Lifespan dispersion in stagnant and decreasing periods of life expectancy in Eastern Europe

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Abstract

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Introduction

The 20th century was marked by sizable improvements in mortality and health in most countries in the world (World Health Organization 2000). However, these improvements were shattered in the second half of the past century, as Eastern European countries experienced an unprecedented period of stagnation and, in some countries, decreases in life expectancy at birth after 1960 (Human Mortality Database 2016). For example, Belarus, Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, Slovenia and Ukraine presented a substantial period of stagnation in male life expectancy from the 1960s to the mid 1980s, with life expectancy levels between 65 and 70 years. During this period, Russia exhibited the lowest level in male life expectancy in the region, males were living on average 63.7 years in 1960 and 62.72 in 1985 (Human Mortality Database 2016). Similar trends were experienced by females but with higher levels in life expectancy, they were living on average 72.31 years in 1960 and 73.23 in 1985. After 1985, all of these countries experienced a brief period of improvements in life expectancy, which coincided with Gorbachev's anti-alcohol campaign. For instance, Russian males rose life expectancy by two additional years from 1985 to 1987. However, after 1987 these countries experienced divergence in life expectancy trends. Slovenia and the Czech Republic rose continuously life expectancy and by 2014 Czech males had an average length of life of 75.7 years and Slovenian of 77.95 (Human Mortality Database 2016). The rest of the countries, particularly those from the former Soviet Union, experienced a pronounced period of deterioration and some countries, such as Russia and Latvia experienced losses of around 7.5 years in male life expectancy between 1987 and 1994, which led to levels not seen since the 1950s (Shkolnikov et al. 2001). Opposing this trend, from 1994 there was an unexpected period of improvements in countries like Russia, Latvia and Estonia (Meslé et al. 2000). However, while all of the countries experienced improvements since that year, life expectancy in Russia stopped increasing in 1998 and presented a downturn up to the mid 2000s, when life expectancy started rising up to the present (Human Mortality Database 2016). Although in the new century most of the countries in this region improved life expectancy, large differences between them remain. For instance, by 2010 the gap between life expectancy in Slovenia and Russia for males was more than 13 years (Human Mortality Database 2016).

National trends in life expectancy are important and have been extensively studied in Eastern Europe (Meslé 2004, Cockerham 1997, Chenet et al. 1996). Nonetheless, they conceal heterogeneity and variation at age at death. Studying lifespan variability alongside life expectancy is an important subject since individuals may take decisions, such as changing lifestyle behaviors, based on their uncertainty about when they will die (van Raalte et al. 2014). Therefore, if lifespan variation is increasing alongside life expectancy decreases means that not only are people dying younger but they are also facing more uncertainty about the eventual timing of death. Previous research has shown that lifespan variability is largely explained by mortality at infancy and early-adult ages between populations (Wilmoth and Horiuchi 1999, Shkolnikov et al. 2003; 2011, Vaupel et al. 2011). The fact that Eastern Europe experience high levels of premature adult mortality (Rehm et al. 2007) underscores the need of understanding mortality trajectories under these atypical patterns, which could be associated to higher levels of lifespan variability.

Until now, studies have mostly focused on lifespan variation in the context of mortality improvements with increases in life expectancy (Vaupel et al. 2011, Wilmoth and Horiuchi 1999), and recently also in socioeconomic and educational differences (van Raalte et al. 2014; 2011, Shkolnikov et al. 2003). These studies have shown a negative relationship between life expectancy and lifespan variability. That is, countries with higher life expectancy experienced lower levels of uncertainty about their age at death (Vaupel et al. 2011). We complement such studies by focusing in the Eastern European case, which shows atypical periods of mortality upheavals with different patterns in life expectancy. We analyze how lifespan variation has changed since the 1960's for 12 countries from this region and which ages and causes of death have contributed the most to the observed variability of age at death. We use high quality mortality data from the Human Mortality Database (2016) and Human Cause-of-Death Database (2016), along with demographic techniques to disentangle the impact of specific-ages and causes of death that drive changes in lifespan variability.

Data & Methods

Data

We used death counts, exposures and period life tables from the Human Mortality Database (2016) for 12 countries from 1960 to the most recent year available in the data set. The countries included in the study are Belarus, Bulgaria, Czech Republic, Hungary, Poland, Russia, Slovakia, Ukraine, Slovenia, Estonia, Latvia and Lithuania. Data for Slovenia is available since 1983. These data contain information on life table's measures (e.g. d_x, ℓ_x, e_x,q_x) by single age, sex and country. For each population, we investigated life expectancy and life disparity since birth. We decided not to analyze variability at death conditioned on survival to any older age, as previous studies have done (e.g. van Raalte et al. (2014)), because of the high proportion of deaths concentrated in younger ages (see Appendix's figure 8). Furthermore, our decision is also founded by the upsurge in young age mortality in the 1990s (see Appendix's figure 8) and the low levels of life expectancy that Eastern European countries experienced in the last century (Meslé 2004).

Cause of death classification

We group causes of death in seven categories using the tenth revision of the International Classification of Diseases (ICD-10) (for details on the ICD-10 codes for each cause, see Table 1). The categories are as follows: mortality amenable to alcohol consumption (for example, alcohol abuse, cirrhosis), infectious & respiratory diseases, cancers, circulatory diseases, diabetes, birth conditions, and all other causes (labeled as residual causes). We analyze conditions amenable to alcohol consumption because of the high proportion of mortality related to these causes in Eastern Europe (Rehm et al. 2007) following a recent classification proposed by Grigoriev and Andreev (2015) (we also included the cause "Alcohol abuse", ICD code F-10). Similarly, we analyze circulatory diseases separately because of their impact in the rising of life expectancy in this region (Meslé 2004). We included infectious & respiratory diseases and birth conditions as categories because they are amenable to health care improvements (Beltrán-Sánchez 2011), and we analyze diabetes separately because the relationship between alcohol consumption and diabetes prevalence is not clear (Blomster et al. 2014).

We rely in information produced by Human Cause-of-Death Database (2016), which contain comparable cause-specific information by year for eight of the countries in the study (Belarus, Czech Republic, Poland, Russia, Ukraine, Slovenia, Estonia, Latvia and Lithuania). These data was corrected by miss-certification, age-specific variations by means of a universal and standardized methodology. We truncate the cause-of-death analysis at age 85 because of classification quality and focus on the period after 1994 because comparable information is available for the eight countries (Human Cause-of-Death Database 2016). Furthermore, we focus on this period because countries in Eastern Europe have recently showed wide country-specific variations, particularly between former USSR and Central European countries (Meslé 2004).

[Table 1 about here]

Dispersion measure

Several dispersion measures have been proposed to analyze lifespan variability (van Raalte and Caswell 2013). In this article, we use $e^{\dagger}$ as a dispersion indicator (Vaupel and Canudas-Romo 2003). It is defined as the average remaining life expectancy when death occurs; or life years lost due to death (Vaupel 1986). For example, when death is very variable, some people will die before their expected age at death, contributing many lost years to life disparity. When people survive to older ages, the difference between the age at death and the expected remaining years decreases, and life disparity gets smaller. It can be expressed as

$$e_x^{\dagger} = \frac{1}{\ell_x} \int_x^{\omega} \ell(a)\mu(a)e(a)da \tag{1}$$

where $\ell(a)$, $\mu(a)$,ω and $e(a)$ are the survival function, the force of mortality, the open-aged interval (100+ in our case), and remaining life expectancy, respectively.

We selected this measure because of its easy public health interpretation (Shkolnikov et al. 2011) and its decomposable and additive properties (Zhang and Vaupel 2009). These properties allow us to calculate contributions of ages that decrease lifespan variability from those that increase it by using demographic methods (Zhang and Vaupel 2009).

The close relationship with other lifespan variation indices, such as Keyfitz's life table entropy (Vaupel and Canudas-Romo 2003), and the high correlation between them suggests that conclusions would likely be the same regardless of the measure chosen (van Raalte and Caswell 2013, Vaupel et al. 2011, Wilmoth and Horiuchi 1999).

Demographic methods

We first examine changes in age-specific mortality by calculating rates of mortality improvements (Rau et al. 2013) with smoothed mortality surfaces (Camarda 2012) following the next formula:

$$\rho(x, t+1) = -\ln \frac{m(x, t+1)}{m(x, t)} \tag{2}$$

where $m(x, t)$ represents the age-specific mortality rates of age x at time t.

