Decomposition of regional convergence in population ageing across Europe

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Abstract

BACKGROUND

In the face of rapidly ageing population, decreasing regional inequalities in population composition is one of the regional cohesion goals of the European Union. To our knowledge, no explicit quantification of the changes in regional population ageing differentiation exist.

OBJECTIVE

We investigate how regional differences in population ageing developed over the last decade and how they are likely to evolve in the coming three decades, and we examine how demographic components of population growth contribute to the process.

METHODS

We use the beta-convergence approach to test whether regions are moving towards a common level of population ageing. The change in population composition is decomposed into the separate effects of changes in the size of the non-working-age population and of the working-age population. The latter changes are further decomposed into the effects of cohort turnover, migration at working ages and mortality at working ages.

RESULTS

European NUTS-2 regions experienced notable convergence in population ageing during the period 2003-2012 and are expected to experience further convergence in the coming three decades. Convergence in ageing mainly depends on changes in the population structure of East-European regions. Cohort turnover plays the major role in promoting convergence. Differences in mortality at working ages, though quite moderate themselves, have a significant cumulative effect. The projections show that when it is assumed that net migration flows at working ages are converging across European regions, this will not contribute to convergence of population ageing.

CONTRIBUTION

The beta-convergence approach proves useful to examine regional variations in population ageing across Europe.

Keywords: Beta-convergence, population ageing, demographic decomposition, population structures, cohort turnover, migration at working ages, mortality at working ages, Total Support Ratio, NUTS-2

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1. Introduction

Population ageing is the most evident demographic challenge of European countries and regions. The unprecedented increase in the share of the elderly population raises concerns about the sustainability of social and economic developments (Bloom et al. 2015; Feldstein 2006). The sharp increase in the proportion of the elderly dependent population is expected to have a significant negative impact on pension systems (Ediev 2013; Gruber and Wise 2009; Hammer and Prskawetz 2013), social and health care (Mahon and Millar 2014), and public and personal transfers towards the elderly (Dukhovnov and Zagheni 2015; Lee and Mason 2010).

Differences in the past and current developments of demographic structures contribute to substantial spatial variation of ageing across European countries (Diaconu 2015) and across regions (Gregory and Patuelli 2015). Regional policies in European Union aim to reduce variation in all aspects that can influence differentiation in the quality of life, including demographic developments (European Commission 2015; Giannakouris 2008). According to the European Commission's logic, convergence in ageing is desirable because it will contribute to the reduction in regional life quality disproportions.

To check whether the goals of the European Commission are being met, we investigate how regional differences in ageing have changed over the period 2003-2012. In order to examine whether current trends in regional variation in ageing will continue, we also examine Eurostat regional population projections for the upcoming three decades. In order to examine to what extent policy measures could be effective in promoting convergence in population ageing we assess the causes of changes in the working-age population: migration, mortality and cohort turnover i.e. the difference between numbers of young people entering and older people leaving working ages, To the extent that cohort turnover affects convergence in ageing, there is little room for policy options as the impact of cohort turnover can only be affected in the long run. To the extent that mortality affects convergence in ageing, one main question is whether convergence in mortality would lead to convergence in ageing. To the extent that migration affects convergence in ageing, policy makers may aim to affect the direction of migration flows between regions and countries.

We identify the role of demographic components that cause changes in the ratio of the working-age to the non-working-age population (*total support ratio*, TSR, see section 3.2), thus influencing convergence in ageing. For that reason, we decompose the convergence in TSR into the separate effects of changes in the non-working-age population and changes in the working-age population. The latter is further decomposed into separate effects of cohort turnover, migration at working ages, and mortality at working ages. Finally, we examine the time differences of convergence in TSR during the observed and projected parts of the study period. The temporal decomposition of convergence in ageing helps to identify the turning points in the recent development of regional differences in population structures and examine the possible future development.

2. Demographic transition and convergence in ageing

The demographic development after the baby boom is characterized by accelerating population ageing, as the relatively large cohorts of the baby boom come out of working ages, and below-replacement fertility does not provide equally large successive cohorts (Lee 2003). Thus, convergence in population ageing at the late stages of demographic transition is a natural hypothesis. For example, as Dudley Kirk points out (1996:366), similarities in demographic transition made United Nations and World Bank base their population forecasts on the assumption of a standard transition. Though, different timing of the second demographic transition due to cultural and behavioral variability (Lesthaeghe 2010) may affect the speed of convergence in ageing considerably. Thus one important question is whether the variability in population ageing does or does not lead to convergence in ageing at the regional level in Europe and whether future changes may be different from recent trends. We expect that cohort turnover, which reflects the existing disproportions in population structures, will lead to convergence in ageing, but it is less obvious what will be the effect of mortality and migration.

