplice, Tachov, Bruntál and Karviná, life expectancy at birth for men and women at both the start and the end of the observed period was lower than the national average by more than one unit of standard deviation (see the note below Figure 1). There are a number of interrelated factors behind why the highest mortality rates have typically been found in these districts. Possible factors include the lower socioeconomic status of inhabitants in these districts, the worse educational structure, the higher unemployment rate, and the less favourable impact of the economic transformation in these districts (*Baštová – Hubáčková – Frantál*, 2011; *Burcin – Kučera*, 2000). Conversely, the most favourable mortality conditions were recorded in some large cities (Prague, Brno, and also Pilsen for men), all the districts in the Vysočina Region, and most districts in the Hradec Králové Region and the Pardubice Region.

Significant mortality differences between men and women were found mainly in the south-eastern part of the Czech Republic. While women's life expectancy at birth in, for example, the districts of Břeclav, Hodonín, Uherské Hradiště and Vsetín was rather high, men in these districts reached relatively low values of life expectancy at birth. This could be due to the lifestyle of the population in the area and types of local economy and economic sectors that are most common in the area, all of which are, in general, less favourable for males. On the contrary, the lowest differences in women's and men's mortality were recorded in some large cities (namely, the Capital of Prague and Pilsen) and their suburban areas.

Looking at the transformation of regional differentiation in mortality within the state, it is apparent that the regional pattern changed little over the course of the period analysed (Figure 1). It is, however, possible to notice some exceptions to this. For example, in the first period analysed, 57 districts surpassed the district of Mladá Boleslav in terms of male life expectancy at birth, but in the recent period there were

7) A map showing the names of the districts and regions is included in Appendix 1.

Figure 1 Male and female life expectancy at birth in the districts of the Czech Republic, 1991–1995 and 2011–2015



Notes: The boundaries between intervals were determined based on multiples of the standard deviation of life expectancy at birth in the given period for the studied sample of districts (s) and their distance from the average life expectancy at birth in the given period for the Czech Republic as a whole (M). Intervals are right restricted, i.e. if a district reaches displayed threshold value, it belongs to the interval with lower life expectancy. Hatched area represents unavailability of data (in district Jeseník, which was established in 1996, in period 1991–1995).
Source: Czech Statistical Office, 2017; authors' calculations.

only 7 such districts. The extraordinary improvement in mortality that is represented by this dramatic shift in the hierarchy of Czech districts in terms of attained life expectancy at birth was primarily caused by the swift expansion of the automobile industry in the area (Škoda car maker and its suppliers) and the related improvement in the socioeconomic conditions of the population in the region. Conversely, the peripheral district of Šumperk ranked 24th in male life expectancy at birth in the 1991–1995 period, but in the 2011–2015 period it ranked 66th.

4. RESULTS

The following analysis of mortality convergence tendencies at the district level in the Czech Republic in the 1991–2015 period is divided into two parts: subchapters 4.1 and 4.2. The first explores changes in regional differentiation, and it does so using statistics that do not take into consideration the population size of districts. The results obtained using this unweighted approach can be a source of valuable information – for instance for policymakers who are interested in learning whether regional mortality differences are decreasing (*Janssen et al.*, 2016).

The observed convergence (or divergence) expressed by a Gini coefficient that does not take into consideration the population size does not, however, necessarily reflect the real decrease or increase in differences within the given population, that is, differences at the individual level. An example would be a situation where in a given state, on the one hand,

Table 1 Characteristics of regional differences in overall and temporary life expectancies in Czech districts by sex, 1991–1995, 1996–2000, 2001–2005, 2006–2010 and 2011–2015

Indicator	Statistic	1991–1995	1996–2000	2001–2005	2006–2010	2011–2015
Males						
e_0	G	0.00827	0.00795	0.00838	0.00854	0.00766
	G_w	0.00931	0.00937	0.00994	0.01017	0.00939
$_{50}e_0$	G	0.00212	0.00172	0.00169	0.00170	0.00133
	G_w	0.00208	0.00167	0.00173	0.00179	0.00143
$_{20}e_{50}$	G	0.00941	0.00851	0.00828	0.00823	0.00722
	G_w	0.01071	0.00978	0.00912	0.00914	0.00839
e_{70}	G	0.02466	0.02385	0.02590	0.02360	0.02152
	G_w	0.02559	0.02752	0.03126	0.02803	0.02611
Females						
e_0	G	0.00638	0.00617	0.00607	0.00560	0.00597
	G_w	0.00617	0.00599	0.00602	0.00580	0.00626
$_{50}e_0$	G	0.00176	0.00137	0.00104	0.00104	0.00095
	G_w	0.00160	0.00130	0.00099	0.00095	0.00092
$_{20}e_{50}$	G	0.00467	0.00445	0.00420	0.00359	0.00359
	G_w	0.00448	0.00399	0.00401	0.00347	0.00353
e_{70}	G	0.02005	0.02054	0.02060	0.01804	0.02009
	G_w	0.01995	0.02039	0.02092	0.02005	0.02109

