A Cohort Survival Comparison between Central–Eastern European and High-Longevity Countries

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Abstract

Despite the recent and great improvements in survival across Central and Eastern Europe, this region still lags far behind more developed populations. We take a cohort perspective to investigate the mortality gap between these countries and a group of today's high-longevity countries, thus showing how cohort survival contributes to overall mortality difference. We decompose the *Truncated Cross-sectional Average Length of Life* measure in order to isolate the contributions that age and cohort make to the mortality gap. Using data from the Human Mortality Database, from 1959 to 2013, we find that – compared to their counterparts in high-longevity countries – most Central and Eastern European cohorts born from 1959 onwards have higher mortality levels from birth to the age reached in 2013. Also in comparison to these countries, we find a survival advantage for some Central and Eastern European cohorts, e. g. for Czech cohorts born in the early1960s and for those from former USSR countries born during the 1960s.

Keywords: east-west mortality gap; cohort mortality; age-cohort decomposition; longevity; truncated data, Cross-sectional Average Length of Life.

Introduction

Improvements in mortality do not take place uniformly across regions. Generally, mortality is higher in places where the standard of living is lower. In Europe, it is well-documented that the mortality levels of the Central and Eastern European countries are far higher than those of more developed regions (WHO, 1995; Mustard, 1996; Meslé, 1996; Velkova et al. 1997; Meslé and Vallin, 2002; Andreev et al. 2003; Meslé, 2004). For instance, in the early1990s, the mortality gap stood at over 10 years between Eastern European countries with the lowest life expectancies and Western ones with the highest (Bobak and Marmot, 1996). Yet, despite the great survival improvements in the Eastern European countries, mortality differences persist in Europe (Leon, 2011; Shkolnikov et al. 2013; Mackenbach, 2013; Meslé and Vallin, 2017).

The mortality gap between Central–Eastern and Western Europe is due mostly to changes in health and disease patterns over time (Bobak and Marmot, 1996; Andreev et al. 2003; Meslé et al. 2012; Nolte et al. 2000), and it is usually attributed to differences in socioeconomic, environmental, and public-health investments (Watson, 1995; Bobak and Marmot, 1996; Bobak, 1996; Forster, 1996; Velkova et al. 1997; Vogt et al. 2017). From the end of World War II to the mid-1960s, the increasing use of antibiotics and immunization led to Central and Eastern Europe (CEE) achieving huge progress in survival from infectious diseases, particularly among the youngest ages (Meslé and Vallin, 2002; Vallin and Meslé, 2004). At this time, CEE countries converged towards lower mortality levels, and some almost succeeded in catching up with Northern and Western European countries (Meslé and Vallin 2002; Meslé 2004). Then, in places where mortality at the youngest ages had already reached low levels, a new challenge emerged in the form of improving longevity (Vallin and Meslé, 2004; Canudas-Romo, 2010; Bergeron-Boucher et al. 2015). Following the epidemiologic transition (Omran, 1971), more developed regions showed great progress in survival by degenerative and man-made diseases. Conversely, in the CEE countries, particularly in the former USSR, where high mortality hit adults the hardest, from the mid-1960s to the mid-1980s, adult and old mortality increased for men and stagnated for women (Bobak and Marmot, 1996; Shkolnikov et al. 1997;

Meslé and Vallin, 2002). As a result, mortality began to diverge between Central–Eastern and Western Europe (Vallin and Meslé, 2004; Shkolnikov, 2004).

From the late 1980s, a new divergence in mortality trends began to emerge *within* the CEE countries, thus producing a clear gap between Central and Eastern Europe. In Central Europe, health improvements reduced mortality from cardiovascular disease, which in turn increased life expectancy (Meslé 2004). In contrast, the former USSR countries, followed a brief period of improvement (1985–1986), with a sharp increase in mortality due to the economic crises of the 1990s and low investments in public health (Leon et al. 1997; Meslé, 2004; Andreev et al. 2003; Shkolnikov, 2004; Gavrilova et al. 2001; Grigoriev et al. 2010).

However, since the beginning of the 21st century, a new mortality trend has been observed in the former USSR countries, where mortality from cardiovascular disease and external causes of death at adult ages have started to decline (Grigoriev et al. 2010; Jasilionis et al. 2011; Shkolnikov et al. 2013; Grigoriev et al. 2014, Grigoriev and Andreev, 2015). In Russia, for instance, life expectancy at birth for both sexes increased by more than 5 years between 2004 and 2014, reaching 70.91 years in 2014,– the highest level in the country's recent history (Human Mortality Database, 2017). Another huge survival improvement took place in Belarus, where male life expectancy increased by about 2 years in one calendar year (2011–2012) (Grigoriev and Andreev 2015). Despite this recent great mortality improvement in the former USSR countries, in terms of health, their populations still lag behind Western European countries.

As already mentioned, more developed countries, like those in Western Europe, have shown long-term improvements in health, while also experiencing a sustainable decline in mortality over the past decades. From a cohort perspective, a continuous decrease in mortality over time leads to several generations experiencing the gradual benefits of health improvements, with younger cohorts benefiting more because their mortality experience begins at levels lower than those of older cohorts.

In the case of discontinuous or short-term health progress, on the other hand, only a few cohorts can enjoy the benefits of health advances. The anti-alcohol campaign that the Soviet Union established in a specific time frame (1985–1986) provides an example of this. The campaign reduced the mortality of several cohorts at adult ages during the mid-1980s, leading to a short period of increasing life expectancy (Shkolnikov and Nemtsov, 1997; Shkolnikov et al., 2004; Shkolnikov, 2012; Grigoriev and Andreev, 2015). Then, the economic crises of the 1990s hit certain age groups in the former USSR countries harder than others, with some cohorts experiencing greater negative health effects than others (Shkolnikov, 2012).

German reunification also exemplifies the importance of period changes in reducing mortality. After the fall of the Berlin Wall, mortality improved for all age groups in East Germany, but at a differential pace among ages (Vogt, 2013; Vogt and Kluge, 2015, Vogt et al. 2017), which suggests that the mortality gap differs across birth cohorts. For instance, the Eastern European cohorts born in 1890, 1900 and 1910 converged to Western European mortality levels faster than the younger cohorts (born in 1920 and 1930) (Vogt and Missov, 2017). Thus, we can speculate that the mortality differences between East and West German older cohorts fell faster than those between younger cohorts. This indicates that the contributions to mortality gap during the East–West Germany differ across birth cohorts in Germany.