In this paper we use the methodological concept of beta-convergence to test if the variation in ageing across European regions has increased or decreased. This method was originally developed in the economic literature to study income inequalities (Barro 1991; Barro et al. 1991; Baumol 1986). The method was rarely applied to demographic data before and, to our knowledge, was never used to analyze the development of regional differences in the population age composition. Previous demographic papers used convergence analysis techniques to study spatio-temporal regularities in mortality (Edwards 2011; Edwards and Tuljapurkar 2005; Goesling and Firebaugh 2004; Janssen et al. submitted; Neumayer 2004; Richardson et al. 2014; Tuljapurkar and Edwards 2011), fertility (Dorius 2008; Wilson 2011) and migration (Barro and Sala-i-Martin 2003; Huber and Tondl 2012; Kubis and Schneider 2015; Ozgen, Nijkamp, and Poot 2010).

With the use of convergence analysis we investigate whether regional differences in ageing increase or decrease over time in Europe. Beta-convergence occurs when regions which were less aged at the beginning of the study period experience stronger population ageing than the regions that were initially more aged. If there is beta convergence, the model predicts that all regions would reach the steady-state level of population ageing in the future. If the condition is not satisfied, the modeling shows that the regions experience divergence, and there is no reason to expect a reduction in inequality.

3. Data and methods

3.1. Data

This paper uses Eurostat data on population structure (Eurostat 2015d) and mortality records by one-year age groups for the period 2003-2012 (Eurostat 2015a). The data are aggregated at the NUTS-2 level, version of 2010 (Eurostat 2015c). At the moment of data acquisition (March 2015), mortality records covered the period up to 2012. For the majority of regions, data on population structure are available since 2003. Hence, the availability of data limited the observed study period to 2003-2012. We also used Eurostat regional projections (Eurostat 2015b) for three more decades, 2013-2042.

For some regions, data were partially missing. Due to the changes in administrative division at the NUTS-2 level, there were no data for all five regions of Denmark before 2008 and two regions in the eastern part of German, Chemnitz (DED4) and Leipzig (DED5) before 2006. Furthermore, mortality data were missing for Ireland in 2012, and population structure data were missing for Slovenia in 2003-2004. We reconstructed the missings using the data from national statistical offices.

Exploratory data analysis showed inconsistency of population estimates for the regions of Romania. There was a Census in Romania in 2011 that registered a large, and previously underestimated, decrease in population size. Evidently, the outmigration from Romania was underreported. Yet, no rollback corrections were made, and Eurostat provides non-harmonized data for Romanian regions. Thus, we harmonized the population figures for Romanian regions[3].

Finally, we excluded all non-European remote territories of France, Portugal, and Spain[4], which are outliers both in geographical and statistical terms.

The data set used for the analyses contains data for 263 NUTS-2 regions of EU28[5] for the observed (2003-2013) and projected (2014-2042) periods.

3.2. Measuring ageing

We measure population ageing as a decrease in the ratio of the working-age population to the non-working-age population. In line with Eurostat and UN definitions, we consider ages 15 and 65 as the margins of the working-age population. Thus, the measure of ageing that we use is the ratio of population aged 15-64 to the population below 15 years of age and above 65. We call this indicator the Total Support Ratio (TSR), which is in fact the inverse of the widely used Total Dependency Ratio (UN

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[3] Using 2003 population structure as the reference and the mortality data, we estimate cohort-wise the anticipated population structure in 2012 with an assumption of no migration. The difference between the estimated and the observed population is explained by migration. While harmonizing the data, we kept the observed migration trends and distributed the excessive migration evenly across all the years of observation before 2012.

[4] The excluded NUTS-2 regions are: ES63, ES64, ES70, FR91, FR92, FR93, FR94, PT20, and PT30.

[5] Currently (as of 2016), European Union consists of 28 countries, which are: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and United Kingdom.

Population Division 2002). There is some confusion around the use of the term Support Ratio in the literature. Quite often children are not included in the calculation of the Support Ratio (Lutz 2006; Lutz, O'Neill, and Scherbov 2003; O'Neill et al. 2001). In that case, the indicator only shows the relative burden of the elderly population; UN Population Division (UN Population Division 2002) calls this indicator Potential Support Ratio. In other papers, that deal not only with age structures of population but also with labor force participation and transfer accounts, by Support Ratio authors usually mean the ratio of effective labor to effective consumers (Cutler et al. 1990; Lee and Mason 2010; Prskawetz and Sambt 2014). Another definition says that the Support Ratio is the size of the labor force as a share of the adult population (Börsch-Supan 2003). We prefer to explicitly call the ratio of the working-age to the non-working-age population the Total Support Ratio, in line with the logic of the three versions of Dependency Ratio: Total, Youth, and Old-age.