The life disparity measure $e^{\dagger}$ has the additive property that, once it has been decomposed by age between two periods, the sum of every age-specific contribution to the difference is the total change in $e^{\dagger}$ between these two periods. We perform such decomposition by single period-year, single-age and causes of death based in a continuous change model (Horiuchi et al. 2008). This method has the advantage that it assumes that covariates change gradually along the time dimension. In addition, since we have yearly information, previous research suggests that is better to aggregate decomposition results for short time intervals (one year in our case) than to carry out decomposition for larger periods (Horiuchi et al. 2008).

Results

Age-specific mortality rates of improvements

Figure 1 shows the age-specific rates of mortality improvements for males in 12 Eastern European countries (results for females are shown in Appendix figure 10). The respective values are expressed in percent. Little changes or no improvements (-0.5% to 0.5%) are depicted in white. Improvements in mortality are shown in blue and mortality deterioration in red. Darker tones mean major changes in mortality rates.

Almost every country experienced a continuous 20-year period of mortality deterioration, from the mid-1960s to the mid-1980s. Mortality rates exhibited increases mainly concentrated in the ages between 20 and 80 years. After 1985, 8 countries experienced sizable improvements in mortality (Russia, Ukraine, Latvia, Lithuania, Poland, Belarus, Czech Republic and Estonia) for a period of 5-10 years. Opposing this trend, in the 1990s every country, except Slovenia, presented an intense worsening in mortality rates, particularly in the countries part of former Soviet Union. Nevertheless, since the last decade of the past century and the beginning of the 2000s Slovakia, Slovenia, Hungary, Latvia, Poland, Belarus, Estonia and Czech Republic have reduced age-specific mortality rates in almost every age. The biggest improvements are related to the most recent years. However, Russia, Ukraine and Poland's recent data point towards a downturn in population's health in middle and adult ages.

Results for women are similar than men in Russia, Ukraine, Latvia, Lithuania, Belarus and Bulgaria but with significantly lower magnitude (see Appendix figure 10). Importantly, some countries such as Slovakia, Slovenia, Poland, Czech Republic and Estonia experienced a continuous trend of mortality improvements in almost the entire period.

[Figure 1 about here]

Trends in life expectancy and lifespan disparity

Previous research suggests that lifespan disparity should be analyzed alongside life expectancy (Shkolnikov et al. 2011). Figure 2 shows male's life expectancy at birth (e_0) and lifespan disparity ($e^\dagger$) trends for Eastern European countries from 1960 to the most recent year available (Appendix figure 9 shows also females' results). From 1960 to 1984 life expectancy stagnated for most of the countries, some of them even experienced decreases (e.g. Russia, Latvia, Estonia, Ukraine). This period was followed by a notable increase in life expectancy in the mid-1980s. However, in 1987 life expectancy among these countries started to diverge. Slovenia and the Czech Republic exhibited a continuous increase from that point onwards. Hungary, Poland, Bulgaria stagnated for a short period and then continued an upward trend until 2014. The rest of the countries (Russia, Latvia, Estonia, Ukraine, Belarus and Lithuania) experienced a marked decrease in life expectancy from 1988, with the lowest value in 1994. From that point on, almost every country improved life expectancy, with the exception of Russia and Ukraine. These last countries exhibited a decrease in life expectancy after 1998, and since 2006 they have continuously experienced improvements in the average length of life. The trends for both male and females are similar (figure with females' results are shown in Appendix figure 9). Yet, the magnitude of the changes is shorter for women and the level of life expectancy is significantly higher than men.

Lifespan disparity $e^\dagger$ trends show similar patterns of stagnation between 1960 and 1980. Russia and Lithuania exhibit the highest levels in this period, between 17 and 19 years lost due to death; while the Czech Republic presents the lowest level throughout the same years, between 13 and 14. Importantly, the Czech Republic was not the record life expectancy holder between these years. Around the mid-1980s all the countries experienced a common shift and declined lifespan disparity, with the exception of Hungary. This period coincides with the life expectancy improvements showed in the same years. After 1991, Lithuania, Russia, Latvia and Estonia significantly increased lifespan disparity with the top pick in 1994-1995, but not with the same levels observed in life expectancy. For example, Russian life expectancy reached levels of life expectancy comparable to the 1950's level, while lifespan disparity shows levels comparable to the 1970's level. In addition, in 1994, when Russia reached the lowest life expectancy level, lifespan disparity is close to the levels observed in Latvia, Estonia and Lithuania, which had higher life expectancy in the same year. Countries such as Hungary, Poland, Bulgaria, Slovakia, Slovenia, Czech Republic continuously decrease variation at age at death since 1994. The rest of the countries also experienced improvements since that year up to 2010-2014, but with higher variability between periods. Such improvements, however, are not as steeper as the life expectancy increases in these countries. Females show similar trends but with lower levels of lifespan disparity over the whole period by country (see Appendix figure 9).

[Figure 2 about here]

Absolute and relative changes in life expectancy and lifespan disparity

Previous studies have shown a negative correlation between life expectancy and lifespan disparity when measured with $e^\dagger$ (Shkolnikov et al. 2011). Nevertheless, we argue that this association could be spurious since most of variability measures and life expectancy are weighted by the density of deaths at each age.[1] In particular, $e^\dagger$ is weighted with life expectancy itself, as has been shown $e^\dagger = \mathcal{H} * e_0$, where $\mathcal{H}$ is Keyfitz's entropy (Vaupel and Canudas-Romo 2003). In addition, trends in e_0 and $e^\dagger$ suggest that in periods of stagnation and mortality upheavals similar levels of life expectancy do not correspond to similar levels in lifespan disparity. Therefore, we focus on changes to improve in analyzing the dynamics between life expectancy and lifespan variability, as has been previously proposed (Smits and Monden 2009, Fernandez and Beltrán-Sánchez 2015).

Figure 3 shows absolute and relative yearly changes (first differences) in life expectancy e_0 and lifespan disparity $e^\dagger$ by sex and period. The period 1960-1987 is related to stagnation and improvements in life expectancy. 1988 to 1995 with periods of mortality deterioration, and 1996 onwards is characterized by divergence between countries in life expectancy trends, and recently with life expectancy improvements. Grey dots correspond to a negative association between life expectancy and lifespan disparity (e.g. increases in e_0 with decreases in $e^\dagger$), while red dots correspond to a positive association (e.g. increases in $e_0$with increases in $e^\dagger$).

During 1960-1987, almost 33% of changes correspond to decreases in e_0 and decreases in $e^\dagger$, in both males and females. These changes were mostly lower than one year of change. Conversely, 26.5% of positive changes in e_0 are related to higher lifespan variability. The rest of the changes correspond to the opposite direction between these measures. In 1988-1995, when most of the changes correspond to significant decreases in e_0, 17.9% of changes in male life expectancy are related to decreases in e_0 and in $e^\dagger$. Importantly, the magnitude of such changes in life expectancy do not reflect the same magnitude in changes in lifespan disparity. For example, Russia lost 3 years of male life expectancy between 1992 and 1993, while lifespan disparity shows a negligible increase. From 1994 to 1995 this country increase life expectancy by almost one year, while $e^\dagger$ shows a positive increase comparable to the one observed between 1992 and 1993. Finally, from 1996 onwards, when most of these countries experienced life expectancy improvements, only 8.7% is related to decreases in e_0 and $e^\dagger$ at the same time, while 21.4% of the total positive changes correspond to increases in lifespan disparity.

Under the negative association between e_0 and $e^\dagger$ framework, we would expect that an increase in e_0 should correspond to a decrease in $e^\dagger$. However, these results suggest that changes in life expectancy and

[1]Acknowledgment to Adam Lenart

lifespan disparity are driven by age-specific mortality dynamics, but not in the same direction as they do in periods of life expectancy improvements. These results point towards the trade off between premature and mature mortality dynamics (Zhang and Vaupel 2009).

[Figure 3 about here]

Age-specific decomposition

Figure 4 shows age-specific contributions to the change in lifespan disparity $e^\dagger$ for ages 0-4 by period (results for females are shown in Appendix figure 11). The periods are labeled as follows according to life expectancy trends in figure 2: stagnation from 1960 to 1980 (grey), improvements from 1980 to 1987 (blue), 1987-1994 is related to a period of deterioration (red), 1994-2000 is labeled as divergence between countries (green), and convergence corresponds to the period 2000-2010 (magenta). Results show that, over all the period (1960-2010), sizable contributions to lifespan variability compression were made in ages below five in both females and males. Particularly between 1960-1980 (grey), when some countries like Bulgaria, Belarus, Hungary, Lithuania, Poland and Russia reduced $e^\dagger$ by one year. However, some countries, such as Latvia, Lithuania and Bulgaria, increased lifespan variability in periods of life expectancy deterioration (red) in these ages.