Given the different political regimes, the fact that Central–Eastern European socioeconomic and medical policies have differed from those of Western Europe over recent decades, and because changes have had major effects on some CEE birth cohorts but not on others, we wondered whether the mortality gap between CEE and Western European countries also varies across birth cohorts. Further, we hypothesized that the contribution of each birth cohort to the overall mortality gap in a given time period can vary.

Our aim here is to compare mortality between CEE and a group of high-longevity countries (HLC) through a measure similar to period life expectancy, but based on available cohort survival data. To accomplish this, we calculate and then decompose the *Truncated Cross-sectional Average Length*

of Life (*TCAL*) measure (Canudas-Romo and Guillot, 2015). By decomposing the gap in *TCAL* by age and cohort, we can analyse the survival trajectories of CEE cohorts in comparison with their HLC counterparts. Moreover, such decomposition, makes it possible to identify the short- and long-lasting effects of survival advantage/disadvantage at a given age for a certain CEE cohort. We complement previous studies by adding cohort mortality dynamics in order to help form a better understanding of the mortality gap between CEE and HLCs.

Methods

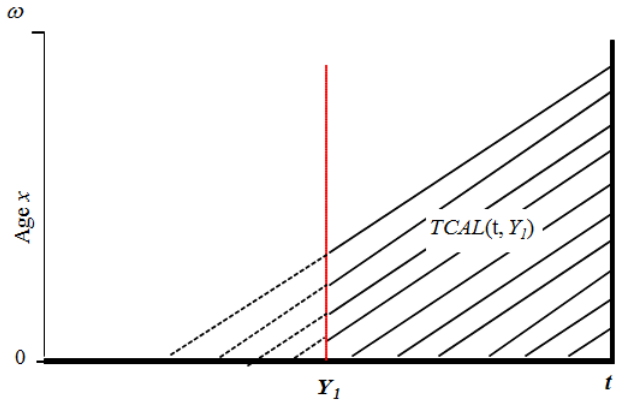
The *TCAL* is a cross-sectional measure that summarizes historical mortality information about all cohorts present at a given time, and it is not limited to populations with complete cohort mortality data (Canudas-Romo and Guillot, 2015). It derives from the *Cross-sectional Average Length of Life* (*CAL*) measure, developed by Brouard in 1986 (Brouard, 1986). *CAL* can be interpreted as the mean length of life lived by an average cohort present in a given period, in terms of the population's mortality experience (Guillot, 2003). The difference between *CAL* and *TCAL* is that the second one can be calculated for populations without complete cohort mortality data. *TCAL* provides a novel way of comparing mortality and investigating survival disparities between populations by considering all the information availabale for all cohorts presente at a given time–regardless of whether or not they have complete cohort data, and regardless of whether the data come from a young or old cohort. The *TCAL* measure has an advantage over assessments of just a single year, which, from a period analysis perspective, combines pieces of mortality information from different cohorts. It also has an advantage over assessing, one by one, each individual cohort present at a given time while not knowing how they jointly contribute to the overall survival disparities between populations.

To calculate the $TCAL$, we define the year, *t*, for which we are interested in estimating the measure, and also the earliest year for the available mortality series, Y_1. Thus, the *TCAL* for year *t*, truncated at year Y_1, is computed as:

$$TCAL(t,Y_1) = \int_0^{\omega} \ell(x,t,Y_1)dx \qquad (1)$$

where $\ell(x,t,Y_1)$ is the survival function for cohorts reaching age x in year t, whose members were born in year $t-x$. In the Lexis diagram shown in Figure 1, we see that $TCAL(t,Y_1)$ includes mortality rates from year Y_1, which are located along diagonals that cross the age axis at time t.

Note that some of the cohorts were born after year Y_1 and have full cohort information. For cohorts born before the year Y_1, only partial cohort mortality data are available; so we assume a set of death rates for the years before year Y_1. Since our interest is in the mortality gap between populations, the *TCAL* differences will be consistent if we use the same set of death rates for the years before Y_1 in all the examined countries (Canudas-Romo and Guillot, 2015). In order to eliminate any confounding effects of death rates before the year Y_1, we assume death rates equal to zero for all the years before Y_1, thereby focusing our comparisons solely on the cohort information available.



Source: Author's illustration.

Figure 1 – Lexis diagram for the location of death rates used in $TCAL(t,Y_1)$

To compare two populations at time t, both *TCALs* must be truncated at the same year (Y_1), which means, in this case, that the mortality series for all CEE countries and for the group of HLCs

must start at Y_1. Thus, after comparing the *TCALs* of each CEE country with the group of HLCs, we see which populations had higher mortality levels according to historical mortality data. Lower *TCAL* values correspond to populations that had higher cohort mortality levels.

The difference in *TCALs* between the group of HLCs and each CEE country, *i*, is then:

$$TCAL_{HLC}(t,Y_1) - TCAL_i(t,Y_1) = \int_0^{\omega} \left[\ell_{HLC}\left(x,t,Y_1\right) - \ell_i\left(x,t,Y_1\right) \right] dx \quad (2)$$

Where the integral corresponds to the cohorts present at time *t*, aged 0 to ω and both populations have the same set of age-specific death rates in year Y_1. The cohort survival differences on the right side of equation (2) allow us to identify the mortality contribution of each cohort present in year *t*. The difference between *TCALs* is comparable to the difference between life expectancies in that it shows the number of years one population lags behind another.

