Reply to reviewers
We appreciate the reviewers' comments; their detailed reading of the manuscript and many suggestions that have greatly improved the article. Our responses to the reviewers' comments are outlined below in regular font with reviewer's comments in bold font.

Reviewer 3

This is an important paper focusing on lifespan variation in the Central and Eastern European countries with their abnormal changes in life expectancy in the second half of the 20th – beginning of the 21st centuries. It explores the age- and cause-specific changes in lifespan disparity at different periods of life expectancy change.

Hope that my further comments would be useful in improving the manuscript.
Thanks for the careful reading and suggestions. Below are the changes/responses to the comments.

The introduction part is a little bit messy. The description of well-known trends in life expectancy in CEE is not structured enough. I would recommend referring to three groups of countries within CEE – Central Europe, Baltic States and Former USSR (something like this). Besides that, it seems strange to paste the key findings at the end of introductory part.

As far as possible we grouped our discussion around three main groupings that experienced more similar trends: Central Europe + Bulgaria, the Baltic Countries, and other former Soviet Union (FSU) countries. We hope that this patterning helps to anchor the trajectories geographically and has livened up some of the more dense sections of the paper. In addition, we recreated all decomposition figures in concordance with the grouping by adding a specific label and background color in each country.

The text containing the main findings at the end of the introduction was deleted from this section and merged with the first paragraph of the discussion to highlight the main contribution of the study. It now reads:

"*… Over the study period, the acute mortality crises of the 1990s caused greater year-to-year fluctuation in lifespan variation than in life expectancy. Life expectancy and life disparity moved independently from one another, particularly during periods of life expectancy stagnation caused by uneven age-specific mortality change. Fluctuations in life disparity were, to a large extent, caused by fluctuation in mid-life mortality that was directly or partially attributable to mortality amenable to alcohol consumption, with different net effects depending on the country and time period.*"

In the methodology part, the authors do explain the choice of e-dagger measure and provide the sensitivity analysis of other measures of lifespan inequality. However, it seems that for the reader it would be more useful to have the discrete formulae of e-dagger and its age-and cause-specific decomposition used in this paper.

Regarding the decomposition, we added a paragraph explaining with more detail the decomposition method and how the age-cause specific effects between two time points are derived following the line integral model (Horiuchi et al 2008). In addition, we added a footnote with our discrete formula for e-dagger, and in the final version of the paper a link to a repository with the data and R-code to reproduce all results in the paper will be available.

"*The decomposition method used in this paper is based on the line integral model (Horiuchi et al 2008). Suppose f (e.g. $e^{\dagger}$ or life expectancy) is a differentiable function of n covariates (e.g. each age-cause specific mortality rate) denoted by the vector $\boldsymbol{A} = [x_1, x_2, \dots, x_n]^T$. Assume that f and $\boldsymbol{A}$ depend on the underlying dimension t, which is time in this case, and that we have observations available in two time points t_1 and t_2. Assuming that $\boldsymbol{A}$ is a differentiable function of t between t_1 and t_2, the difference in f between t_1 and $t_2$can be expressed as follows:*

$$f_2 - f_1 = \sum_{i=1}^{n} \int_{x_i(t_1)}^{x_i(t_2)} \frac{\partial f}{\partial x_i} dx_i = \sum_{i=1}^{n} c_i, \qquad (2)$$

where c_i is the total change in f (e.g. $e^{\dagger}$ or life expectancy) produced by changes in the i-th covariate, x_i. The c_i's in equation (2) were computed with numerical integration following the algorithm suggested by Horiuchi et al (2008). This method has the advantage of assuming that covariates change gradually along the time dimension.

We perform such decomposition by single age, period and cause of death.."

I guess that the choice of the periods for analysis (stagnation, improvement, deterioration, divergence and convergence) should be discussed more and in the methodology section. I am not sure that the last period of convergence started in 2000. A little bit later?

As suggested by the reviewer, we now included a full description in the methods section on how the periods were determined. Regarding the post-2000 convergence period. The statistical break point found with the hierarchical estimation was 2001. We decided to start the period in 2000 to cover since the start of the 21st century. While it is true that some countries such as Russia and Ukraine started later following the same trend of increasing life expectancy, the coefficient of variation after 2000 continued decreasing. To alleviate any concerns about the choice and labels of the periods that we use, we added the next paragraph.