[Figure 4 about here]

Figure 5 shows age-specific contributions to the change in male lifespan disparity ($e^\dagger$) above age 4 by period (results for females are shown in Appendix figure 11). Over periods of stagnation (grey), changes in lifespan disparity are driven by positive contributions, which expand age at death variation, in young and young-adult ages; and negative contributions (compression of variation) at older ages in all countries (except in Slovenia because of data availability). It is worth noting that these contributions offset each other since contributions from older ages are comparable to those made by young and young-adults in Russia, Slovakia, Ukraine, and Poland. In fact, in Bulgaria and Belarus, the negative contributions in older ages are greater than those positive made by the younger ages.

A similar pattern is observed during periods of mortality deterioration (red). Most of lifespan variability increases are explained by expansion of mortality at young and middle ages, with small compression at older ages in this period. However, some countries like Slovenia, Slovakia, Poland and Czech Republic show negative contributions to $e^\dagger$ in ages between 5 and 30, which compress the variation.

Opposing these trends, in periods of improvements (blue), almost all of the countries followed a western pattern with lifespan variability decreases mostly caused by contributions in young and young-adult ages, and small negative contributions at older ages. However, some countries like Slovakia, Poland and Hungary show atypical patterns with negative contributions to $e^\dagger$ in ages between 5 and 30. From 1994 (green and magenta), all countries show lifespan variability compression at young and young-adult ages and expansion at older ages. However, the contributions at older ages in countries like Hungary, Slovenia, Latvia, Poland, Czech Republic and Estonia are sizable, compared with the rest of the countries. Russia and Ukraine are special cases since in the period 1994-2000 they experienced lifespan variability compression at young ages.

[Figure 5 about here]

Cause of death decomposition

After 1994, almost all the countries experience lifespan variability compression at young and young-adult ages and expansion at older ages. This pattern suggest age-specific mortality improvements (Zhang and Vaupel 2009). Therefore, we aim to analyze the cause-of-death contributions to lifespan disparity ($e^\dagger$). Particularly, those causes related to alcohol consumption and circulatory diseases, which are closely related to mortality dynamics in Eastern Europe (McKee and Shkolnikov 2001). We broke the period into two: 1994-2000 (divergence) and 2000-2010 (convergence).

Figures 6 and 7 show cause-specific contributions to $e^\dagger$ for 1994-2000 and 2000-2010, respectively (results for women are shown in Appendix figures 12 and 13). Figures show decomposition results for Russia, Ukraine, Latvia, Lithuania, Poland, Belarus, Czech Republic and Estonia. Red colors are related to mortality amenable to alcohol consumption, blue corresponds to infectious & respiratory diseases, cancers are in orange, circulatory diseases in green, diabetes in pink and birth conditions in yellow. The rest of causes and mortality above age 84 is depicted in grey.

From 1994 to 2000 (figure 6), a large amount of lifespan disparity is explained by contributions related to causes amenable to alcohol consumption. Particularly in Latvia, Lithuania and Estonia where contributions were made in both young and older ages. The rest of the countries also experienced contributions from these causes, but with lower magnitudes. Birth conditions and infectious & respiratory diseases also contributed largely in young ages. Cancers, circulatory diseases and diabetes made negligible contributions to $e^\dagger$ in this period. Similarly, in the period 2000-2010 (figure 7), most of changes in lifespan disparity are explained by causes amenable to alcohol consumption in all of the countries. Circulatory diseases also had an impact in countries like Estonia and Lithuania. As in the previous period, infectious & respiratory diseases mostly helped to decrease variation in younger ages. Results for females are similar, however the effect of cancers is higher than in males (see Appendix figures 12 and 13).

[Figures 6 & 7 about here]

Discussion

Changes in life expectancy (e_0) and lifespan disparity ($e^\dagger$)

Eastern Europe experienced atypical mortality trends since 1960 compared to other European regions and with the pattern observed in the record life expectancy (Oeppen and Vaupel 2002). These countries experienced a fairly large period of stagnation (1960-1990) with a mean life expectancy around 66 years. After Gorbachev's anti-alcohol campaign was implemented and the Soviet Union broke up, some of these countries exhibited and unprecedented decrease in life expectancy. Russia and Latvia's male life expectancy declined from 64 in 1991 to 57 and 58 in 1994, respectively. To put this in perspective, Russia and Latvia were having the same level of life expectancy as Slovakia used to have in 1959 and contradicting the best practice upward tendency (Oeppen and Vaupel 2002). This reversal in life expectancy was mainly driven by mortality at younger ages (15-75) caused by hazardous alcohol consumption (Shkolnikov et al. 2001, Leon 2011). Opposing this trend, in the last decade life expectancy has showed significant improvements in all the Eastern European countries, yet high levels of inequality between and inside the countries remain (Leon 2011).

Our results show that, although life expectancy experienced major variations in most countries in Eastern Europe, changes in lifespan variability ($e^\dagger$) do not correspond in intensity with those observed in life expectancy trends. Since the 1970s, most studies have shown that temporal increases in life expectancy correspond to decreases in lifespan disparity (Wilmoth and Horiuchi 1999). However, a high proportion of changes in Eastern Europe in life expectancy resulted in changes in lifespan variability in the same direction. Nearly half of the total changes in life expectancy during 1960-1987 correspond to changes in the same way on $e^\dagger$. Nevertheless, during the mortality crisis experienced in these countries and after 1996, the proportions changed to lower values, but still they represent over 20% of the total changes. Although these results do not follow the classic trend, previous research have found similar outcomes for some countries (Shkolnikov et al. 2003, Wilmoth and Horiuchi 1999, Zhang and Vaupel 2009). These authors argue that increases in life expectancy coinciding with increases in lifespan disparity point towards a new trend driven by expansion of mortality at advanced ages and to the difficulties of further averting deaths in young and middle-adult ages.

Age-specific contributions to changes in $e^\dagger$

We further analyze lifespan variability dynamics by specific ages to disentangle changes driven by an early-age component and an old-age component, as noted by Zhang and Vaupel (2009). Unlike the common pattern observed in previous studies, our results show that changes in $e^\dagger$ were mainly by an offsetting effect caused by higher lifespan disparity in younger ages in periods of stagnation (1960-1980) and during the mortality crises between 1987-1994, with lower variability in ages above 55 in the same periods. These trends, however, are atypical if we compare them with what has been observed in western European countries. For instance, in Finland the early-component led to mortality compression, while the old-age component led mortality expansion since the 1970s (van Raalte et al. 2014). In addition, the contributions made by younger ages mostly drive lifespan variability, while the old-age component's contributions are very small in most studies (Wilmoth and Horiuchi 1999). Opposing this, the contributions to lower lifespan variability of the old-age component are such, in periods of stagnation and mortality deterioration, that it completely counterbalances the effect of the younger ages above age 10. A similar effect was previously documented in Russia, showing that the contributions to lifespan variability were mainly positive, between ages 20 and 55, between 1960 and 1980 relative to the values observed in 1959 (van Raalte and Caswell 2013). Therefore, if expansion at younger ages and compression at older ages are opposing each other, means that most of Eastern European countries' disparity at age at death was driven by decreases in mortality rates in very young ages (0-10), as shown by the mortality rates of improvements. This is consistent with previous research that documented improvements in infant mortality and increases in young and middle-aged mortality that led to a substantial deterioration in the health status of the populations in Czech Republic, Hungary and Poland (Chenet et al. 1996), three of the wealthiest former socialist countries. Similarly, the pronounced decline in males' life expectancy in the 1990s was mainly caused by premature adult mortality in both men and women (Cockerham 1997, Rehm et al. 2007). Although women also experienced deterioration in life expectancy in these nations, men were specially susceptible to dying prematurely, leading to large sex-differences in Poland, Hungary, Russia, and the European post-Soviet Republics (McKee and Shkolnikov 2001). Importantly, out of the 12 countries included in our study, only Slovenia and the Czech Republic followed a pattern similar to that observed in the western countries.

In periods of improvements in life expectancy (1980-1987), most of the countries show an opposing trend of that observed in periods of stagnation and deterioration, with younger ages contributing to decrease variation of age at death and older ages contributing to higher variability. In Russia, for example, Shkolnikov et al. (2003) found that early-adult mortality compression between 1979 and 1989 can be attributed to a decrease in alcohol-related mortality as consequence of Gorbachev's anti-alcohol campaign. Our results show that Ukraine, Lithuania, Latvia, Poland, Belarus, Czech Republic and Estonia also compressed mortality at younger ages. This effect could potentially be attributed to Gorbachev's campaign, at least in those countries part of the former Soviet Union. However, Slovakia, Hungary and Bulgaria did not follow the same pattern, experiencing a negligible expansion in lifespan disparity at younger ages.