We can rewrite equation (2) using the definition of cohort survival as:

$$TCAL_{HLCs}(t,Y_1) - TCAL_i(t,Y_1) = \int_0^{\omega} e^{-\int_0^x \mu_{HLC}(a,t-x+a)da} - e^{-\int_0^x \mu_i(a,t-x+a)da} dx \quad (3)$$

where $\mu_{HLCs}\left(a,t-x+a\right)$ and $\mu_i\left(a,t-x+a\right)$ are the forces of mortality at age *a* and time *t-x+a* for, respectively, the HLCs and population *i*. As the *TCAL* condenses the available cohort mortality history into one measure, equations (2) and (3) show that any differences between *TCAL*s allow us to identify cohort-specific contributions to the mortality gap. Thus, the age-cohort contribution $\Delta\left(a,t-x,i\right)$ to the difference between the $TCAL_{HLCs}$ of the HLCs and that of the population *i*, $TCAL_i$ can be estimated as:

$$\Delta(a,t-x,i) = \left[\frac{\ell(x,t,Y_1,HLCs) + \ell(x,t,Y_1,i)}{2} \right] \ln \left[\frac{{}_1p_a(t-x,HLCs)}{{}_1p_a(t-x,i)} \right], \quad (4)$$

where $\ell(x,t,Y_1,i)$ and $\ell(x,t,Y_1,HLCs)$ are the survival functions for the cohort aged *x* at time *t* in, respectively, the group of HLCs and population *i*; and ${}_1p_a(t-x,HLCs)$ and ${}_1p_a(t-x,i)$ are the

probabilities of surviving from age a to $a+1$ for the cohort born in year $t-x$ in, respectively, the HLCs and population *i*. Finally, instead of the integrals in equations (2) and (3), the sum over cohorts and ages of the age-cohort contributions, $\Delta(a,t-x,i)$, returns the difference in *TCALs*

$$TCAL_{HLCs}(t,Y_1) - TCAL_i(t,Y_1) \approx \sum_{x=1}^{\omega}\sum_{a=0}^{x-1}\Delta(a,t-x,i)\,. \qquad (4)$$

By means of such decomposition, we compare mortality between birth cohorts from different populations.

The main limitation of the method is data availability. In principal, we would be interested in presenting as much cohort data as possible. However, this is not possible for many regions of the world, such as in the CEE. Furthermore, despite constraints on data quantity, data quality improves over time. Thus, any measure with a cohort perspective will include some of the quality bias that exists in the older information.

Data

From the Human Mortality Database (2017), we selected 11 Central and Eastern European (CEE) countries: Belarus, Bulgaria, Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Russia, Slovakia, and Ukraine. The high-longevity countries (HLCs) included in the analysis are: Australia, Austria, Belgium, Canada, Denmark, Germany, Finland, France, Iceland, Ireland, Italy, Japan, the Netherlands, Norway, New Zealand, Portugal, Spain, Sweden, Switzerland, the United States, and the United Kingdom. The same selection of HLCs has been used elsewhere (Ho and Preston, 2010; Canudas-Romo and Engelman, 2012; Canudas-Romo and Guillot, 2015) to represent the lowest mortality levels. For this group, we calculated period age-specific death rates by adding annual death counts and exposures from each country.

We used mortality series from 1959 to 2013, except in the cases of Canada and Bulgaria, where HMD data are currently available only up to, respectively, 2011 and 2010. In order to compare mortality levels between each CEE country and the group of HLCs, we truncated all series

in 1959, the first year of available HMD data for most of the CEE countries; then, we calculated the *TCAL* in 2013, truncated in 1959 – or, as expressed in equation (1), *TCAL* (2013, 1959) .

The HMD data provide detailed historical information on mortality for most industrialized countries. It should be noted, however, that the quality of data for 1959–1969 is lower than in later years for Latvia, Russia, Ukraine and Belarus (Jasilionis, 2017; Shkolnikov and Jdanov, 2016; Pyrozhkov et al. 2015; Gregoriev, 2015). Also, data for 1959–1979 in Lithuania should be used with caution, while the quality of the data in Estonia for 2001–2009 is lower than in previous years (Jasilionis, 2017; Jasilionis, 2017). Information from earlier years (for old ages) should also be treated with caution, due to data quality issues in the former USSR countries. In Central Europe, the quality of data in Slovakia from 1959 to 1961 and in Hungary for 1959 is lower than in later years (Mészáros and Jasilionis, 2015; Jasilionis and Radnóti, 2016).

It is also relevant to mention here that the HMD publishes cohort death rates only for cohorts that have at least 30 years of data. For instance, period death rates for Ukraine are currently available up to 2013, but cohort death rates are available only up to the cohort born in 1983. Therefore, to avoid an interruption in the cohort series, we used period death rates to reconstruct the diagonals. This was done consistently across all the countries analysed, for both CEE countries and HLCs.

We further carried out a sensitivity analysis using data for countries that have enough cohort data to construct complete (*i*) cohort life tables, which we then compared with (*ii*) cohort life tables based on period rates in a diagonal manner. Based on the HMD data and combining females and males for the 1900 cohort, disparities between life expectancies at birth for each country were minor: (*i*) 59.3 and (*ii*) 59.2 years for Denmark, (*i*) 55.1 and (*ii*) 55.0 years for the Netherlands; (*i*) 59.6 and (*ii*) 59.4 years for Norway; and (*i*) 58.8 and (*ii*) 58.7 years for Sweden. Both the sensitivity analysis and the consistency of the procedure for all countries reassured us that our results are not biased by the set of death rates selected.

Results

Table 1 gives rankings of life expectancy at birth from highest to lowest. The table covers life expectancy at birth (e_0), based on current mortality in 2013, and *TCAL (2013, 1959),* which captures the available mortality history from 1959 of all cohorts present in 2013, for each CEE country by sex. As expected, all CEE countries lag behind the group of HLCs. In comparing e_0 with *TCAL*, Table 1 displays *TCAL* values that are lower than e_0 for all countries. This is explained by *TCAL* taking into account the higher mortality levels in the historical mortality data while they are not considered in e_0.

When the Central and Eastern European countries are ranked according to *TCAL* and e_0, the Central European countries are clustered at the top, while the Eastern European countries are at the bottom. This suggests that both historical and current mortality in Eastern Europe are higher than those in Central Europe. For instance, Ukraine and Russia have the highest mortality levels according to both the *TCAL* and e_0, while the Czechia and Poland are in the top 3 for both rankings. Despite this overall picture, we also identify some country-specific arrangements in Table 1. For instance, Estonian women move from the top of the life expectancy ranking (e_0 = 81.3 years), to 3rd position in the *TCAL* (77.9 years); Estonian men also go down in the rankings when transiting from e_0 to the *TCAL*, from 4th (e_0 = 72.7 years) to 6th (*TCAL* = 66.7 years). Since the beginning of the 21st century, Estonia has shown remarkable mortality improvements. From 2000 to 2010, Estonian life expectancy increased by 4.2 years for women and 5.2 years for men. Indeed, these recent increases in life expectancy were three times and 11 times higher than over the previous decade for, respectively, women and men. This exemplifies the existing differential between current and cohort mortality, as depicted by life expectancy and *TCAL*.