"We focused on five periods determined by trends of the coefficient of variation of male life expectancy. from 1960 to 1980 labeled ``Stagnation'', ``Improvements'' from 1980 to 1988, ``Deterioration'' in 1988-1994, ``Divergence between 1994 and 2000, and ``Convergence'' thereafter. Periods were determined using a divisive hierarchical estimation algorithm for multiple change points analysis. The statistical break points were 1960, 1976, 1986, 1993 and 2001. We instead used complete decades or historical events which made the interpretation of the results easier, which were all within 3 years of the cut points. For example, the period 1960-1979 (complete years) included the two decades with no substantial changes in the coefficient of variation between life expectancies. The next break point (1986) was extended to 1988 to include completely Gorbachev's anti-alcohol campaign, which was implemented in the period 1985-1988. The following break point was used exactly since it allows the period 1988-1993 to include

the dissolution of the Soviet Union in late 1991 and the largest drops in life expectancy in Russia, Latvia, Estonia, Lithuania, and less marked in Ukraine, Belarus, and Bulgaria in 1992-1993. Finally, the year 2001 was changed to 2000 to start with the 21st century."

Data from HMD for 12 countries and HCoD for 8 countries are used. Is it impossible to get the rest cause-specific data from the WHO mortality databases? I realize that it is much more convenient and reliable to get the data from the "scientific" databases where all the data are checked for their consistency. But I believe that the authors could obtain the data from the WHO mortality databases as well or at least to discuss why it is impossible to use those data for 4 countries that are not covered in HCoD.

We followed the reviewer's suggestion and analyzed data from WHO for Bulgaria, Hungary, Slovakia and Slovenia. All except one (Slovakia) experienced the change from ICD9 to ICD10 in the period studied in the manuscript from 1994 to 2010. Bulgaria started coding deaths with ICD10 in 2005, Hungary in 1996, and Slovenia in 1997.

There are several limitations of using WHO data for alcohol related mortality in this set of countries. Firstly, deaths coded with ICD9 (Table 5. ICD9-9 from WHO documentation) are not sufficiently disaggregated to analyze some of the specific causes of death that we are interested in. For example, the codes that in ICD10 (F10) account for deaths due to alcohol psychosis, alcohol abuse, and alcohol dependence syndrome in ICD9 are 291, 305.0, 303.0, 303.9. However, 291 is grouped in the category of other psychoses (codes 291-294, 297-299) in WHO data, 305 is not available and the rest are grouped in 303 (we use this group for our analysis in this section). Similarly, deaths caused by poisoning by exposure to alcohol (X45 in ICD10) are not ungrouped in the WHO data, all of them (E860.0, E860.1, E860.2 and E860.9) are in the category "Accidental poisoning by other solid and liquid substances" which includes E860-E866, and 980.0, 980.1 and 790.3 (Excessive blood level of alcohol) do not appear in the list. The bridge codes were taken from the Center for Disease Control and Prevention from USA.

As noted above, the relationship of ICD codes when changing revisions is very complex for many conditions. Consequently, various levels of the classification (e.g. alcohol related mortality) do not reflect actual long-term trends in mortality. Moreover, available raw data cannot be used to draw any conclusions about patterns without a thorough analysis of the quality of the data (Vallin et al. 1988). In order to establish comparable continuous time series on causes of death it is necessary to reconstruct mortality trends, assess the statistical impact of changes of coding practices, and an automatized routine that allows to compare between countries described elsewhere (Pechholdová et al 2017).

An additional limitation is the completeness of the data. WHO recovers data from statistical offices without any assessment of completeness. For instance, Hungarian data do not show any information on some causes of death after 1996, while for others there is a complete time series.

We mitigate the issue of ICD comparable information using the recently published Human Cause of Death Database (HCoD). This database performed quality checks and reconstructed mortality trends for the countries showed in the manuscript following Pechholdová et al (2017) when

needed. Further, to mitigate the completeness limitation, we use the HCoD's cause of deaths structure and applied it to the mortality rates in the HMD.

To show these limitations, we did a country-specific analysis with this information to decide whether the data was reliable enough to include the country in the manuscript for the cause-of-death analysis. We additionally created an interactive app to analyze the results in the panel 'Rupture analysis' at https://demographs.shinyapps.io/CEE_App/. A summary of these analyses is below.

Bulgaria: Stroke and Other circulatory categories show a clear rupture in the year when ICD changed. This rupture suggests that they complement each other. Grouping all cardiovascular (i.e. IHD, Stroke and Other circulatory) could make comparable the trends. However, infectious and respiratory diseases also show clear change in trends after ICD 10 was implemented, and it is not clear which category was accounting for these conditions before that period.

Hungary: Missing information for most of the years and causes of death. Bad and problematic data overall.

Slovakia: It uses ICD10 throughout the entire period. There is a strange trend in Infectious and respiratory diseases in the late 1990s. In the rest in recent years, and it seems that Stroke and Other circulatory complement each other.