After 1994 all of the countries followed the western pattern, with early ages compressing lifespan disparity and older ages expanding it. However, between countries large differences appeared. In Slovakia, Slovenia, Hungary, Lithuania, Latvia, Poland and Estonia, sizable contributions to decrease lifespan variability were made, while the rest of the countries' contributions were smaller compared with those experienced between 1980 and 1987. Importantly, during this period, most of these countries experienced improvements in life expectancy and decreases in lifespan disparity, which suggest that countries that have have successfully averted premature deaths have higher life expectancy and lower life disparity levels, as previous research pointed out (Vaupel et al. 2011).

In the overall period, since 1960, the trade-off between compression and expansion of mortality caused by changes in age-specific mortality has driven lifespan variability's changes. This offsetting effect caused that similar levels of lifespan disparity, such as the ones observed in 1994 in Russia, Lithuania, Latvia and Slovakia, do not correspond to similar levels of life expectancy. These phenomenon was previously found in the United States, that showed an unanticipated high variability in age at death due to mortality at very young and older ages compared with the average lifespan, suggesting that countries with similar life expectancy could have different levels of lifespan inequality (Shkolnikov et al. 2003).

Cause-of-death contributions to changes in $e^{\dagger}$ *after 1994*

Alcohol related mortality has played an important role in lifespan variability and life expectancy trends since the 1980s in Easter European countries (Rehm et al. 2007, Shkolnikov et al. 2003; 2001). Our study improves in this subject by further decompose age-specific contributions by causes of death after 1994 for eight countries (Belarus, Czech Republic, Estonia, Latvia, Lithuania, Poland, Russia and Ukraine). First we analyze cause-specific contributions to the difference between 1994 and 2000 to capture the effect just after the lowest values of life expectancy in some of these countries were observed into the new century. We found that a large part of lifespan variability can be explained by improvements in causes amenable to alcohol consumption in Latvia, Lithuania, Czech Republic and Estonia above age 20. These conditions also had an impact in Russia and Poland, but with a lower effect. Similarly, Birth conditions, along with infectious and respiratory diseases helped to decline variation at age at death, mostly in very young ages. Results for women were alike, however cancers also contributed in Lithuania, Poland, Czech Republic and Estonia.

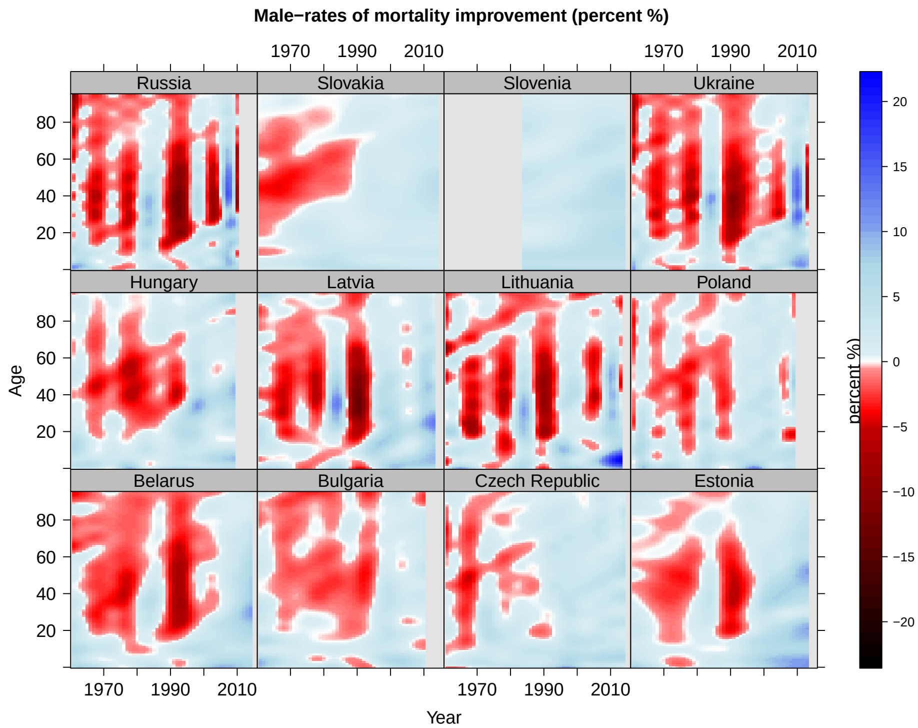
We then investigate the causes-of death driving changes in lifespan disparity in the first decade of the 21st century. Our results underscore the role of causes of amenable to alcohol consumption across the lifespan and infectious & respiratory diseases in younger ages in all of the eight countries. These results are consistent with the mortality decrease observed in 2004-2010 in Russia, which can be explained by lower alcohol use and reduction in deaths caused by causes amenable to its consumption (Shkolnikov et al. 2013). Our study extends on these results by quantifying the effect of causes amenable to alcohol consumption on lifespan disparity in countries that are likely to experience similar patterns.

Figures and tables

Table 1: Classification of causes-of death amenable to alcohol consumption

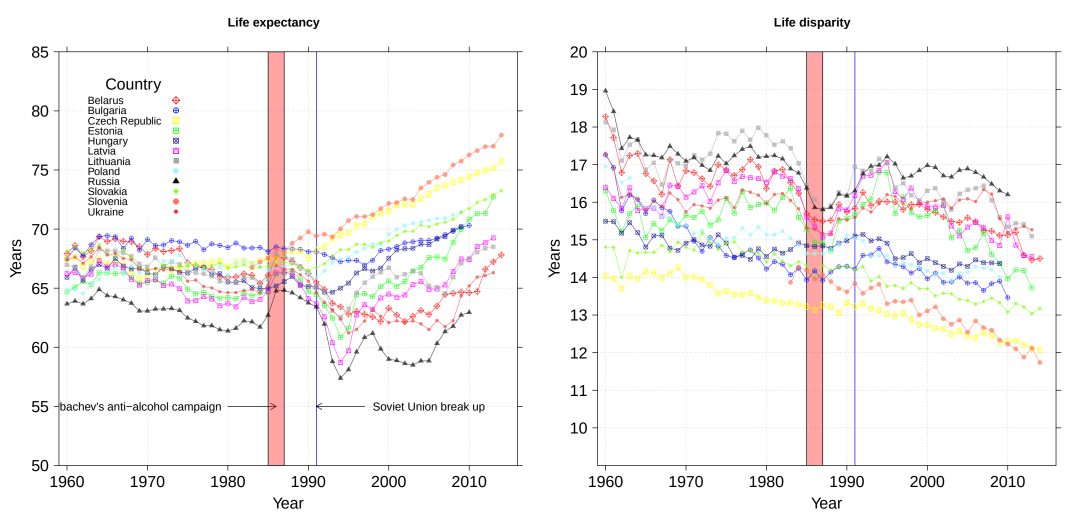
Category	ICD-10 codes
1) Mortality amenable to alcohol consumption	
Alcohol abuse; acute myocardial infarction; atherosclerotic cardiovascular and heart diseases; other IHD; intracranial haemorrhage; cereblar infarction, occlusion and stenosis; other cerebrovascular diseases; alcoholic cirrhosis of liver; transport accidents; accidental exposure to smoke, fire and flames; accidental poisoning by alcohol; accidental poisoning by other substance; suicide and self-inflicted injuries; assault; event of undetermined intent; complication of medical and surgical care.	F10; I21-I23; I25.0, I25.1; I20, I24, I25.2 to .9; I60-I62; I63, I65, I66; G45, I64, I67; K70; V01-V99; X00-X09; X45; X40-X44, X46-X49; X60-X84; X85-Y09, Y35, Y36; Y10-Y34; Y40-Y84.
2) Infectious & respiratory diseases	
Diarrhea and gastroenteritis; tuberculosis; septicemia; other bacterial diseases; HIV disease; viral hepatitis; other viral diseases; other specified intestinal infections; other and unspecified infectious and respiratory diseases; influenza; pneumonia; other acute respiratory infections; asthma; other chronic onstructive pulmonary disease; pneumonitis due to solids and liquids; pneumoconioses and chemical effects; other respiratory diseases, principally affecting the interstitium; other diseases of the respiratory system.	A09; A15-A19, B90; A40-A41; A20-A28, A30-A39, A42-A44, A46, A48-A49; B20-B24; B15-B19; A80-A89, B00-B09, B25-B34; A00-A09; A50-A75,A77-A79, A90-A99, B35-B60, B64-B89, B91, B92, B94-B97, B99; J09-J11; J12-J18; J00-J06, J20-J22, U04; J45-J46; J40-J44, J47; J69; J60-J68. J70; J80-J84; J30-J39, J85-J98.
3) Cancers	
Malignant neoplasms of lip, oral cavity, and pharynx; esophagus; stomach; colon; rectum and anus; liver and intrahepatic bile ducts; pancreas; other malignant neoplasms of digestive system; neoplasm of larynx; of trachea, bronchus and lung; skin; breast; cervix uteri; uterus; ovary; prostate; other genital organs; bladder; kidney and other urinary organ; meninges, brain and other parts of central nervous system; leukemia; other malignant of lymphoid, hematopoietic and related tissue; malignant neoplasms of independent (primary) multiple sites; other cancers: in situ neoplasms, benign neoplasms and neoplasms of uncertain or unknown behavior.	C00-C14; C15; C16; C18; C19-C21; C22; C25; C17, C23-C24, C26; C32; C33-C34; C43, C44; C50; C53; C54-C55; C56; C61; C51, C52, C57, C58, C60, C62, C63; C67; C64-C66, C68; C70-C72; C91-C95; C81-C90, C96; C97; C30-C31, C37-C41, C45-C49, C69, C73-C80; D00-D48.
4) Circulatory diseases	
Rheumatic heart diseases; essential hypertension; hypertensive disease; pulmonary heart diseases; non rheumatic valve disorders; cardiac arrest; heart failure; other heart diseases; sequelae of cerebrovascular disease; diseases of arteries, arterioles and capillaries, other circulatory diseases	I00-I09; I10; I11-I15; I26-I28; I34-I38; I46; I50; I30-I33, I40-I45, I47-I49; I51; I69; I70-I78; I80-I99.
5) Diabetes	E10-E14
6) Birth conditions (including maternal deaths)	O00-O99; P00-P96; Q00-Q99; R95
7) **Residual causes**	Rest of conditions and mortality above age 85