Source: Czech Statistical Office, 2017; authors' calculations.

a few regions with large populations showed strong convergence of mortality towards a low level while, on the other hand, there were a large number of regions with smaller populations in which mortality characteristics were stagnating at a high level. In this case, it may happen that indicators that do not include population size will signal a slight divergence caused by the large number of regions lagging behind. On the other hand, statistics weighted for population size will indicate that mortality conditions are converging, which is caused by the larger share of population in a few large converging districts. Therefore, in assessing trends in regional differences in mortality it is useful to always consider both approaches in harmony with the objective of the particular study. While the results in the first subchapter focus on the unweighted measures, characterising the districts as a whole, the second is devoted to an analysis of mortality conditions that reflects the population size of individual districts. This is an analysis of convergence within the population.

4.1 Convergence of mortality in the Czech districts in the 1991–2015 period: unweighted measures

The first step in our analysis involves assessing regional mortality trends from the perspective of decreasing or increasing inequalities between districts. The starting point for identifying these trends is to look at changes in the unweighted Gini coefficients over time (Table 1).

When it comes to men, the regional differences in life expectancy at birth decreased between the first and the last of the periods analysed, but the decrease was not a gradual one. While between the 1991–1995 period and the 1996–2000 period there was only a slight decrease in the differences between districts, during the first decade of the new millennium mortality conditions diverged. There was greater variability in male mortality conditions in the 2006–2010 period than in the 1991–1995 period. The mortality convergence observed in the overall period of analysis can therefore be ascribed to the convergence of the values of life expectancy at birth in the 2011–2015 period.

This mortality trend warrants a closer analysis. As well as the trend in life expectancy at birth, which expresses intensity of mortality across the whole lifespan, it is also possible to trace changes in regional differences for the measure that characterises the level of mortality in selected age intervals (Table 1).

With regard to temporary life expectancy of men between exact ages 0 and 50, what is first noticeable when compared to life expectancy at birth is the small level of regional differences. This is mainly because in this age interval mortality was already low during the period of analysis and had little potential to decrease further. A pronounced decline in regional differences occurred between the 1991–1995 and 1996–2000 periods, due mainly to the rapid improvement of mortality measures caused by improving health-care parameters (*Burcin*, 2008). Unlike life expectancy at birth, temporary life expectancy stagnated until the 2006–2010 period (Table 1). Greater mortality variability was observed in the 2011–2015 period compared to the preceding period. The increase in regional differences observed until the 2006–2010 period in terms of overall mortality thus cannot be ascribed to the trend in this age category.

In the temporary life expectancy of men between exact ages 50 and 70 it was possible to observe the homogenisation of districts more or less across the entire period of analysis. A decrease in the pace of convergence is apparent in the period from 2006 to 2010 (compared to preceding periods), but after 2010 the convergence trend continued again. Again, it can be confirmed that this age group did not contribute to the increase in the differences between districts in terms of overall life expectancy at birth recorded in the first decade of the 21st century.

Logically it is mortality in the oldest age group, measured as life expectancy at exact age 70, that has the biggest influence on the trend towards the convergence of districts in life expectancy at birth. Mortality in the oldest age group also exhibits the biggest regional differences. The Gini coefficients stagnated in the 1990s, so there were no fundamental changes in the variations between districts in terms of mortality in the oldest age group. After the turn of the millennium differences between districts grew and the greatest variations were observed in the 2001–2005 period. Given that this period is also characterised by changes at the level of old-age mortality, it can be assumed that the differences increased mainly between those districts with better access to health care, better living conditions, and where the population has a better lifestyle, and those districts that tend to have the opposite characteristics. This assumption will be tested in further sections of the analysis. The end of the period of analysis was marked by a return to mortality convergence.

There was less variation in mortality between districts among women than men in every period and for each of the indicators considered here (Table 1). In this respect, the biggest difference between the sexes was observed for temporary life expectancy between exact ages 50 and 70, where the Gini coefficient for women was roughly half that for men. This is fully consistent with the above-mentioned continued differences in mortality rates and the trend towards declining mortality differentiated by sex.

As in the case of men, among women variations in life expectancy at birth between districts decreased over the course of the period of analysis, but followed a different course of development over time. Among women the life expectancy at birth in districts was converging up until 2006–2010. However, more recently there has been a slight increase in the variation in mortality between districts. Variations between districts in temporary life expectancy among women in age intervals 0–50 and 50–70 grew smaller over the observed period and the start of the 21st century showed a stagnating trend.