Slovenia: shows major ruptures in attributable to alcohol mortality, stroke and other circulatory diseases. More worrisome, however, is the rupture shown in infectious and respiratory diseases and in the residual causes.

In light of the above, we decided not to include WHO data in our study as we were worried about the data integrity and felt strongly that it was better to err on the side of caution.

References:

Center for Disease Control and Prevention. Alcohols and Public Health: Alcohol-related disease impact (ARDI). Visited on 08/02/2018. https://nccd.cdc.gov/dph_ardi/Info/ICDCodes.aspx

Pechholdová, M., Camarda, C. G., Meslé, F., & Vallin, J. (2017). Reconstructing Long-Term Coherent Cause-of-Death Series, a Necessary Step for Analyzing Trends. European Journal of Population, 1-22.

Vallin, J., Meslé, F., Caselli, G., & Egidi, V. (1988). Les causes de décès en France de 1925 à 1978 (Vol. 1). Ined.

The choice of the groups of causes of deaths is fully relied on the papers by Rehm et al. that is not convincing enough especially when second and third categories are identified. For

examples, epidemiological studies by David Leon et al. and by David Zaridze et al. show relative risks associating alcohol consumption with cause-specific mortality in Russia. I believe that similar studies were also held in other CEE countries. The results of these studies could strengthen the cause of deaths classification used in this paper.

It is true that classifying alcohol related mortality has several limitations (fully explained in the revised version of the paper), particularly when circulatory diseases are partitioned. Therefore, to overcome the limitation that you mention we made the following major changes to the manuscript. We shifted the focus away from trying to partition mortality into alcohol and non-alcohol related mortality, since attributing the proportion of mortality from amenable causes is anyway problematic. Instead in our description of the COD results we paid more attention to co-movements of circulatory disease, traffic accidents and external mortality to mortality that is wholly attributable to alcohol. This way, we can infer over which ages/periods alcohol was likely to have played a larger role in changes to these larger COD groupings.

Moreover, after carefully reviewing the previous version and taking into account reviewers 1 and 3's suggestions, we decided that the added value of keeping IHD separate from other circulatory diseases was low for the purposes of this study, and changing coding practices were visible for some countries in trends between these causes. Thus, in the new version of the manuscript we opted to combine all circulatory disease mortality and added the following to the limitations section:

"…in the Soviet era ill-defined cardiovascular diseases were often classified as 'atherosclerotic cardiosclerosis', which is a subset of ischemic heart diseases (Jasilionis et al. 2011, Shkolnikov 2012). Different countries abandoned this practice at different rates, which had the effect of misclassifying deaths between the IHD, stroke and other circulatory disease categories. While some degree of misclassification within circulatory disease is corrected for by the HCD team (Pechholdova 2017), for comparative purposes we felt it safer to combine all circulatory disease categories."

It is true that some studies have studied the role of alcohol on mortality in some other countries included in the paper. Most of these studies are included in Rehm et al's articles. Therefore, we use these as reference. To strengthen the role of alcohol as determinant of mortality we also included the next references in the cause-of-death classification section:

Zaridze, D., Brennan, P., Boreham, J., Boroda, A., Karpov, R., Lazarev, A., ... & Peto, R. (2009). Alcohol and cause-specific mortality in Russia: a retrospective case–control study of 48 557 adult deaths. The Lancet, 373(9682), 2201-2214.

Zaridze, D., Lewington, S., Boroda, A., Scélo, G., Karpov, R., Lazarev, A., ... & Sherliker, P. (2014). Alcohol and mortality in Russia: prospective observational study of 151 000 adults. The Lancet, 383(9927), 1465-1473.

Leon, D. A., Chenet, L., Shkolnikov, V. M., Zakharov, S., Shapiro, J., Rakhmanova, G., ... & McKee, M. (1997). Huge variation in Russian mortality rates 1984–94: artefact, alcohol, or what?. The lancet, 350(9075), 383-388.

McKee, M., Sűzcs, S., Sárváry, A., Ádany, R., Kiryanov, N., Saburova, L., ... & Leon, D. A. (2005). The composition of surrogate alcohols consumed in Russia. Alcoholism: Clinical and Experimental Research, 29(10), 1884-1888.

References:

Jasilionis, D.; Meslé, F.; Shkolnikov, V. M. & Vallin, J. (2011). Recent Life Expectancy Divergence in Baltic Countries. *European Journal of Population / Revue européenne de Démographie, 27,* 403

Pechholdová, M., Camarda, C. G., Meslé, F., & Vallin, J. (2017). Reconstructing Long-Term Coherent Cause-of-Death Series, a Necessary Step for Analyzing Trends. European Journal of Population, 1-22.