In order to show the performance of CEE countries in relation to the HLCs, Table 1 presents the differences in e_0 and in *TCALs* between each CEE country and the group of HLCs in 2013. In both cases, the greatest differences are between the former USSR countries and the HLCs. For instance, the Russian male *TCAL* was 14.1 years lower than the *TCAL* in HLCs in 2013, while

the gap in e_0 is 13.2 years. In the Czechia, however, the male gap in *TCAL* (Czechia vs. HLCs) is 3.8 years, about 10 years lower than the male *TCAL* difference between Russia and the HLCs. Considering this smaller difference in *TCALs* between the Czechia and the HLCs compared with the gap between Russia and the HLCs, one may conclude that the historical improvements in male survival have been much greater in the Czechia than in Russia.

Note that the male gap in life expectancy (CEE vs. HLCs) for most CEE countries is smaller than the difference in *TCALs* (Table 1). In Hungary, the male gap in e_0 is 29% lower than the gap in *TCALs*, while in Estonia the male difference in life expectancy is almost 60% lower than the difference in *TCALs* (Estonia vs. HLCs). In other words, the difference is higher in male historical mortality than in current mortality when comparing CEE countries with HLCs. The differences in current mortality may possibly have been reduced by recent mortality improvements in the male mortality of CEE countries compared with HLCs. Among women, by contrast, Table 1 shows higher gaps in e_0 (CEE vs. HLCs) than differences in *TCALs* (CEE vs. HLCs) for all countries except the Czechia. For instance, Lithuania's female life expectancy is lagging behind the HLCs by 5.1 years, while the difference in cohort mortality is 20% lower. In the Ukraine, the female gap in e_0 (Ukraine vs. HLCs) is more than one year higher than the difference in *TCALs* (Ukraine vs. HLCs). This may be explained by the slow progress over recent decades in the female mortality of CEE countries when compared with HLCs. The greater disparity in female life expectancies may possibly be explained by some past mortality improvements among women that were captured by the *TCAL* but not by life expectancy.

Table 1 - Central-Eastern European countries, life expectancy at birth (e_0), *TCAL* and differences to the high longevity countries' e_0 and *TCAL* for males and females in 2013.

Country (i)	e_0 (2013)	Rank e_0	Differences in e_0 between Country i and HLCs*	*TCAL* (2013,1959)	Rank *TCAL*	Differences in *TCAL* between Country i and HLCs**
			Female			
Estonia	81.33	1	-3.16	77.91	3	-3.77
Czechia	81.15	2	-3.34	78.81	1	-2.87
Poland	80.92	3	-3.57	78.27	2	-3.41
Slovakia	79.97	4	-4.52	77.70	4	-3.98
Lithuania	79.37	5	-5.12	77.41	5	-4.27
Hungary	79.01	6	-5.48	76.30	6	-5.38
Latvia	78.73	7	-5.76	76.29	7	-5.39
Belarus	77.89	8	-6.60	75.61	9	-6.07
Bulgaria***	77.25	9	-5.97	75.81	8	-5.43
Russia	76.29	10	-8.20	73.97	11	-7.71
Ukraine	76.21	11	-8.28	74.57	10	-7.11
			Male			
Czechia	75.15	1	-3.18	71.80	1	-3.84
Poland	72.98	2	-5.35	69.36	3	-6.29
Slovakia	72.90	3	-5.43	69.40	2	-6.24
Estonia	72.72	4	-5.61	66.70	6	-8.95
Hungary	72.13	5	-6.20	67.62	5	-8.02
Bulgaria***	70.31	6	-7.58	68.71	4	-6.38
Latvia	69.26	7	-9.07	64.96	8	-10.68
Lithuania	68.52	8	-9.81	65.93	7	-9.72
Belarus	67.23	9	-11.10	64.09	9	-11.56
Ukraine	66.31	10	-12.02	63.77	10	-11.87
Russia	65.10	11	-13.23	61.50	11	-14.14

Source: Authors's calculation, based on HMD data.

Notes: * e_0(2013) for HLCs is 78.33 years for males and 84.49 years for females.

** *TCAL(2013,1959)* for HLCs is 75.64 years for males and 81.68 years for females

*** Mortality serie from 1959 to 2010 - e_0(2010) for HLCs is 77.89 years for males and 83.22 years for females *TCAL(2010,1959)* for HLCs is 75.09 years for males and 81.24 years for females

To further understand the differences in cohort survival, Figures 1 (Central European countries) and 2 (Eastern European countries) show the age-cohort decomposition of the *TCAL* difference between each CEE country and the group of HLCs, with females and males being indicated by, respectively, figures A and B. Such decomposition allows us to investigate the contribution that cohorts present in 2013 make to the gap in *TCALs* between each CEE country and the HLCs. Figures 1 and 2 show the Lexis surfaces of the cumulative age and cohort contributions to the difference in *TCALs*. Each data point (age-*x* and time-*t*) in these figures represents the cumulative difference in cohort survival up to the specific age-*x* and year-*t*. Negative values are associated with higher survival in the HLCs.