Again, it is possible to state that the observed increase in variation between districts at the end of the studied period can primarily be ascribed to variations between districts in mortality in the oldest group of women. Variations in life expectancy among women at exact age 70 were the only of the unweighted statistics that did not decrease between the first and the last periods analysed. Until the 2001–2005 period the differences between districts actually grew, and while these differences did decrease in the 2006–2010 period, this was only a temporary deviation. In the final period analysed regional differentiation was again comparable to what was observed in the 1991–1995 period. However, it is again necessary to use other possible tools of analysis to explain the observed course of development as those tools could better specify whether the variation changed only at the level of districts or whether within the population overall. And above all it will then be possible to identify the districts that were the main contributors to the changes in variation observed over time. The weighted versions of the Gini coefficient will be used for this purpose, along with an analysis based on the distribution functions.

4.2 Convergence of mortality in the Czech districts in the 1991–2015 period: weighted measures

This subchapter presents an analysis of mortality convergence in the Czech population using mortality indicators, like in the preceding section, but it also takes into consideration the population size (weight) of individual districts.[8] The weighted Gini coefficients on which the analysis of developmental trends is based are shown in Table 1. Although districts in the Czech Republic do not have the same population sizes (in this article the Capital of Prague is analysed alongside districts), in terms of the convergence and divergence tendencies in mortality there are no great differences between the weighted and unweighted statistics during the studied period (Table 1). Therefore, the basic developmental trends in mortality variations are not discussed in detail below, and the comments instead focus on the specific features by which the results of the weighted and unweighted formulas differ.

Among men the observed regional disparities are higher when the weighted measures are used than when the population size is not taken into consideration. Exceptions were the 1991–1995 and 1996–2010 periods regarding the temporary life expectancy between exact ages 0 and 50, where, however, the differences between districts are very small. As far as women are concerned, the differences between the results produced by each of the two versions of the formula were not too pronounced. The greater variation observed among men when population weights are included is primarily caused by the population size of the capital city. When using the weighted version of the formula, Prague has a weight of more than 10%, and throughout the studied period it had one of the best male mortality rates. The mortality rate of women in Prague was also lower than in most other districts, but the difference was not as pronounced as among men.

Generally, it can be stated that the variation between districts in the total life expectancy of men increased over most of the studied period in the case of the weighted form of the Gini coefficient (the exception being in the most recent period between 2011 and 2015). The biggest contribution to this increase in variation again comes from the trend in variation in the oldest age group, as differences between districts in the case of the younger age groups of men decreased or stagnated over time.

When it comes to women, the variation between districts in total life expectancy fluctuated, with a rather more noticeable increase in variation observed at the end of the studied period, that is, after 2010. This was primarily due to the trend in the variation of mortality among the oldest age group. To the contrary, particularly noteworthy is the rapid decrease from already low values among population below the age of 50.

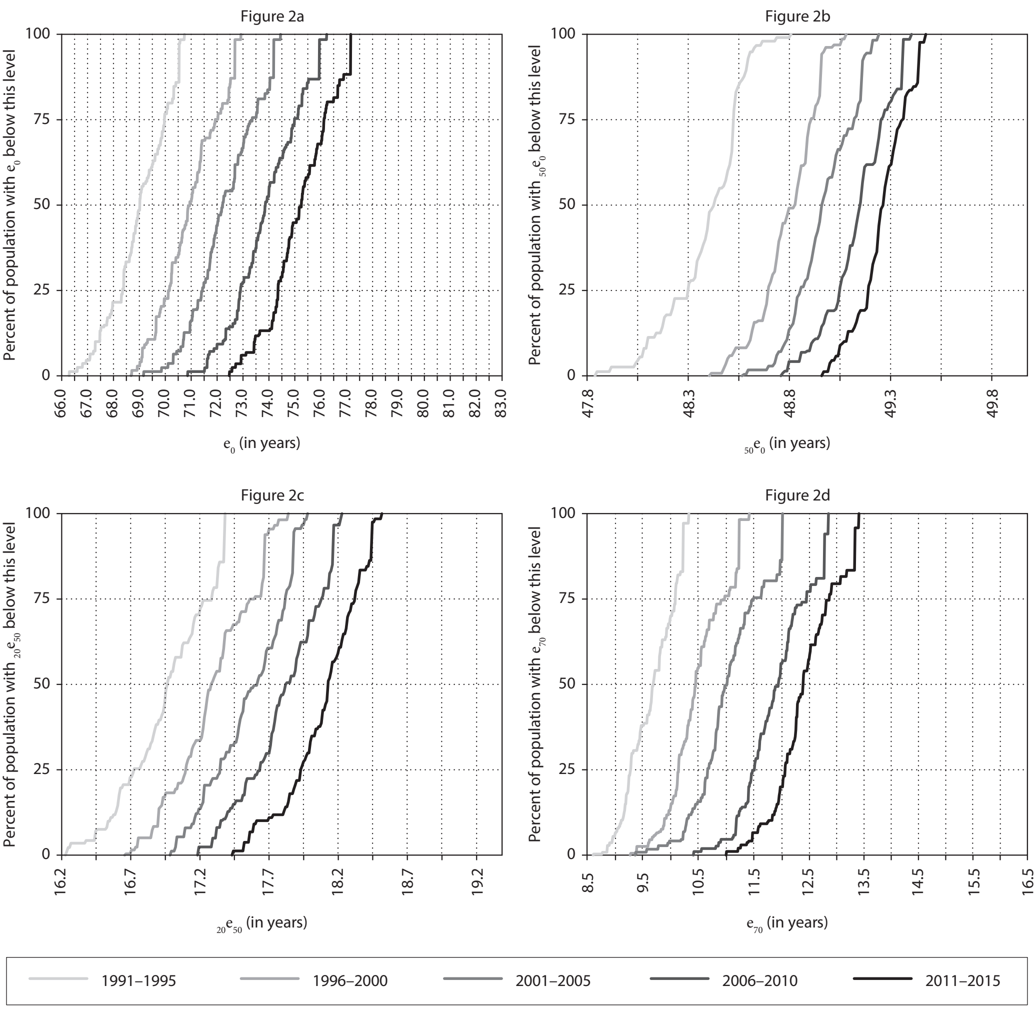
Deeper insight into the observed aggregate trends is provided by the curve of the distribution functions, which shows the share of the population of Czech districts by attained (total or temporary) life expectancy (Figure 2a–d, 3a–d). In these figures, there are two important points to focus on. First, it is possible to trace what changes occurred in attained mortality rates. If mortality improves in the population over time, the curve shifts to the right towards higher life expectancies. Second, it is possible to examine the variation in mortality. When there is a decrease in the lifespan differences between district populations, the curve straightens. If, for example, the value of a particular indicator in the analysis was in some period the same in all the districts, the curve would represent this as a straight vertical line.