Figure 1: Male mortality surface showing rates of mortality improvements



Source: own calculations based on Human Mortality Database (2016) data. Note: The regular light -grey areas indicate no data available. Russia, Hungary, Bulgaria and Poland after 2010. Slovenia before 1983.

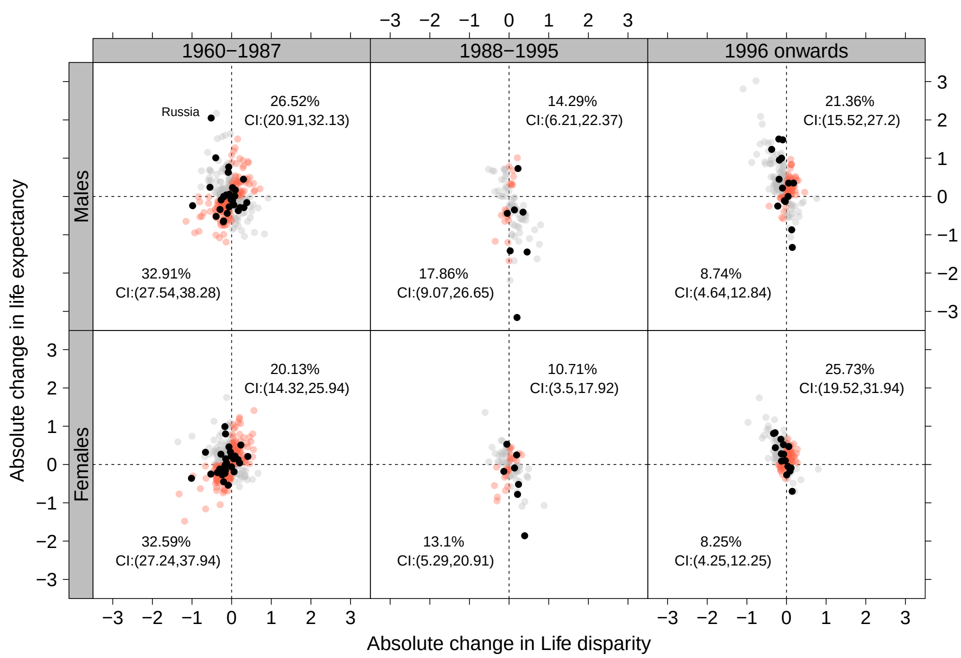
Figure 2: Trends in males life expectancy (e_0) and lifespan disparity ($e^{\dagger}$) for 12 Eastern European countries, 1960-2014



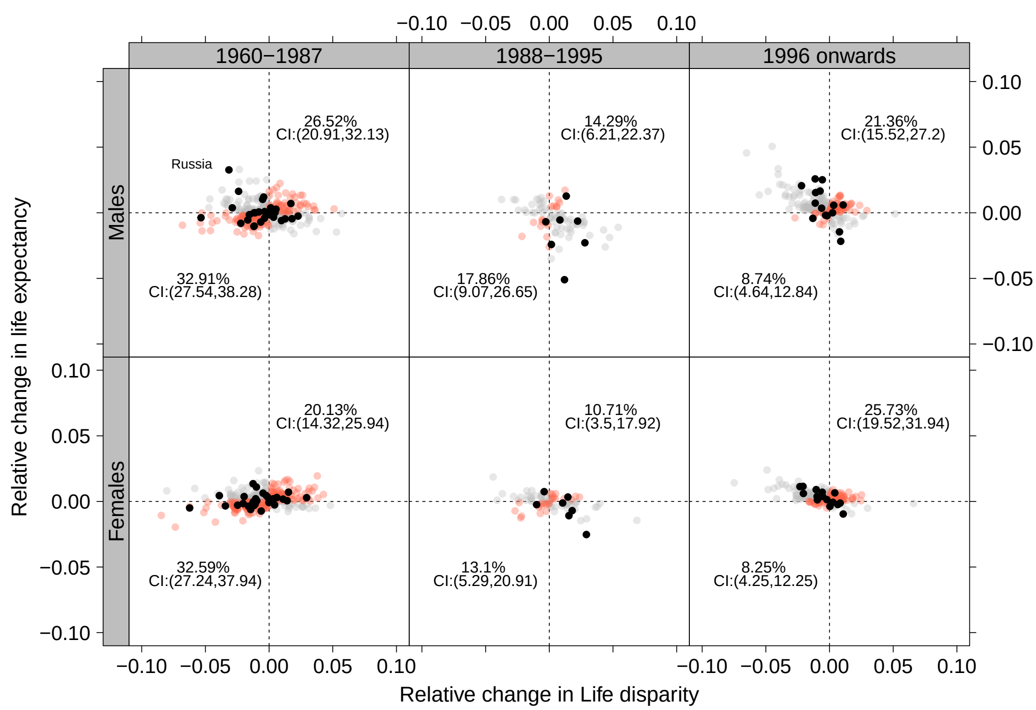
Source: own calculations based on Human Mortality Database (2016) data.

Figure 3: Absolute and relative yearly changes in life expectancy and lifespan disparity, 1960-2010