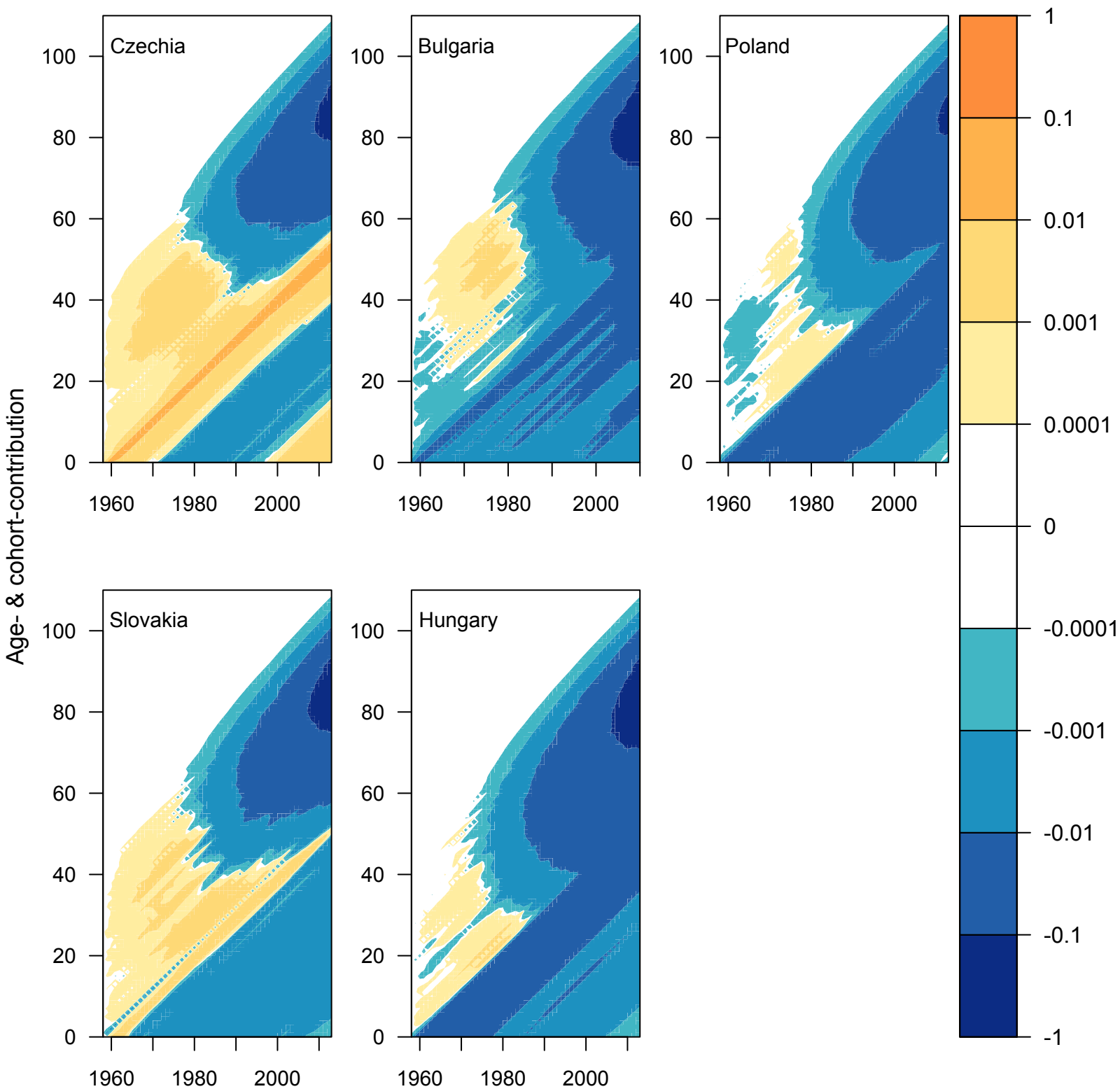
Figures 1A and 1B for females and males, respectively, show lower mortality levels for most cohorts in the HLCs than in their counterparts in Central Europe for both sexes. With the exception of some Czech and Polish cohorts, all Central European cohorts present in 2013 contribute to the overall mortality disadvantage between each Central European country and the HLCs in 2013.

In comparison, the overall picture of the Czechia vs. the HLCs stands out from those of the other Central European countries. Figures 1A and 2A show that Czech cohorts born in the late1950s and during the 1960s – especially those born in the early1960s –had a particular survival advantage over their counterparts in HLCs from birth until the age they reached in 2013. After World War II and up to the mid-1960s, mortality in the Czechia greatly decreased due to their extending health coverage to the entire population. At this time, Czech life expectancy at birth increased at the same rate as in France, and both countries achieved a similar mortality level (Rychtaříková, 2004). In addition to confirming the great mortality improvement during the 1960s, our decomposition reveals the long-lasting effect of lower mortality at younger ages for Czech cohorts compared with the HLCs. The low mortality in infancy and childhood lasts until 2013, and it is seen in the Czechia's higher cohort survival for cohorts born from 1959 to the early 1970s. These figures also suggest a more recent cohort development, i.e. lower infant/child mortality in the

Czechia than in the HLCs. These recent mortality improvements in the Czechia may contribute to the slightly lower gap in e_0 (Czechia vs. HLCs) than in *TCALs*.