3.3. Decomposition of growth in the Total Support Ratio

To explain which demographic factors cause changes in the TSR we apply a two-step decomposition. First, we examine to what extent changes in the TSR are due to changes in the size of the working-age population and to what extent to changes in the size of the non-working-age population. Second, we examine the demographic causes of changes in the working-age population.

At the **first step**, the overall change in the TSR is decomposed using the formula of Das Gupta (DasGupta 1991):

$$TSR_2 - TSR_1 = \frac{W_2}{NW_2} - \frac{W_1}{NW_1} = \\ = \left[\frac{1}{2} * (W_2 + W_1) * \left(\frac{1}{NW_2} - \frac{1}{NW_1}\right)\right] + \left[\frac{1}{2} * \left(\frac{1}{NW_2} + \frac{1}{NW_1}\right) * (W_2 - W_1)\right] \quad (1)$$

where W is working-age population; NW is non-working-age population; subscripts 1 and 2 denote the beginning and the end of the period, respectively. The two right hand side terms of equation 1 represent the separate effects of changes in non-working-age and working-age populations on the TSR, respectively.

At the **second step**, the working-age term in the second term of the right hand side of equation 1 is decomposed further into changes due to the three components of the demographic balance at working ages: cohort turnover, migration, and mortality.

To estimate the components of change in working-age population we use the demographic balance formula:

$$W_2 = W_1 + CT + M_W - D_W \quad (2)$$

where CT is cohort turnover between periods 1 and 2, M_W is net migration at working ages, and D_W is the number of deaths at working ages. As the accuracy of migration records is always a problematic issue, following De Beer, Erf, and Huisman (2012), we derive net migration at working ages indirectly from equation 2 for the observed period, 2003-2012. For the projected period, 2013-2042, the migration data are provided by Eurostat, so we derive the numbers of deaths using the demographic balance formula. Cohort turnover is calculated as the difference between people entering working ages, aged 14, and people leaving working ages, aged 64; we also correct the cohort turnover estimations for those who die or migrate at the ages 14 and 64, assuming that half of them belong to the cohorts that would affect cohort turnover.

Replacing the $W_2 - W_1$ part of the working-age term in equation 1 using the demographic balance formula, equation 2, yields:

$$\frac{1}{2} * \left(\frac{1}{NW_2} + \frac{1}{NW_1}\right) * (W_2 - W_1) = \\ = \left[\frac{1}{2} * \left(\frac{1}{NW_2} + \frac{1}{NW_1}\right) * CT\right] + \left[\frac{1}{2} * \left(\frac{1}{NW_2} + \frac{1}{NW_1}\right) * M_W\right] - \left[\frac{1}{2} * \left(\frac{1}{NW_2} + \frac{1}{NW_1}\right) * D_W\right] \quad (3)$$

The three right hand side terms of equation 3 denote the effects of cohort turnover, migration at working ages, and mortality at working ages on TSR, respectively.

3.4. Beta-convergece aproach to ageing

To estimate beta-convergence we use the classical linear regression model specification, where growth in a variable (in our case, total support ratio) over some period is regressed on the initial level. The specification looks as follows,

$$TSR_2 - TSR_1 = \alpha + \beta \, TSR_1 + \varepsilon \quad (4)$$

where TSR is total support ratio, α is the intercept of the regression line, β is the regression coefficient, ε is the error term. If the regression coefficient is negative, then beta-convergence is observed between years 1 and 2, meaning that initially higher TSR correlates negatively with the subsequent growth in TSR.

In convergence analysis, weights reflecting population sizes are often used (Dorius 2008; Goesling and Firebaugh 2004; Milanovic 2005; Theil 1989). Population-weighted convergence analysis shows whether inequality in the population becomes smaller; unit-weighted (in fact, non-weighted, as all units receive equal weights) convergence analysis tests whether the differences between units (countries/regions/districts) decrease. In this study, we are interested in the development of European regions as statistical units, thus, we choose the unit-weighted convergence analysis. Our choice is driven by the fact that European Cohesion policy is aimed at regions, irrespective of their population sizes[6].