Shkolnikov, V., Meslé, F., & Vallin, J. (2012). Data Collection, Data Quality and the History of Cause-of-Death Classification. In *Mortality and Causes of Death in 20th-Century Ukraine* (pp. 121-130). Springer, Dordrecht.

The authors state that they aim to identify the effect of mortality related to alcohol consumption on lifespan variation from 1994 to 2010. Why this particular period was chosen?

We decided to study the period 1994-2010 for two reasons. Firstly, because the period preceding 1994, associated to the health crisis in some FSU countries, have been extensively studied. Secondly, because this period maximized data availability from the Human Cause-of-Death database. Allowing us to study up to eight countries with comparable information.

To make this clear in the manuscript, we changed the second paragraph in the data section to:
Cause of death data came from the newly developed Human Cause of Death database (2016), which provides coherent cause-specific mortality data time series from 1994 to 2010 for eight of the countries in the study (Belarus, Czech Republic, Poland, Russia, Ukraine, Estonia, Latvia and Lithuania). For inclusion into the database, a universal and standardized methodology was undertaken to redistribute deaths between 104 disease categories in 5-year age groups. We used these data to get the cause-specific proportion by 5-year age groups.

Minor comments:

1. **Mortality increase in CEE countries started not in 1960 but since the mid-1960s**
   It is true that mortality increase, along life expectancy stagnation started after 1960. To make this point clearer we did the following change.

   Introduction: change *"…as parts of Central and Eastern Europe experienced an unprecedented period of stagnation and, in some countries, decrease in life expectancy at birth after 1960…"* with *"…as parts of Central and Eastern Europe experienced an*

unprecedented period of stagnation and, in some countries, decrease in life expectancy at birth around the mid-1960s…"

2. **"larger mortality inequalities in this region compared with western countries in Europe". I am not sure about that. Timonin et al showed that the disparities between western European countries are larger than the disparities between CEE.**

   Thanks for this observation. We rephrased *"…led to lower levels of life expectancy and larger mortality inequalities in this region compared with western countries in Europe (Mackenbach et al. 2008"* to *"…led to lower levels of life expectancy and larger within-country mortality inequalities according to education level in this region compared to western countries in Europe"* to better reflect results in the paper by Mackenbach et al 2008.

   In addition, Timonin et al (2016)'s paper is included in the discussion section: *"…However, while mortality change after the break-up of the Soviet Union led to sharply diverging trends in life expectancy, divergence in lifespan variation between countries was less dramatic. This complements recent work by Timonin et al. (2016) who found that differences between geopolitical regions in life expectancy were more important than increasing within-region disparities in ages at death in driving life expectancy divergence in developed countries from 1970 to 2010."*

   References:

   Mackenbach, J. P., Stirbu, I., Roskam, A. J. R., Schaap, M. M., Menvielle, G., Leinsalu, M., & Kunst, A. E. (2008). Socioeconomic inequalities in health in 22 European countries. New England Journal of Medicine, 358(23), 2468-2481.

   Timonin, S., Shkolnikov, V. M., Jasilionis, D., Grigoriev, P., Jdanov, D. A., & Leon, D. A. (2016). Disparities in length of life across developed countries: measuring and decomposing changes over time within and between country groups. Population health metrics, 14(1), 29.

3. **I have not really understood why such cause of death as "birth conditions" is used in the figure 5.**

   Thanks for this observation. The figures have been corrected and the label "birth conditions" is not included anymore.

Finally, are there any ideas why life disparity has been stagnating in Russia since 2010?

Our decomposition results (https://demographs.shinyapps.io/CEE_App/ selecting Break 4 as 2010) suggest that this could be caused by stagnation in mortality improvements in ages below 60 offset by larger progress above this age. A recent paper by Timonin et al (2017) suggest that this could be a result of uneven progress in reducing cardiovascular mortality at the subregional level in Russia offset by convergence in under-60 mortality.

We added the next sentence to the discussion:
"We additionally identified a recent stagnation (since 2010) in Russian lifespan variation. By looking into decomposition results after 2010, our results suggest that this could be a result of a slowdown in mortality improvements below age 60 offset by larger progress above this age. A recent article by Timonin et al (2017) suggests that this could be a result of uneven progress in reducing cardiovascular mortality at the subregional level in Russia offset by convergence in under-60 mortality."

References:

Timonin, S., Danilova, I., Andreev, E., & Shkolnikov, V. M. (2017). Recent Mortality Trend Reversal in Russia: Are Regions Following the Same Tempo?. European Journal of Population, 33(5), 733-763.