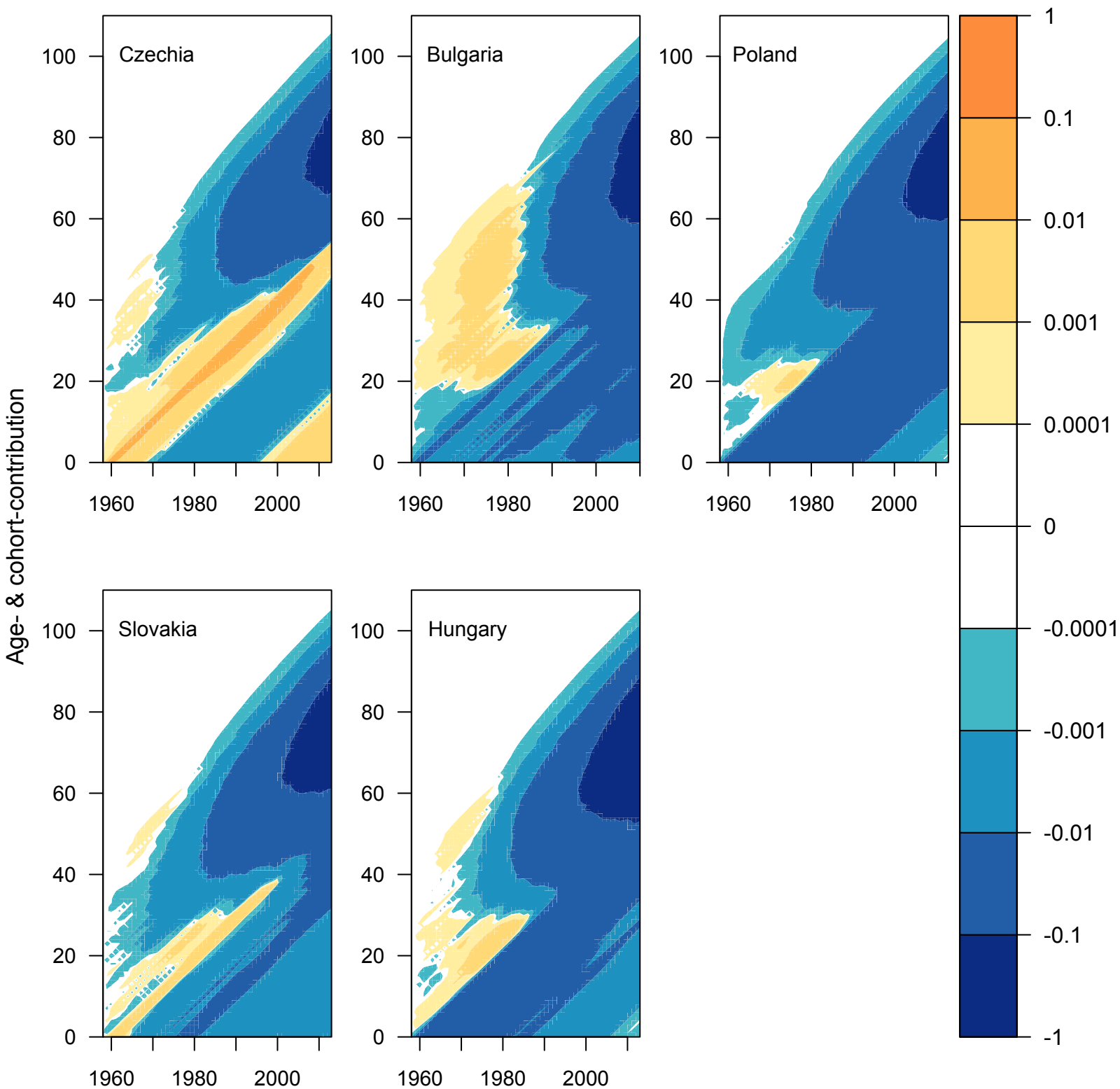
In our window of observation, from 1959 to 2013, Figures 1A and 1B also reveal that Central European cohorts born from the 1920s to the late 1950s experienced lower mortality compared with the group of HLCs. This survival advantage is greater for females than for males. However, all these Central European cohorts have gradually lost their survival advantage compared with HLCs. Figure 1B shows that the male cohorts aged 60–80 in the 2000s are the ones that contribute the most to the mortality gap between Central European countries and HLCs in 2013. Among women, despite the great contribution that the cohorts aged 60–80 in the 2000s make to the differences in *TCALs,* their contribution is lower in comparison to that of men.

Figure 1A - Lexis surface for the cumulative age- & cohort-contributions to the difference in TCALs between CEE countries and other HLCs, Females.



Note:Negative values correspond to higher HLCs survival.
Source: HMD data and authors'own calculation.

Figure 1B - Lexis surface for the cumulative age- & cohort-contributions to the difference in TCALs between CEE countries and other HLCs, Males.