The specification of the regression model allows to perform a decomposition of convergence (beta coefficient) into various separate effects. To understand how each of the demographic factors contributed to beta-convergence in ageing, we decompose the dependent variable, the change in TSR (see section 3.3) , and run separate regressions for each partial change in TSR keeping the explanatory variable, the initial TSR, constant. A partial regression model shows the beta-convergence of regions taking into

[6] One of the objectives of NUTS was to provide more or less comparable administrative division for all countries of Europe. Nevertheless, in 2013, population figures for single NUTS 2 regions ranged from 28.5 thousands in Aland island (Finland) to almost 12 million in Ile-de-France (Paris and surroundings, France).

account only the change in TSR due to the component under consideration. As the components of change in TSR add up to total change, and all the partial models have the same regressor, beta-coefficients of the partial models add up to the total effect. That means, beta-coefficients from convergence models for the change in TSR due to the dynamics of non-working-age population (nw) and working-age population (w) add up to the beta-coefficient of the overall model (g); and beta-coefficients from the models for cohort turnover (ct), migration at working ages (mg), and mortality at working ages (mt) effects on TSR growth add up to beta-coefficient from the model for the working-age population dynamics' effect. For the ease of notation, later in the results section 4.3, we will refer to the partial model using the short symbols in brackets.

To use further the additive feature of the models, we ran a separate regression for each partial change in TSR in each year. The temporal decomposition gives insight into how the convergence process evolves throughout the study period. Summing up, in this paper, we use two dimensions of the decomposition of convergence in ageing: demographic factors of the change in the TSR, and time.

3.5. Software

The analysis and the necessary data preparation were conducted using *R*, a language and environment for statistical computing, version 3.2.4 (R Core Team 2016). Additional packages were used: (i) for package reproducibility, *checkpoint* (Revolution Analytics 2015); (ii) for data manipulations, *dplyr* (Wickham and Francois 2015), *tidyr* (Wickham 2016b), *data.table* (Dowle et al. 2015); (iii) for visualization, *ggplot2* (Wickham 2016a), *viridis* (Garnier 2016), *cowplot* (Wilke 2016); (iv) for mapping, *rgdal* (Bivand, Keitt, and Rowlingson 2015), *rgeos* (Bivand and Rundel 2016). All the scripts are in the attachment for reproducibility.

4. Results

4.1. Descriptive results

The maps in figure 1 clearly reveal the story of a rapidly ageing Europe. The first and the last maps show Total Support Ratios of European NUTS-2 regions at the beginning and at the end of the whole study period, 2003 and 2042, 10 observed and 30 projected years; color scales are fixed for easier comparison. Virtually every single region experience a substantial decrease in the TSR over the study period; the average of all European regions decreased from 2.02 in 2003 to 1.96 in 2013 and is projected to further decrease to 1.37 by 2043, a 33% decrease over a period of 40 years (figure 2).

The spatial variation of the TSR across Europe is distinct both in the beginning and in the end of the study period. The spatial pattern seems very similar despite the 40 years of pronounced changes. Regions in Eastern Europe were relatively high in the initial distribution, and they are expected to remain in the top by the end of the study period: the dots in figure 2, colored according to the macro regions of Europe defined by EuroVoc[7], show quite limited perturbation over time, and the lines showing the averages of subregions suggest the same. Even though the difference between East-European regions and the rest of Europe narrows, the distribution pattern changes only slightly.