(a) Absolute changes

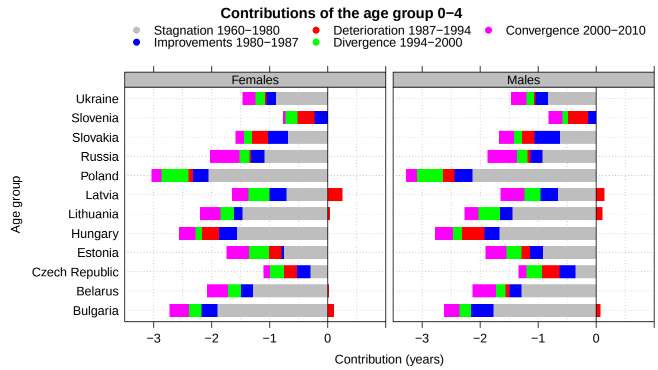


(b) Relative changes



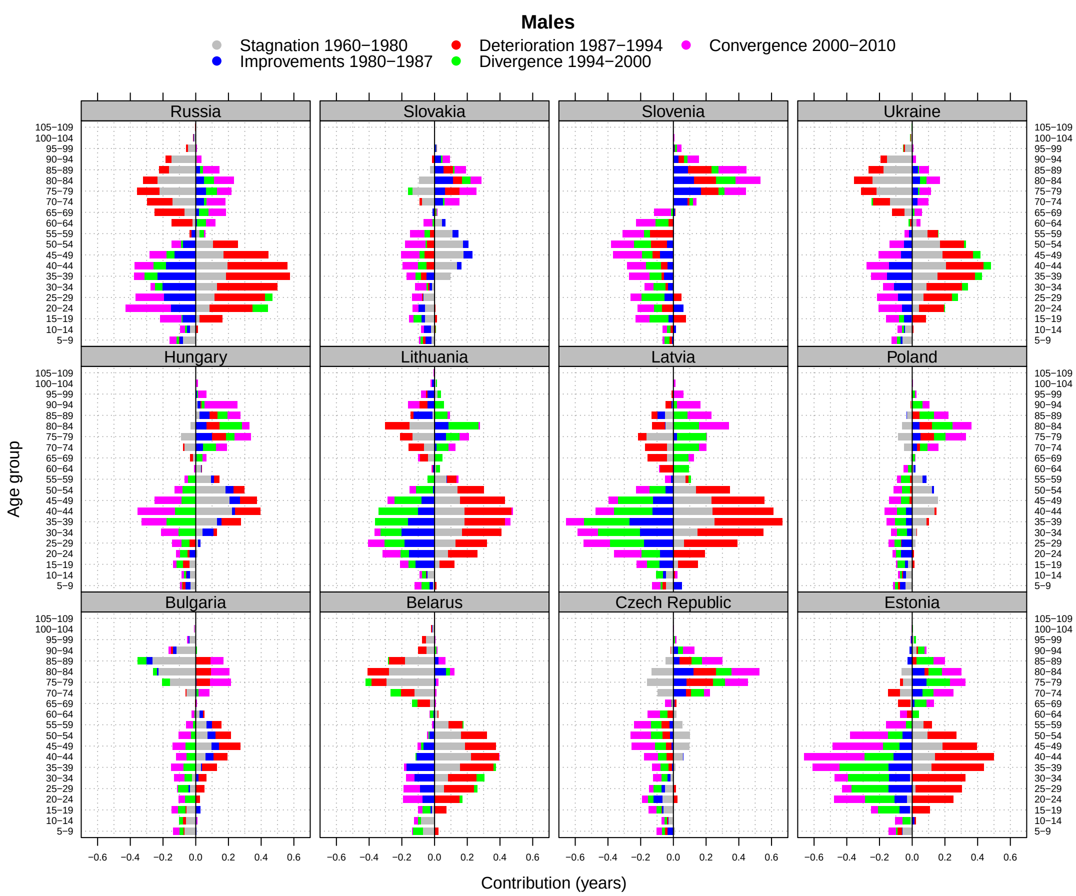
Source: own calculations based on Human Mortality Database (2016) data. Note: data for Slovenia begins in 1983. The black dots are related to changes experienced in Russia. The percentages correspond to the total changes occurred during each period.

Figure 4: Infancy (age-group 0-4) contributions to the change in lifespan disparity $e^{\dagger}$.



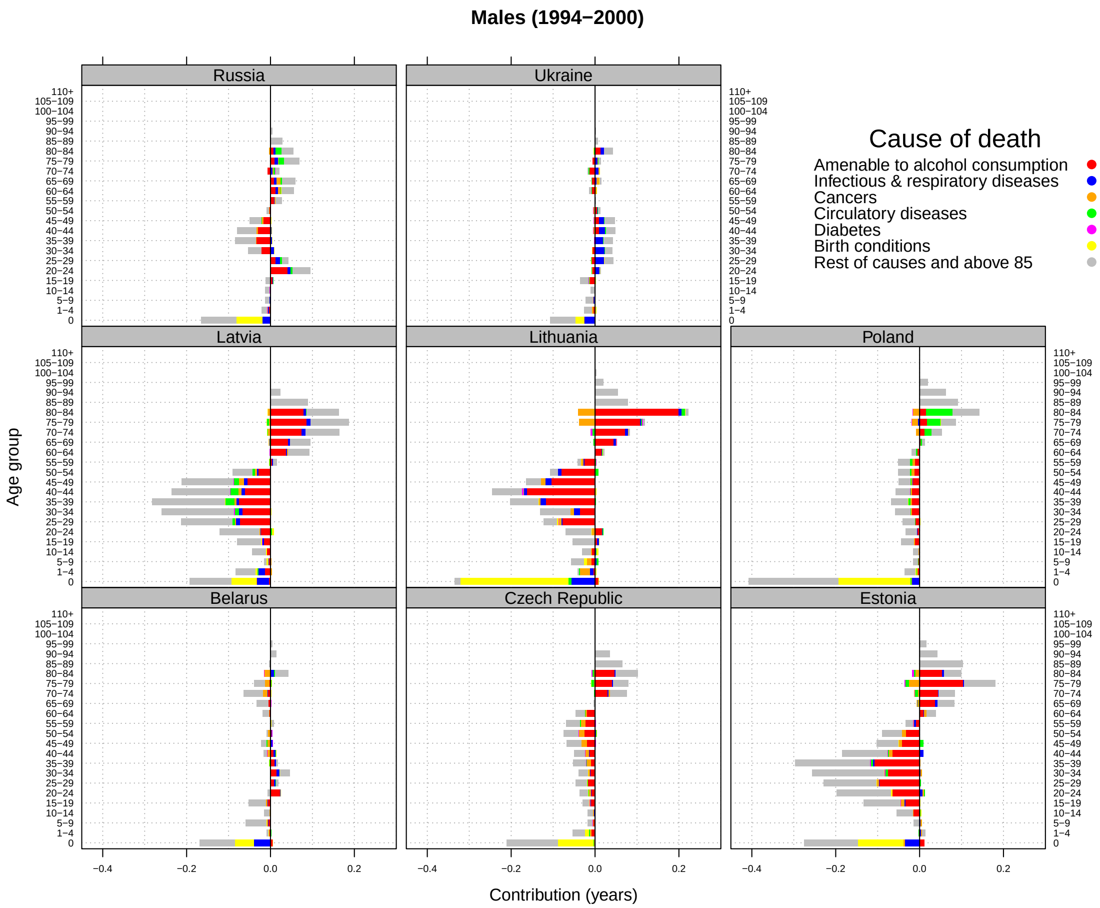
Source: own calculations based on Human Mortality Database (2016) data. Note: data for Slovenia begins in 1983.

Figure 5: Males' age-specific contributions to the change in lifespan disparity $e^{\dagger}$ by periods.



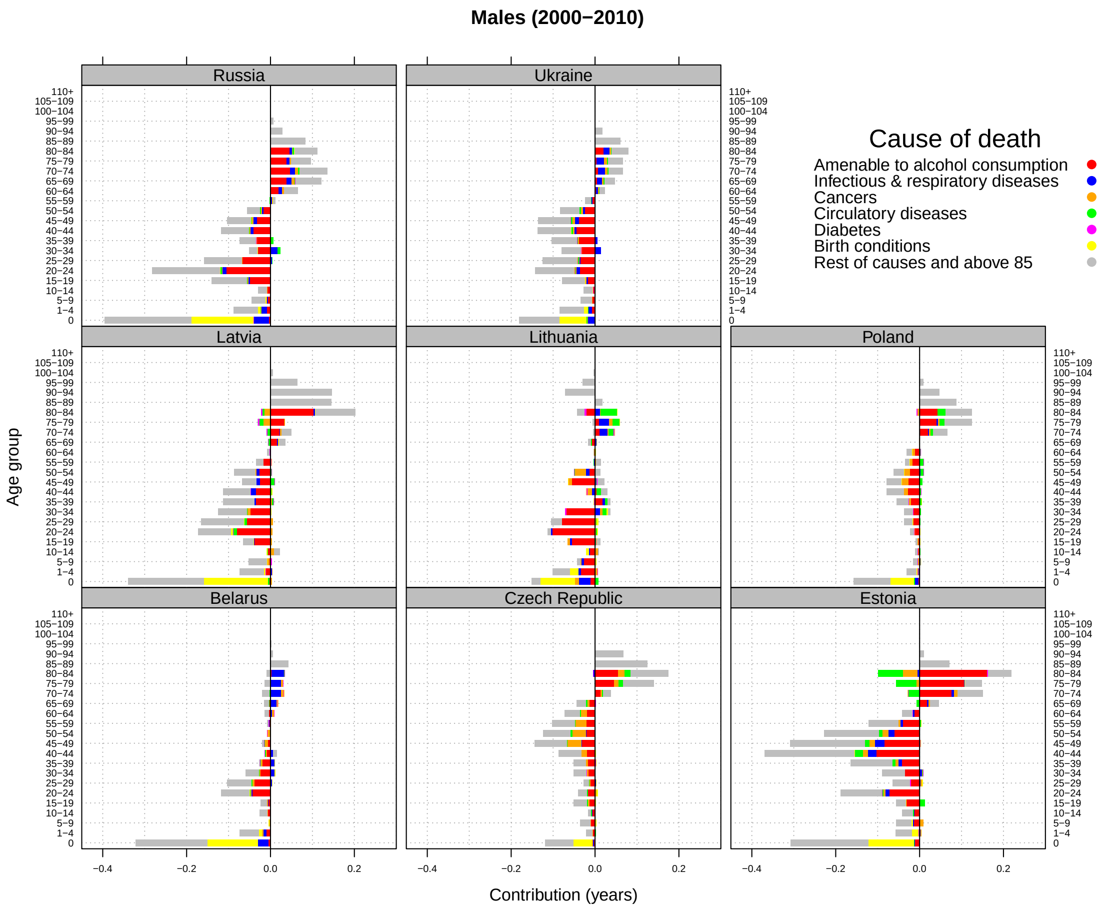
Source: own calculations based on Human Mortality Database (2016) data. Note: data for Slovenia begins in 1983.