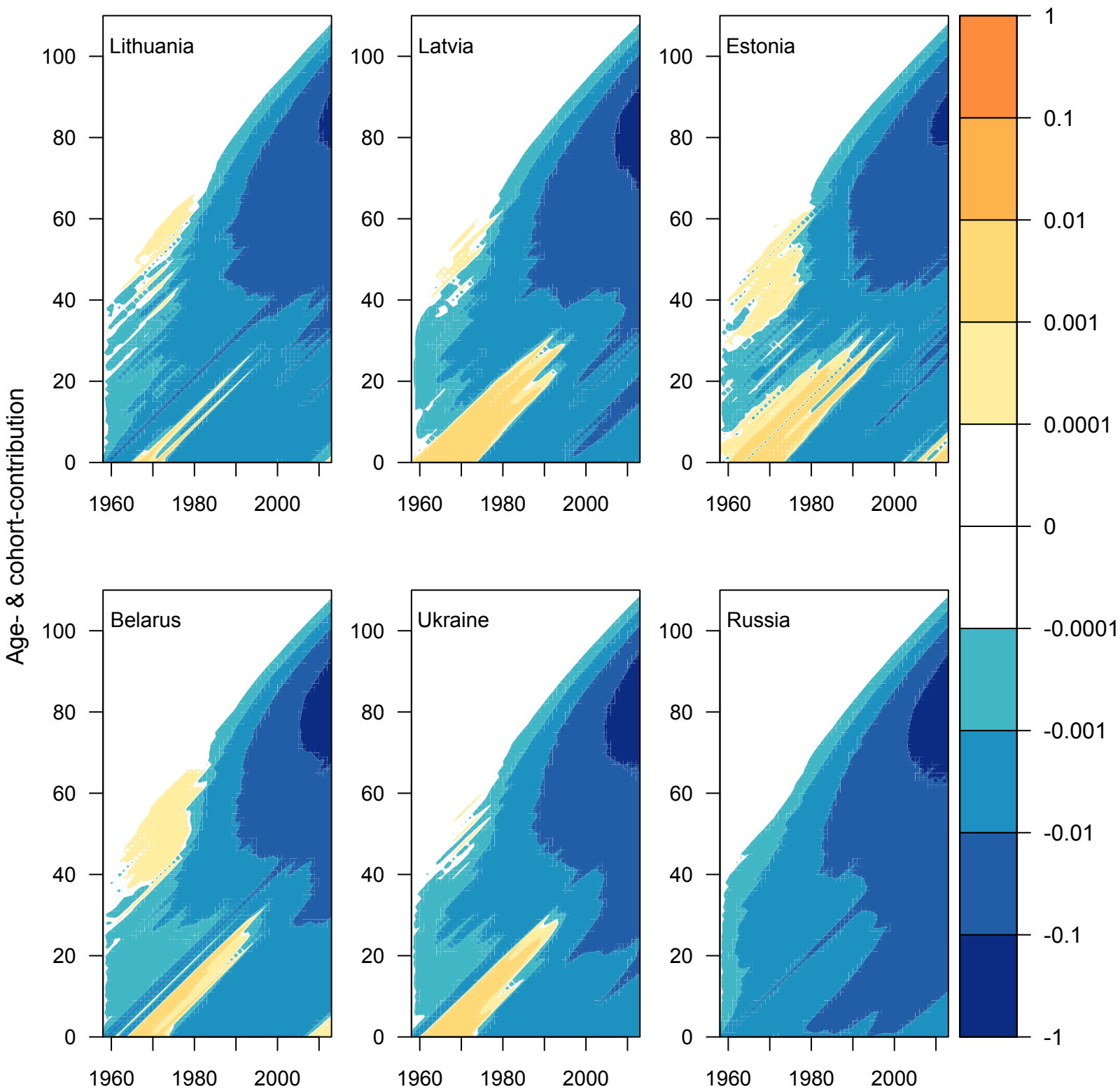


Note:Negative values correspond to higher HLCs survival.
Source: HMD data and authors'own calculation.

For the former USSR countries (Figures 2A and 2B), the overall picture is very similar: a great survival disadvantage exists for most cohorts. Moreover, survival disadvantage (Eastern European countries vs. HLCs) for all cohorts born between 1959 and 2000 increases as the cohorts get older. Note that no Eastern European cohort has experienced lower mortality than HLCs in middle-aged adults. Indeed, the survival disadvantage of Eastern European cohorts greatly increases after age 30.

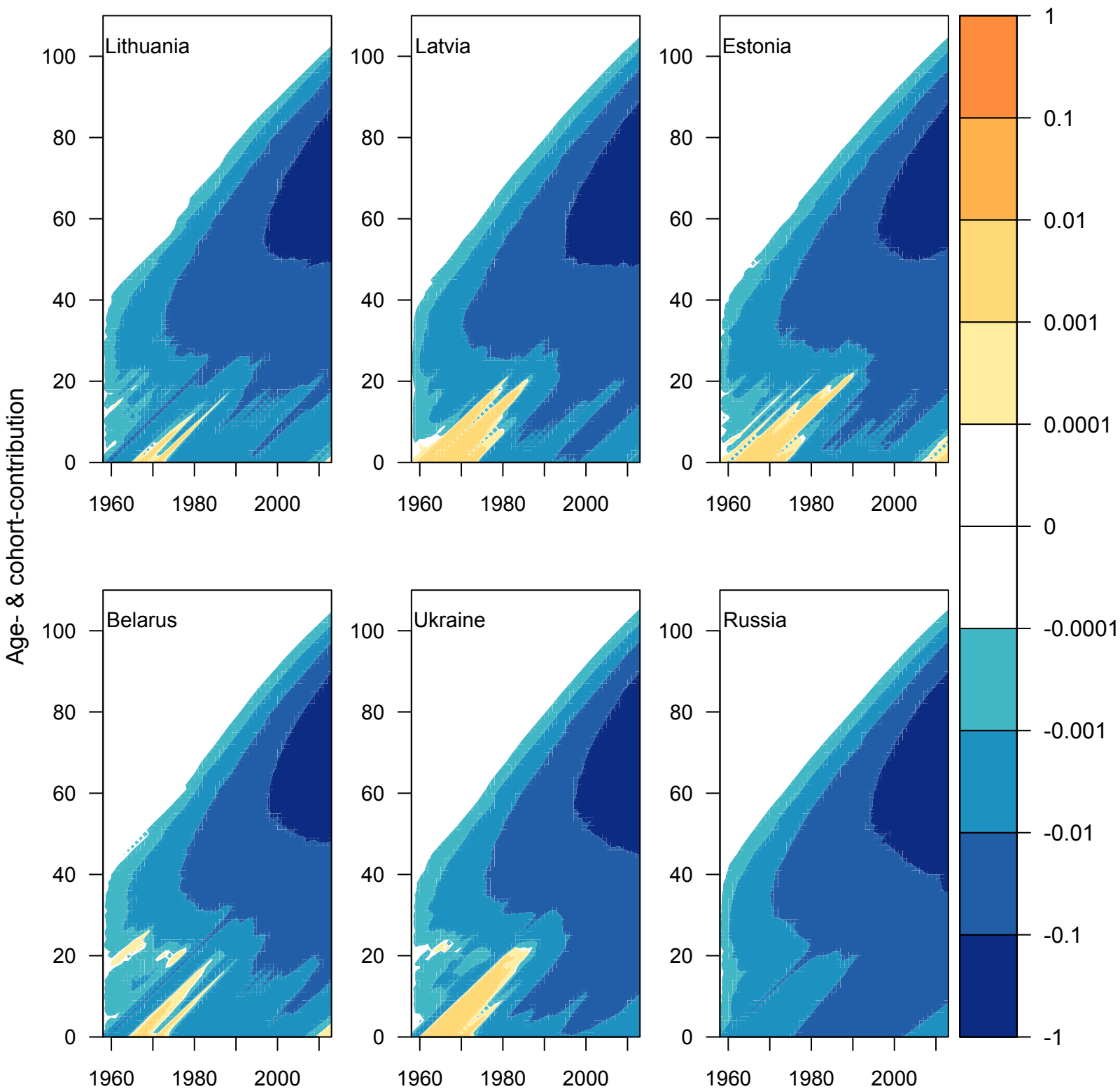
With the exception of Russia, all Eastern European cohorts born during the 1960s and the early1970sexperience a small survival advantage at younger ages than do the HLC cohorts. However, the survival advantage of these cohorts gradually disappears up to 2013 for both sexes. We also observe a longer-lasting effect of this survival advantage in infancy and childhood for females than for males. Note that male cohorts experience survival advantages at younger ages (i.e. up to age 20–25) when compared with HLCs, while female cohorts had this survival advantage until age 30-35. The low mortality levels until adulthood of Eastern European cohorts compared with HLCs was probably triggered by the anti-alcohol campaign oriented toward adults in 1985–1987, when cohorts born in the early1960shad reached ages 20–25. Moreover, our results suggest different effects on males and females as a result of the campaign, which reduced the mortality gap between each former USSR country and the group of HLCs.