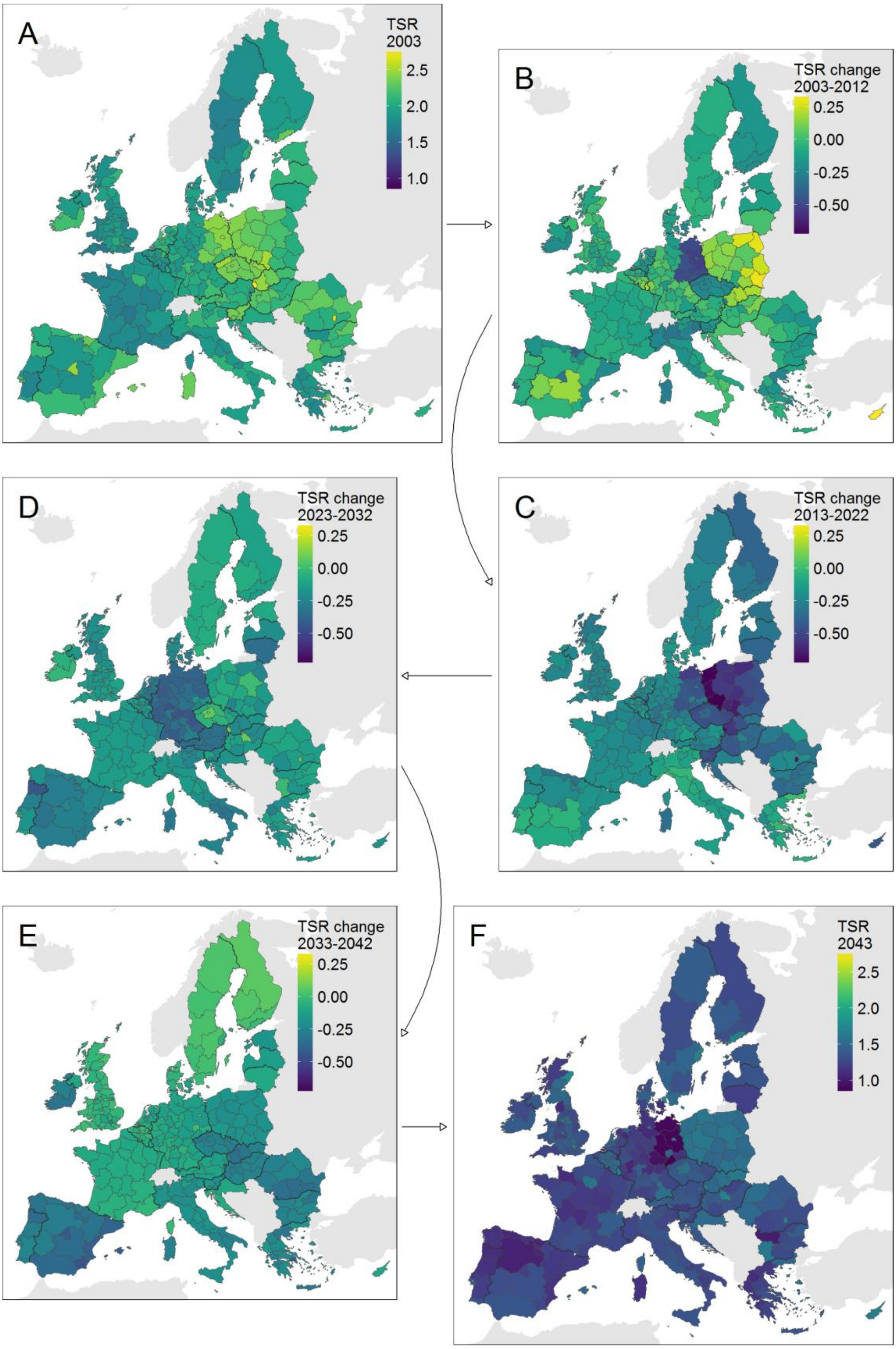
The most prominent changes happen in the regions of Eastern Germany, a very special part of Europe in terms of demographic development (Klüsener and Goldstein 2016). Those regions were "closing the opportunities window" of demographic dividend at the beginning of the study period (Van Der Gaag and De Beer 2015). Thus, they experienced the biggest drop in the TSR during the first decade (figure 1B). With a usual decade-long time lag, East-European regions are starting to experience a similar drop right now, in the second decade of our study period (figure 1C). Yet, unlike Eastern Europe, the regions of Eastern Germany continue to descent from the top of the TSR distribution to the bottom.

Quite a big decrease in the TSR happens in Southern Europe, especially in Spain, where the migration-driven temporary increase in the TSR is gradually changing towards a projected long-run decrease, which is mainly driven by population structure dynamics together with low fertility (more on that in section 4.2). The changes in the TSR over the four decades of the study period suggest that the East-West gradient in Europe is likely to change to a North-South gradient in the coming future.

The development of subregions' average TSR over the study period (figure 2) demonstrates the cyclic effect of demographic waves, which is most evident for Eastern Europe but also visible for other subregions. These demographic waves have a major effect on convergence in ageing (more on that in section 4.3). The most interesting effect is the rapid TSR decrease that starts in 2010, when the large generation of European baby-boomers started to cross the 65 years boundary (Reher 2015; Van Bavel and Reher 2013).