When explaining the above-described divergent trends in mortality among men, the curve representing the 2001–2005 period can be illustrative (Figure 2a).

8) It is important to remember that the same mortality is assumed to apply to all the inhabitants of a given district, so this is not an analysis based on individual data.

The increase in the variation in mortality can mainly be attributed to districts with small populations, which had the worst values of the mortality indicator used. These were mainly industrial districts (e.g. Děčín, Chomutov, Most, Teplice, Louny, and Sokolov in the Ústí nad Labem Region, and Karviná and Bruntál in the Moravian-Silesian Region), which were heavily impacted by the economic transformation, and are also areas with environmental damage. In most districts in the Czech Republic, mortality in the 2001–2005 period saw a decrease from the preceding period, and consequently the corresponding curve shifted to higher values for life expectancy at birth. By contrast, in the group of districts cited above, with the lowest life expectancies at birth, there was a relatively smaller decrease in intensity of mortality. This is why the shift in this part of the distribution curve towards higher values is less noticeable (Figure 2a). This intensification

Figure 2a–d Relative cumulative distribution of the population of the Czech Republic by overall and temporary life expectancies, males, 1991–1995, 1996–2000, 2001–2005, 2006–2010 and 2011–2015

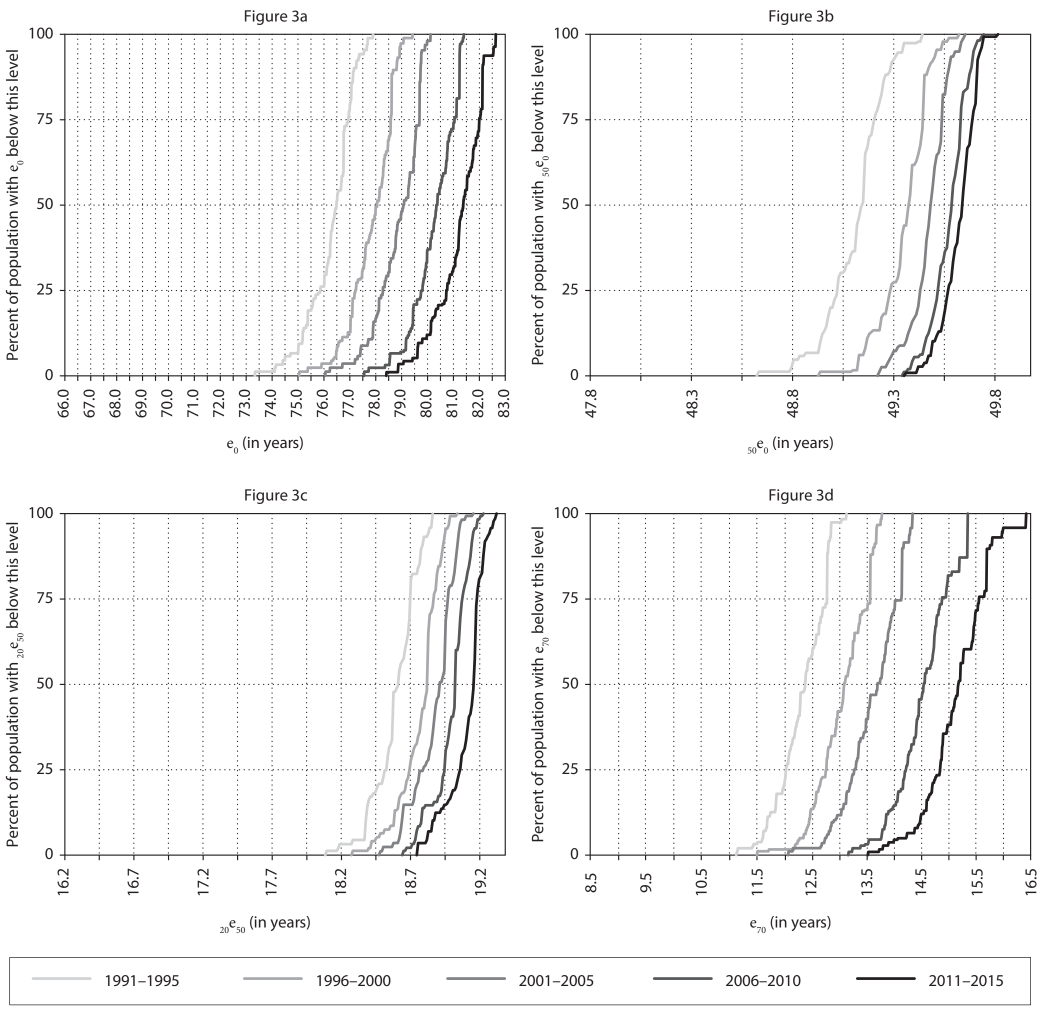


Source: Czech Statistical Office, 2017; authors' calculations.

of the degree to which the districts with the highest mortality are lagging behind led to the increase in the total variation of the indicators. Moreover, this continued in the next period analysed and it was only after 2010 that the variation between the populations of Czech districts in terms of total mortality decreased again. This is visible in the figure (Figure 2a) from the steeper curve of the distribution function.

As well as looking at the overall distribution curve, it is also possible to analyse the development of the values of the interquartile range of the observed indicator, which is defined as the difference between the values of the temporary and overall life expectancies attained by 75% and 25% of the populations of the Czech districts. It is also possible to trace the variation in the upper and lower quartiles of the population separately – i.e. the variation in the one-quarter

Figure 3a–d Relative cumulative distribution of the population of the Czech Republic by overall and temporary life expectancies, females, 1991–1995, 1996–2000, 2001–2005, 2006–2010 and 2011–2015



Source: Czech Statistical Office, 2017; authors' calculations.

of the population living in the districts with the highest and the lowest mortality rates (Table 2).