Figure 2A - Lexis surface for the cumulative age- & cohort-contributions to the difference in TCALs between CEE countries and other HLCs, Females.



Note:Negative values correspond to higher HLCs survival.
Source: HMD data and authors'own calculation.

Figure 2B - Lexis surface for the cumulative age- & cohort-contributions to the difference in TCALs between CEE countries and other HLCs, Males.



Note:Negative values correspond to higher HLCs survival.
Source: HMD data and authors'own calculation.

From a cohort perspective, our results also reveal that the effect of the anti-alcohol campaign differs in the former USSR countries when they compared with HLCs. In Lithuania, for instance, the survival advantage at younger ages of male cohorts born from the mid-1960s to the early1970s did not last until age 20 (Figure 2B). By contrast, in Latvia, Ukraine, and Estonia, male cohorts that experienced lower mortality in infant and childhood than HLCs retained their advantage up to ages 20–25. These aspects may indicate that – compared to changes in the mortality gap between Lithuania and the HLCs – cohort mortality improvements due to the anti-alcohol campaign more greatly narrowed the gaps between Latvia and the HLCs, Ukraine and the HLCs, and Estonia and the HLCs.

Since the 21st century began, recent cohorts are experiencing infant and child survival disadvantage in Eastern European countries when compared with HLCs. Child mortality differences in Belarus and Estonia (Belarus vs. HLCs, and Estonia vs. HLCs) narrowed rapidly for cohorts born from the late 2000s, while child survival progressed slowly in Lithuania, Russia, and Ukraine. Another relevant aspect displayed in Figure 2B for Eastern European countries, is the great contribution of male cohorts aged 40–80 in 2013 to the difference in *TCALs* (Eastern-Europe vs. HLCs). This result points out the important contribution of mortality over age 40 to the mortality gap between Eastern European countries and more developed countries.

Particular attention is paid to Russia, the only country that has not experienced any cohort survival advantage compared with HLCs. In addition to showing the high cohort mortality levels in Russia, Figures 2A and 2B reveal differences in the survival trajectories of Russian cohorts when compared with HLCs. At younger ages, Russian cohorts born from 1960 to the mid-1970s have experienced lower survival disadvantage than those Russian cohorts born between 1980 and 2000. The mortality disadvantage of those Russian cohorts born between 1960 to the mid-1970s lasts until age 20 for males and up to age 30 for females. As already mentioned, the anti-alcohol campaign launched by Gorbachev in 1985–1987 may explain this long-lasting effect of lower mortality difference up to adulthood between Russia and HLCs. Note that, among the former USSR

countries, only Russian cohorts born during the 1960s have not experienced survival advantage when compared with HLCs. Even if the positive effect during the period of the anti-alcohol campaign was greater in Russia and led to more important mortality improvements there than in other countries, it was not enough to compensate for lower survival in the former years.

It should also be mentioned that infant and child mortality is much higher in all Russian cohorts born between 1959 and 2013 than in the HLCs. Despite the great mortality improvements at youngest ages in Russia over recent decades, the country still lags far behind when compared with HLC infant and child mortality. However, women have more quickly progressed to lower levels of infant and child mortality than have men. When compared to HLCs, survival disadvantage is lower for females than for than males at the youngest ages of Russian cohorts born during the 1980s and the 1990s.

Conclusion

This study takes a cohort perspective to present our findings on the mortality gap between Central and Eastern European (CEE) countries and a group of high-longevity countries (HLCs). We have revealed the contribution of cohort survival to the mortality difference between each CEE country and the group of HLCs in 2013. Our decomposition shows a great survival disadvantage for most CEE cohorts present in 2013 compared with their counterparts in HLCs. The age-cohort decomposition of difference in *TCALs* also reveals some survival advantages of particular CEE cohorts over HLCs, as is the case for Czech cohorts born in the late1950s and during the 1960s. These Czech cohorts had a particular survival advantage over their counterparts in HLCs from birth until the age reached in 2013. The survival advantage of these Czech cohorts confirm the documented mortality decline in the Czechia during the 1960s, when Czech life expectancy at birth was very similar to that of high-mortality countries (Rychtaříková, 2004) . We complement this result by showing the long-lasting effect of survival advantage at first ages of Czech cohorts born during the 1960s when compared with HLCs. Except for Russia, the age-cohort decomposition of the difference in *TCALs* also reveals a particular survival advantage of the former USSR cohorts

born during the 1960s and early1970s when comparing them with HLCs. Conversely, the survival advantage of these Eastern European cohorts gradually disappears by 2013 for both sexes. Our results show that the survival advantage at younger ages for these Eastern European cohorts lasted until adulthood (up to age 20 for men, and age 30 for women). This effect was probably triggered by the anti-alcohol campaign oriented toward adults and which was launched by Gorbachev in the mid-1980s (Shkolnikov and Nemtsov, 1997), when cohorts born during the 1960s reached young-adult ages.

The *TCAL* decomposition helping us to observe how cohorts contribution to longevity evolves over time and age. The cohort perspective has been emphasized here because the aim was to understand how CEE populations arrived to current mortality levels. However, the methodology of decomposing *TCAL* is flexible and allows studying in the period and age perspectives by focusing instead on the age-specific contributions and accumulating correspondingly across ages or periods. Although, out of the scope of the current study, analysing all the three perspectives (age, period and cohort) together under the *TCAL* decomposition could complement and enrich the knowledge on population's mortality transition.

Since the 1980s, the high mortality in Eastern European countries has been largely attributed to premature deaths in the middle-aged adult population, particularly among males born in the former USSR. (Shkolnikov et al., 1997; Shkolnikov and Nemtsov, 1997; Meslé and Vallin, 2002; Meslé, 2004) . In our window of observation, from 1959 to 2013, we show that the mortality disadvantages of the middle-aged adult population compared with other HLCs always existed between the former USSR and HLCs. Our results suggest that it is not only mortality among adults that contributes to the current disadvantage gap between the former USSR and HLCs, but that mortality at first ages still contributes to this mortality difference.

To conclude, the decomposition of the *TCAL* differences between CEE countries and HLCs highlights the potential for public health interventions to eliminate and control avoidable mortality gaps in the future.

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