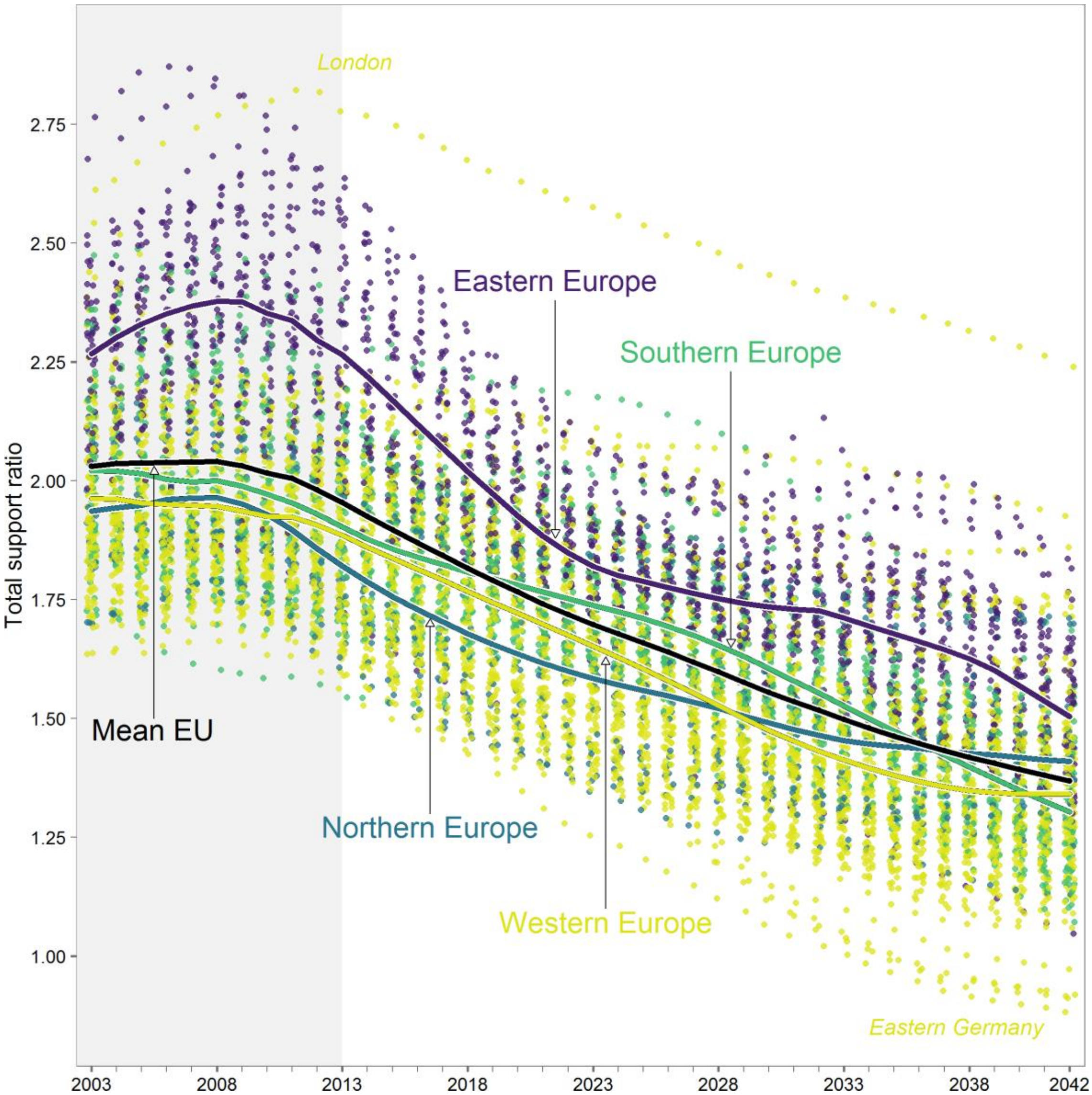
[7] Multilingual Thesaurus of the European Union (EuroVoc 2015)

Figure 1: Total Support Ratio dynamics in the 4 decades between 2003 and 2042



Notes: A – TSR in 2003; B – TSR growth during the observed period, 2003-2012; C, D, E – TSR growth in the 3 decades of the projected period, 2013-2022, 2023-2032, and 2033-2042, correspondingly; F – TSR in 2043. Color scales are fixed for better comparison: 1) in maps A and F; 2) in maps B, C, D, and E.

Figure 2: Total Support Ratio dynamics in Europe during the period 2003-2042, NUTS-2 regions, four subregions' averages, and the European average.