Figure 6: Cause specific contributions to the change in male lifespan disparity $e^{\dagger}$, 1994-2000



Source: own calculations based on Human Mortality Database (2016) data. Note: data for Slovenia begins in 1983.

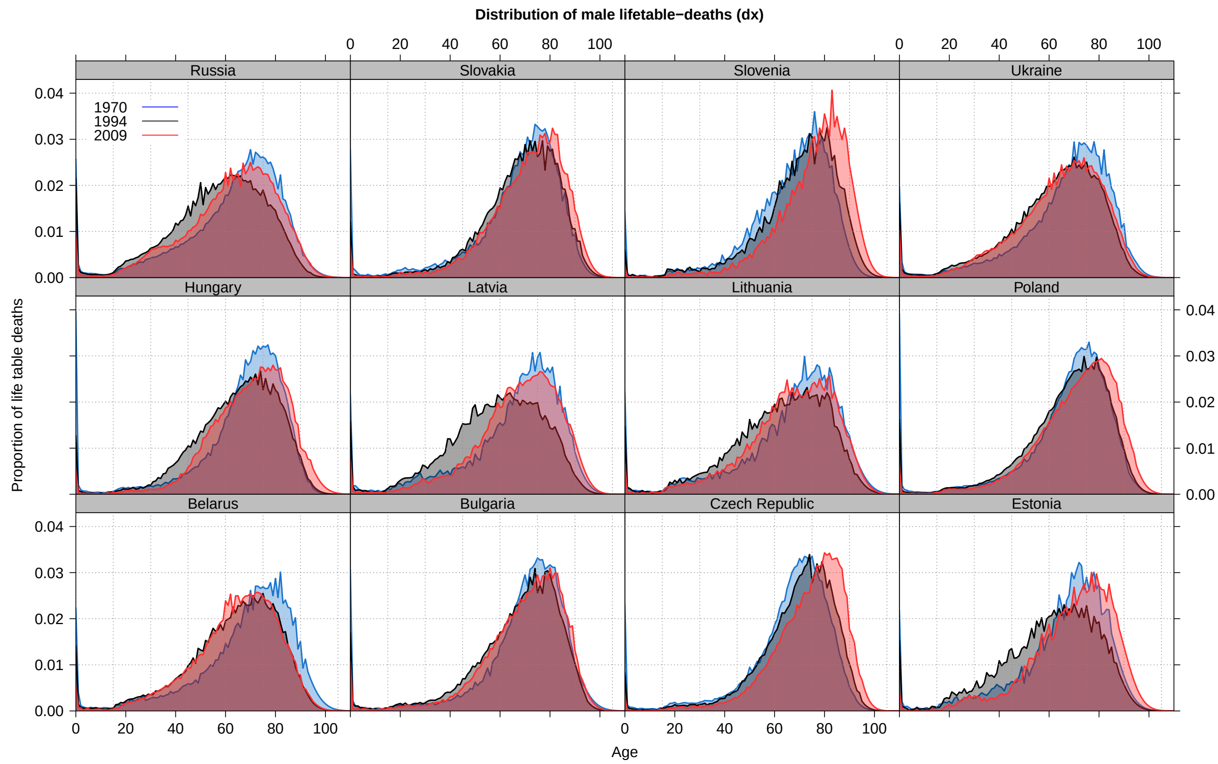
Figure 7: Cause specific contributions to the change in male lifespan disparity $e^{\dagger}$, 2000-2010



Source: own calculations based on Human Mortality Database (2016) data. Note: data for Slovenia begins in 1983.

A Supplemental material: Mortality

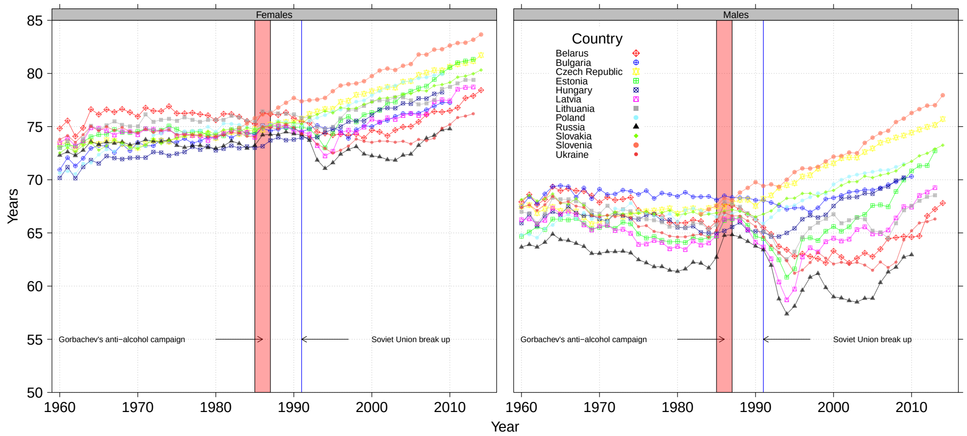
Figure 8: Distribution of deaths for males 1970,1994 and 2009



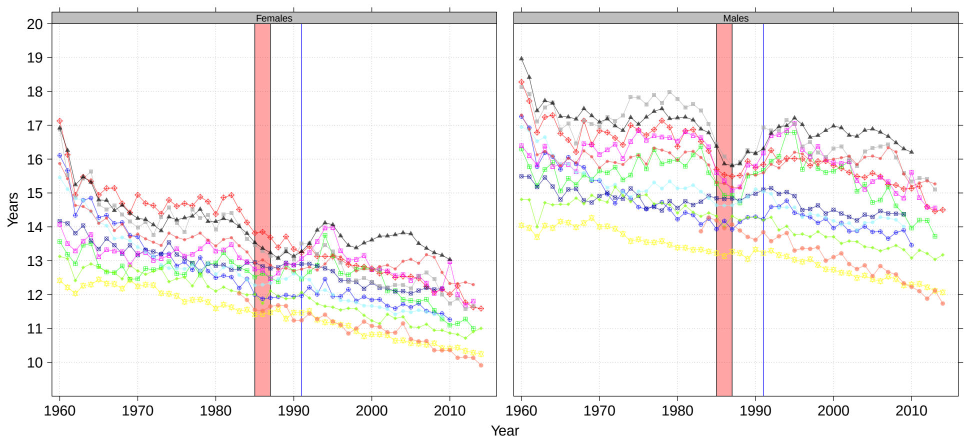
Source: own calculations based on Human Mortality Database (2016) data. Note: the blue distribution for Slovenia corresponds to 1983.

Figure 9: Trends in e_0 and $e^\dagger$ for 12 Eastern European countries by sex, 1960-2014

(a) e_0

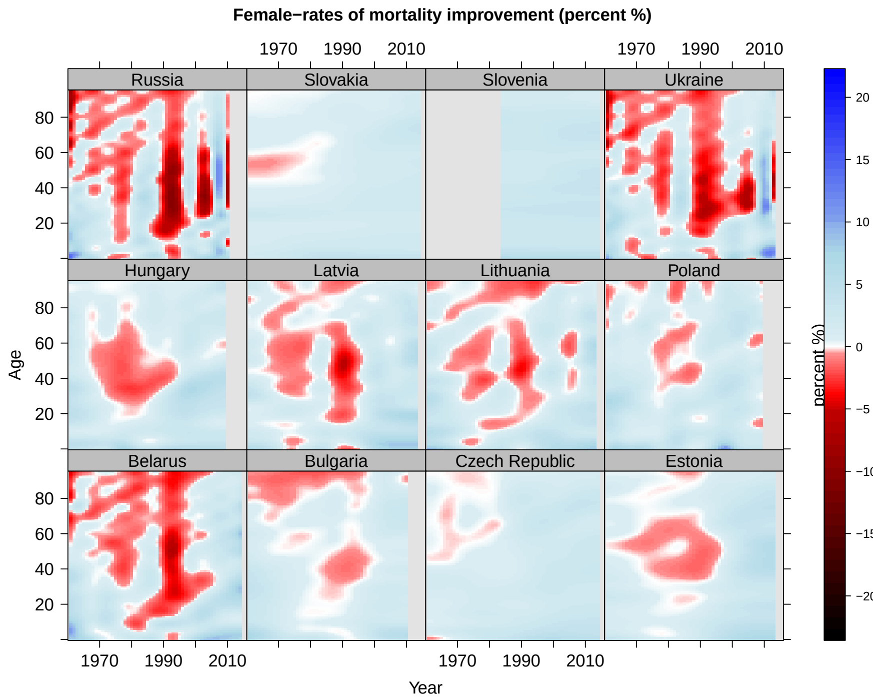


(b) $e^\dagger$



Source: own calculations based on Human Mortality Database (2016) data.