In the case of overall mortality among men, the value of the interquartile range increased from the original 1.6 years until the 2006–2010 period, when it reached almost 2.1 years. In the last period, it then decreased to 1.8 years (Table 2). This indicates rather an increase in variation in the middle half of the population in terms of attained intensity of mortality. In Figure 2a this is apparent in the change in the angle of the overall distribution curve, which grew steeper only in the last period of the analysis. This also confirms the observed trend in the weighted form of the Gini coefficient for overall life expectancy at birth.

If the analysis focuses on the 25% of the male population living in districts with the best mortality conditions (the upper quartile of the curves in Figure 2a), it is clear that life expectancies at birth in this group of the population increased during the period studied and also that they were concentrated within a relatively narrow interval, which in none of the periods rose above 1.3 years. There was also an increase in the range of values for life expectancy at birth corresponding to this upper quartile, which continued until the 2006–2010 period, while in the last period in the analysis the values became more concentrated again (Table 2). This can be interpreted as growing differences between the districts with the best mortality rates. In the majority of periods in the analysis the reason lay in the relatively more pronounced distance of those districts that had the very highest life expectancies (Hradec Králové or Prague). Conversely, the life expectancies at birth among the 25% of the male population with the highest mortality showed relatively high variation not just compared to the upper but also compared to the other quartiles. This supports the above-mentioned observation about the districts with the worst mortality lagging behind the others, which contributed to the increase in overall variation. In the 2001–2005 period, when the biggest differences are observed in the least favourable quartile, this much lower value of life expectancy is found in the districts of Chomutov and Most, and in the next period it was mainly in the district of Teplice.

When it comes to the temporary life expectancy of men between exact ages 0 and 50 it is possible to note that the dynamics of the changes in mortality are decreasing in time as the potential for a further decrease in mortality in this age group is gradually exhausted (Figure 2b). With the exception of the 2001–2005 period, the value of the interquartile range for this age group was around 0.2 years (Table 2). In other words, one half of the population of the Czech Republic was living in districts with almost the same rate of mortality. The homogenisation of districts in terms of mortality in this age interval over the period studied was primarily the result of the decrease in differences in mortality among the population in the first and fourth quartiles – that is, a decrease in the distance of the best districts and also a decrease in how much the districts with the shortest lifespan were lagging behind.