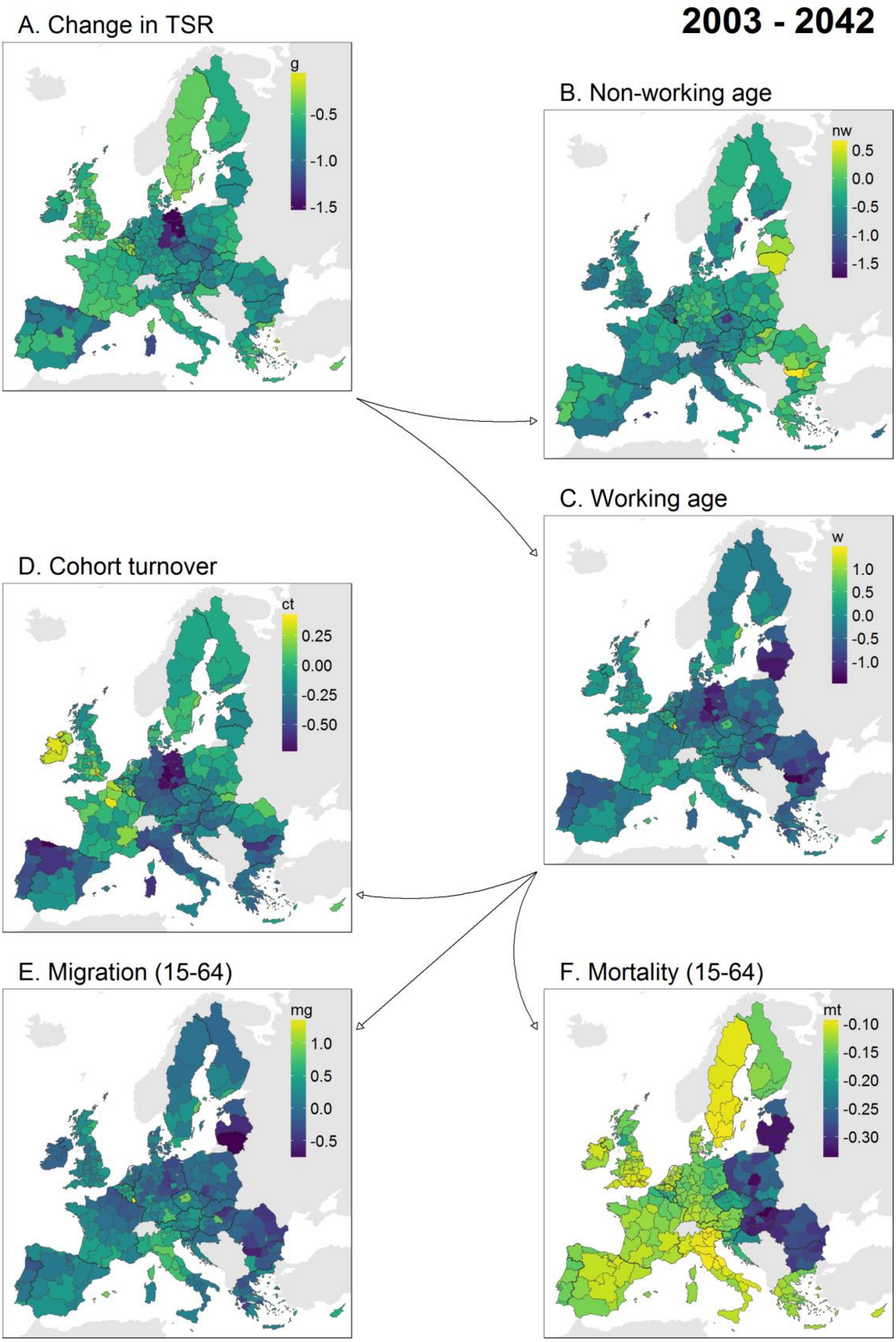


Notes: Each NUTS-2 region's TSR value in each year of the study period is represented with a point colored according to EuroVoc definition of European subregions. Lines represent group averages. The most prominent outliers (London – top; and 5 regions of Easrtern Germany, excl. Berlin, – bottom) are also labeled. Observed period marked with a light-grey background.