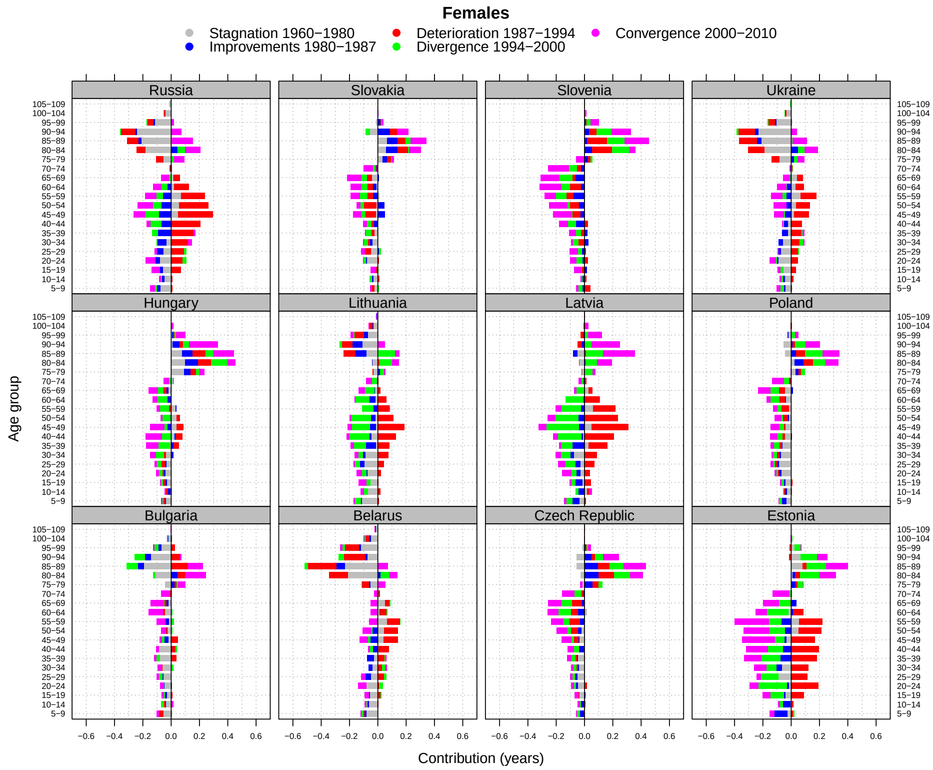
Figure 10: Female mortality surface showing rates of mortality improvements.



Source: own calculations based on Human Mortality Database (2016) data. Note: The regular light -grey areas indicate no data available. Russia, Hungary, Bulgaria and Poland after 2010. Slovenia before 1983.

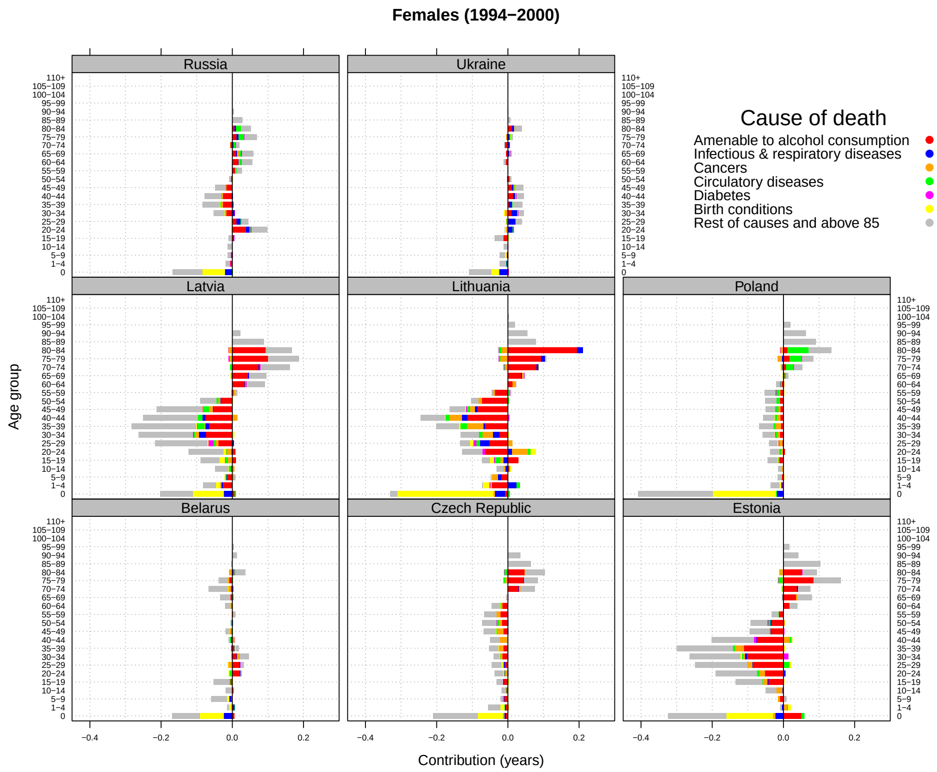
B Supplemental material: Decomposition Results

Figure 11: Females' contributions to the change in lifespan disparity $e^{\dagger}$ by periods.



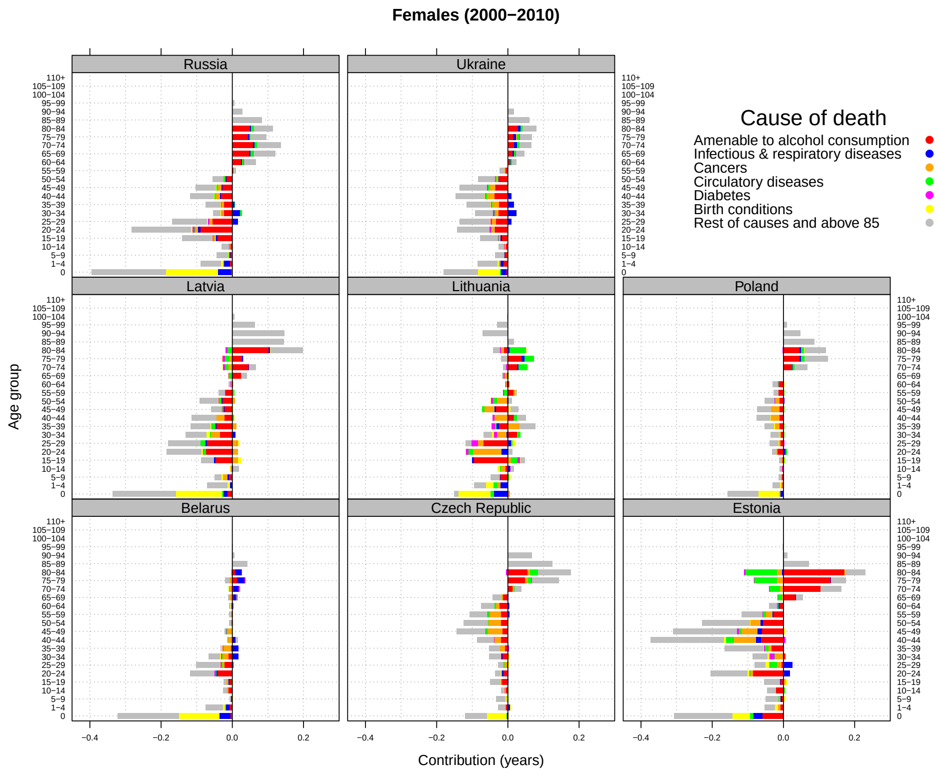
Source: own calculations based on Human Mortality Database (2016) data. Note: data for Slovenia begins in 1983.

Figure 12: Cause specific contributions to the change in female lifespan disparity $e^{\dagger}$, 1994-2000



Source: own calculations based on Human Mortality Database (2016) data. Note: data for Slovenia begins in 1983.

Figure 13: Cause specific contributions to the change in female lifespan disparity $e^\dagger$, 2000-2010



Source: own calculations based on Human Mortality Database (2016) data. Note: data for Slovenia begins in 1983.

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