In the case of the temporary life expectancy of men between exact ages 50 and 70 the shape of the distribution function did not fundamentally change, nor did the pace of their shift in the direction of higher temporary life expectancies. This corresponds to the just relatively slight decrease in the Gini coefficients for men in this age interval (see above). At the same time, the values of the interquartile range decreased from 0.6 years in the first period to 0.4 years in the last period (Table 2). The mortality rates in the middle half of the population were thus very similar, with very little potential for a further decrease in differences. However, regional differentiation was influenced by an increase in the variation of the values of this indicator among the 25% of the population with the best mortality in the last period analysed owing to the positive distance in values for the district of Hradec Králové, and also for the 25% of the population with the worst mortality, especially in the last two periods analysed, owing to the effect of the lagging districts of Teplice and Most (Figure 2c).

The distribution function curves for male life expectancy at exact age 70 confirm that this age group is key to the overall development of the variation in mortality between districts in the Czech Republic (Figure 2d). Moreover, it is the developments in the districts with the best and worst mortality rates that are causing the changes in the overall variation in mortality in this age group. The variation in mortality, expressed as the value of the interquartile range, remained almost unchanged (except for the 2006–2010 period) and hovered at a level just slightly above

Table 2 Range of values of the upper and lower quartiles and the interquartile range for the relative cumulative distribution of the population of the Czech Republic by overall and temporary life expectancies by sex. 1991–1995. 1996–2000. 2001–2005. 2006–2010 and 2011–2015

Indicator	Statistic	1991–1995	1996–2000	2001–2005	2006–2010	2011–2015
			Males			
e_0	$Q_{0.25}$–MIN	2.06	1.48	2.27	2.04	1.88
	IQR	1.61	1.76	1.92	2.08	1.77
	MAX–$Q_{0.75}$	0.77	0.99	1.09	1.24	1.03
$_{50}e_0$	$Q_{0.25}$–MIN	0.44	0.28	0.28	0.28	0.22
	IQR	0.22	0.21	0.26	0.21	0.17
	MAX–$Q_{0.75}$	0.29	0.17	0.12	0.14	0.11
$_{20}e_{50}$	$Q_{0.25}$–MIN	0.49	0.44	0.36	0.45	0.49
	IQR	0.57	0.50	0.47	0.45	0.40
	MAX–$Q_{0.75}$	0.09	0.24	0.16	0.14	0.19
e_{70}	$Q_{0.25}$–MIN	0.66	0.87	1.30	1.09	1.06
	IQR	0.81	0.83	0.83	0.94	0.80
	MAX–$Q_{0.75}$	0.24	0.44	0.52	0.39	0.53
			Females			
e_0	$Q_{0.25}$–MIN	2.48	2.12	2.18	2.21	2.27
	IQR	1.06	1.34	1.39	1.21	1.25
	MAX–$Q_{0.75}$	0.93	0.83	0.41	0.35	0.62
$_{50}e_0$	$Q_{0.25}$–MIN	0.39	0.35	0.20	0.17	0.21
	IQR	0.18	0.16	0.11	0.11	0.12
	MAX–$Q_{0.75}$	0.23	0.17	0.11	0.11	0.12
$_{20}e_{50}$	$Q_{0.25}$–MIN	0.42	0.40	0.30	0.29	0.29
	IQR	0.16	0.16	0.17	0.12	0.12
	MAX–$Q_{0.75}$	0.15	0.16	0.17	0.14	0.13
e_{70}	$Q_{0.25}$–MIN	0.91	1.27	1.21	1.05	1.32
	IQR	0.75	0.80	0.86	0.66	0.71
	MAX–$Q_{0.75}$	0.35	0.21	0.20	0.47	0.86

Notes: The difference in values between the minimum (MIN) and the boundary of the lower quartile ($Q_{0.25}$) describes the range of values falling within the lower quartile; the difference in values between the boundary of the upper quartile ($Q_{0.75}$) and the maximum (MAX) denotes the range of values in the upper quartile. The interquartile range as the difference between the boundary of the upper ($Q_{0.75}$) and lower quartiles ($Q_{0.25}$) is indicated by the abbreviation IQR.
Source: Czech Statistical Office. 2017; authors' calculations.

0.8 years (Table 2). By contrast, primarily until the 2001–2005 period there was an expansion of the interval in which life expectancies at exact age 70 in the upper and lower quartiles ranged. While in 1996–2000 in the quarter of the population with the shortest lifespan these values reached a range of 0.9 years, in the 2001–2005 period the figure was 1.3 years. In districts with the lowest mortality rates the increasing variation was mainly caused by how far ahead Prague, Brno-město, and Hradec Králové were above the others. In the graph, there is also apparent the lagging of approximately 4% of the population with the very lowest life expectancies at exact age 70 (this was the population in the districts of Chomutov, Louny, Most, Teplice, and Sokolov).

Women's life expectancy at birth saw a more gradual increase than men's, which is reflected in the smaller differences between the curves (Figure 3a).

While the trend in the Gini coefficients indicated decreasing regional differences in women's mortality up to the 2006–2010 period, in the interquartile range the values in the first three periods increased (from 1.1 years in the 1991–1995 period to 1.4 years in the 2001–2005 period; Table 2). In the 2006–2010 period, life expectancies at birth in this 50% of the population of Czech districts then grew closer and the interquartile range reached 1.2 years, while in the next period there was again a slight increase in variation.

One question that can be asked is what segment of the population in terms of attained life expectancy at birth caused the drift towards the mortality convergence that was revealed using the Gini coefficients. The shape of the curves indicates that up until the 2006–2010 period women's mortality was converging because of the decreasing variation among the quarter of the population of the lowest overall intensity of mortality. In the 1991–1995 period, life expectancies at birth in this segment of the population were in the range of 0.9 years. The subsequent convergence only stopped in the 2006–2010 period, when the difference between the values in the upper quartile fell to 0.4 years (Table 2). The increase in the range of values to 0.6 years in the 2011–2015 period can be attributed mainly to the populations in the districts of Třebíč, Hradec Králové and Brno-město, which had life expectancies at birth 0.4 years higher than the other districts (Figure 3a).

With regard to the 25% of the population of women with the highest mortality, the range of values of life expectancy at birth is clearly greater than in the other quartiles (Figure 3a, Table 2). The interval of life expectancies at birth attained within the lower quartile narrowed from 2.5 years to 2.1 years in the 1996–2000 period (Table 2). After that, however, the differences increased again and in the last period in the analysis the values of the indicator hovered around the level of 2.3 years. Among the 25% of the population with the lowest values of life expectancy at birth mortality figures came to be concentrated within a wider interval than in the case of the remaining 75% of the population (Table 2). It can be inferred from this therefore that regional inequalities among the female population were mainly influenced by the variation in mortality in the quarter of the population with the highest mortality. The decrease in regional variation in the 2006–2010 period and the subsequent increase after 2010 were conversely supported by the trend in the variation within the quarter of the population living in districts with the lowest mortality rates.

As far as the indicators that express mortality in the defined age intervals are concerned, greater variation was also found within the 25% of the population of women with the worst mortality compared to the one-quarter of the population living in districts with the lowest mortality rates (Figure 3b–d). In particular the temporary life expectancies in the quartile with the worst mortality throughout the period studied hovered within an interval of the same width as the 75% of the population with the better mortality (Figure 3b–c, Table 2). However, it should be added that with regard to temporary life expectancies we can observe among women a strong tendency towards an end to the decrease in mortality and overall towards little variation in mortality between districts. The potential for a further decrease has in the case of some districts almost been exhausted. It is therefore possible to assume that in the near future the variation in these two indicators between districts will probably progress to the homogenisation of districts, as long as it becomes possible to improve the mortality situation in the districts with the very highest mortality rates (these are mainly the districts of Teplice, Most, Sokolov, and Chomutov).

The tendencies in the interquartile range of values of life expectancy among women at exact age 70 are comparable to those expressed by the Gini coefficient, that is, divergence up until the 2001–2005 period, followed by decreasing variation in the 2006–2010 period, and then by an increase again in the 2011–2015 period (Table 2). Among the population of women aged 70 and over with the worst mortality, it is possible to see in the 1996–2000 and 2001–2005 periods in particular approximately 2% of the population that is lagging behind. In the 1996–2000 period this 2% was represented by the population in the districts of Teplice and Rakovník, and in the 2001–2005 period it was the districts of Teplice and Most (Figure 3d). Conversely, in the 2011–2015 period in the upper quartile, the district of Brno-město had a life expectancy at exact age 70 more than 0.4 years higher than the other districts. It is thus possible to say that in this age group of women the slight increase in variation to 2005 was primarily caused by the districts with the highest mortality lagging further behind (especially in the 1996–2000 period), but also by the increasing variation of values in the middle half of the population expressed through an increase in the values of the interquartile range. The decrease in the inter-district differences in the mortality of the oldest group of women in the 2006–2010 period was then supported both by the decreasing differences within the middle half of the population and by the decrease in the lagging of the districts with the lowest life expectancy. Conversely, the districts with the lowest mortality increased their distance from the others in this period. In the last period analysed an increase in variation revealed by the Gini coefficient was caused by the increase in variation in all the quartiles, and especially by the increased distance of the districts with the very best mortality from the others.

5. CONCLUSION AND DISCUSSION

This article focuses on the trend in inequalities in mortality between Czech districts observed in five-year periods between 1991 and 2015. Gini coefficients and the curves of distribution functions for the individual periods were used to analyse trends in regional differences in life expectancy at birth and also the degree of convergence for indicators representing mortality in three successive age groups. For this purpose we used the temporary life expectancies between exact ages 0 and 50 and between exact ages 50 and 70 and at exact age 70.[9] As noted above, this study was motivated by a theoretical question, specifically the assumption contained in selected theories that mortality rates are converging. There were also practical questions that demography is currently dealing with in connection with the convergence and divergence of mortality. This is exemplified by formulating hypotheses about the development of inequality as part of regional forecasts or the preparation of materials designed to help decision-makers adopt effective measures towards reducing the differences between regions within the state. The article thus produced several findings from the perspective of research on regional inequalities that are discussed in more detail below.

First, using current data the stability of the regional pattern of mortality in the Czech Republic indicated in previous studies was confirmed (*Burcin – Kučera*, 2000; 2008; *Dzúrová*, 2000). The highest intensity of mortality was observed during the period studied in the north-western and eastern parts of the Czech Republic. By contrast, the districts with the best mortality rates were mainly found in the Vysočina Region, the Hradec Králové Region, and the Pardubice Region. Low mortality was also observed in some large towns. In reference to observed inequalities in mortality the above-mentioned studies highlighted the influence of differences in the education levels and socioeconomic structure of the population, access to health care, and unemployment rates.

The analysis of convergence revealed that although between the first and last periods in the analysis there was a decrease in inequalities between districts among both sexes in terms of overall mortality according to the Gini coefficients, the decrease in variations was not however continuous for either males or females. Among men inequalities increased between the 1996–2000 and 2006–2010 periods and convergence only appeared in the last period in the analysis, when the values of the Gini coefficients decreased significantly. By contrast, among women districts grew closer in terms of attained life expectancies at birth until the 2006–2010 period, but in the years, that followed those figures increased slightly from the preceding period.

When the Gini coefficients weighted for the populations were used we found similar trends in the development of differences in mortality between districts. The different sizes of the districts did not therefore have a significant influence on the above-described convergence and divergence tendencies.

It was possible to analyse the observed trends in a detailed perspective from two points of view – from the perspective of age groups and from a regional perspective. The first perspective, analysed using temporary life expectancies, helped to reveal which age groups had the biggest influence on the overall development of mortality convergence (divergence). Given the potential for further changes in mortality

9) It should be noted that the age intervals could have been defined in a different way, but the aim here was to distinguish between different mortality patterns and the differing potential for a further decrease in mortality.

in the defined age intervals it could be assumed that a key role was played by the development of mortality among the oldest group aged 70 and over. The regional perspective helped in the search for a response to the question of which districts are the ones most responsible for the observed convergence trends: whether it is the districts with the shortest life expectancies lagging behind the others, the districts with the lowest mortality rates becoming increasingly more distant from the other districts, or whether changes in variation are occurring across all districts.

The analysis confirmed that within the frame of the overall variation in life expectancy at birth a key role was played by the oldest age group. The fastest decrease in mortality in this age group occurred among both men and women between the third (2001–2005) and fourth (2006–2010) periods. The start of the 21st century was also a period in which this age group showed the biggest differences in mortality, especially in the case of men. An analysis of the distribution curves showed that the increase in the variation in mortality (especially up until 2005) in this age group was primarily caused by the lagging districts with the highest mortality rates (Chomutov, Louny, Most, Teplice, and Sokolov), but also by the increase in how far ahead the districts with the longest life expectancy became (Prague, Brno-město, Hradec Králové). Similar trends were observed for both men and women. Younger age groups, and especially the youngest one, played a much smaller role in the overall variation in mortality. There is very little potential at those ages for a further decline in mortality and this manifests itself as a decrease in the pace of mortality decline observed over time. This is especially true with regard to women, where mortality is already very low.

The biggest differences between sexes in terms of mortality were apparent in the 50 to 70 age group – the variation in mortality of men was roughly twice as great as in case of women's mortality. This confirms the assumption about continuing differences in mortality rates from the perspective of sex in this age group. The decrease in mortality in this age group is relatively stable over time for both sexes, but when it comes to women it is very gradual. However, this decrease was mainly due to the average districts growing more even, while the districts with the worst mortality acted against a further decrease in variation. The effect of the lagging districts with the highest mortality rates manifested itself most in the case of men (Teplice, Most).

The analysis of the distribution functions for individual indicators confirmed the fundamental effect the lagging districts have on the overall level of variation in regional mortality which is particularly evident in the case of women. As far as life expectancy at birth (and in some cases also in the defined age groups) among women is concerned the 25% of the population with the highest mortality even had (with the exception of the 1996–2000 period, when the values were almost even) a greater range of values than the other 75% of women.

In terms of the practical application of the results it should be noted how the observed trends contrast with the assumption about an expected decrease in regional differences in mortality that is often inherent within population prognoses (see, e.g., *Bleha – Šprocha – Vaňo*, 2014; *Czech Statistical Office*, 2014; *Fiala – Langhamrová – Hulík*, 2009). As shown above, the decrease in the variation in mortality was apparent among Czech districts only for the younger age groups (up to the age of 70), but this decrease was also held back by the lagging districts with the highest mortality rates (Chomutov, Most, Teplice, Louny, and Sokolov). For the oldest age group, which had the biggest influence on the variation of overall mortality, no clear trend towards decreasing variation was identified.

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Appendix

Appendix 1 **Regions and districts in the Czech Republic, 1. 1. 2015**