4.2. Decomposition of TSR growth

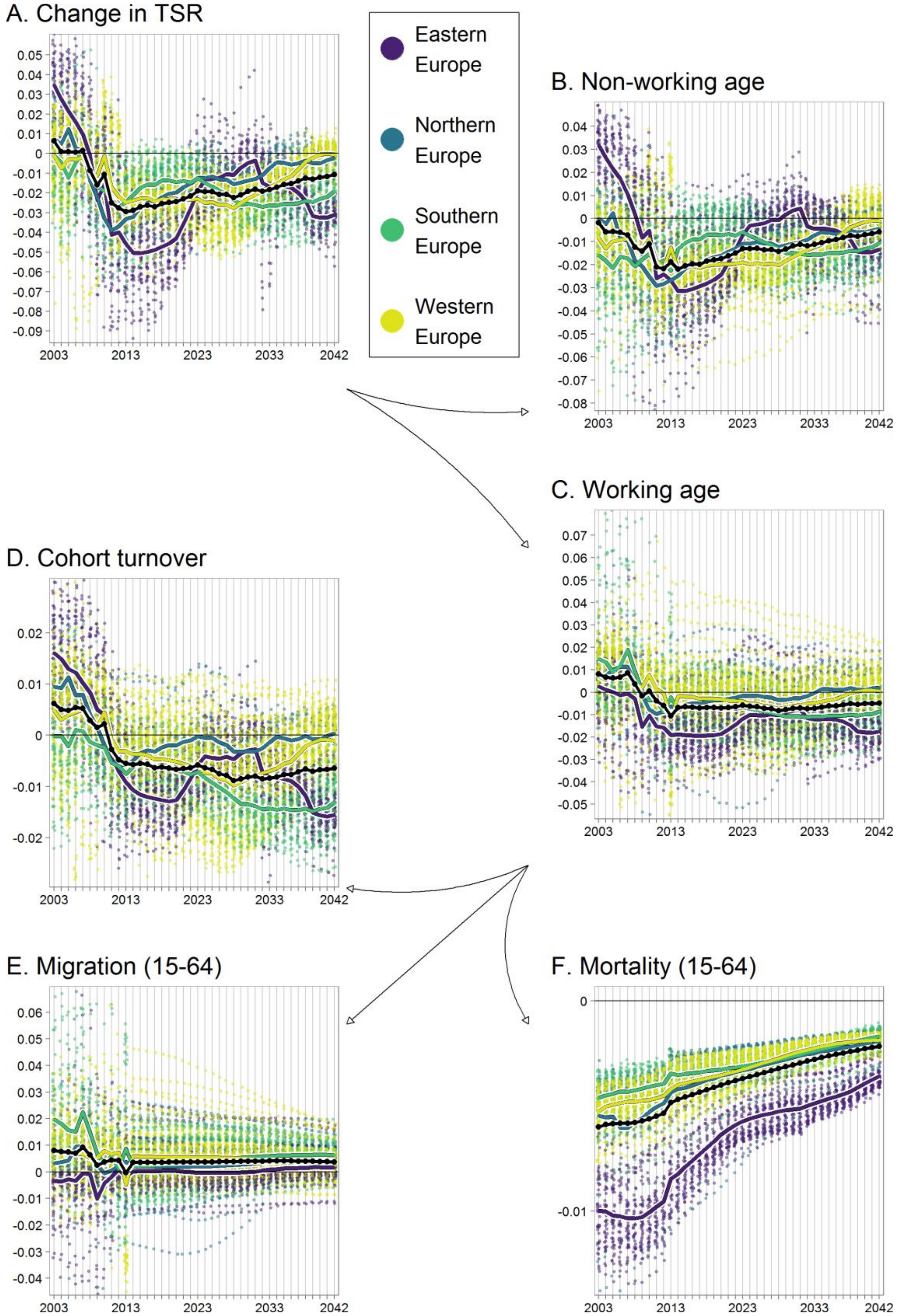
As described in the methodological part of the paper, the overall change in the TSR (g) can be decomposed into the separate effects of changes in the non-working-age population (nw) and the effects of changes in the working-age population (w). The latter can be further decomposed into the effects of cohort turnover (ct), migration at working ages (mg), and mortality at working ages (mt).

Figure 3: Decomposition of change in TSR between 2003 and 2043



Notes: A – overall change; B – change due to dynamics in non-working-age population; C – change due to dynamics in working-age population; D – change due to cohort turnover; E – change due to migration at working ages; F – change due to mortality at working ages. Color scales are panel specific due to the big difference in variables' distributions.

Figure 4: Distributions of the decomposed components of change in TSR, all years between 2003 and 2043



Notes: Each NUTS-2 region is represented with a point colored according to EuroVoc definition of European subregion. Scales on y-axes are panel specific due to the big difference in variables' distributions.

Figure 3 presents the two steps decomposition of change in the TSR during the whole study period (similar sets of maps for each of the decades can be found in the Appendix, figures A1, A2, A3, and A4). Each of the partial effects reveals substantial variation across NUTS-2 regions, countries and EuroVoc subregions. Not only the overall dynamics of the TSR are highly uneven, but also the dynamics of each component.

The map of the overall change in the TSR (figure 3A) highlights the areas that faced the biggest absolute change. In line with the results from section 4.1, Eastern Germany experienced the most pronounced drop in the support ratio; with a considerable gap follow Czech Republic, Slovenia, Spain, Northern Italy, Hungary, and Bulgaria. The biggest increase happened in Belgium (particularly, in Wallonia, the Southern part) and Luxembourg, Sweden, United Kingdom, and Southern France.

The spatial variation in the TSR change due to the dynamics of non-working-age population (figure 3B) reveals two main findings. First, there is an evident North-South gradient, which can be explained by long-persisting European differences in fertility levels. Second, almost all major metropolitan regions are clearly visible because they experience a relatively sharp decline in the TSR due to the changes in the non-working-age population: Stockholm, Helsinki, Copenhagen, London, Amsterdam, Berlin, Prague, Budapest, Bucharest, Vienna, Paris, Rome, Madrid. Evidently, population replacement in the metropolitan areas is mainly driven by migration (figure 3E), rather than cohort turnover. The spatial variation of the TSR growth due to the changes in working-age population (figure 3C) clearly shows the attractiveness of the regions for the labor force.

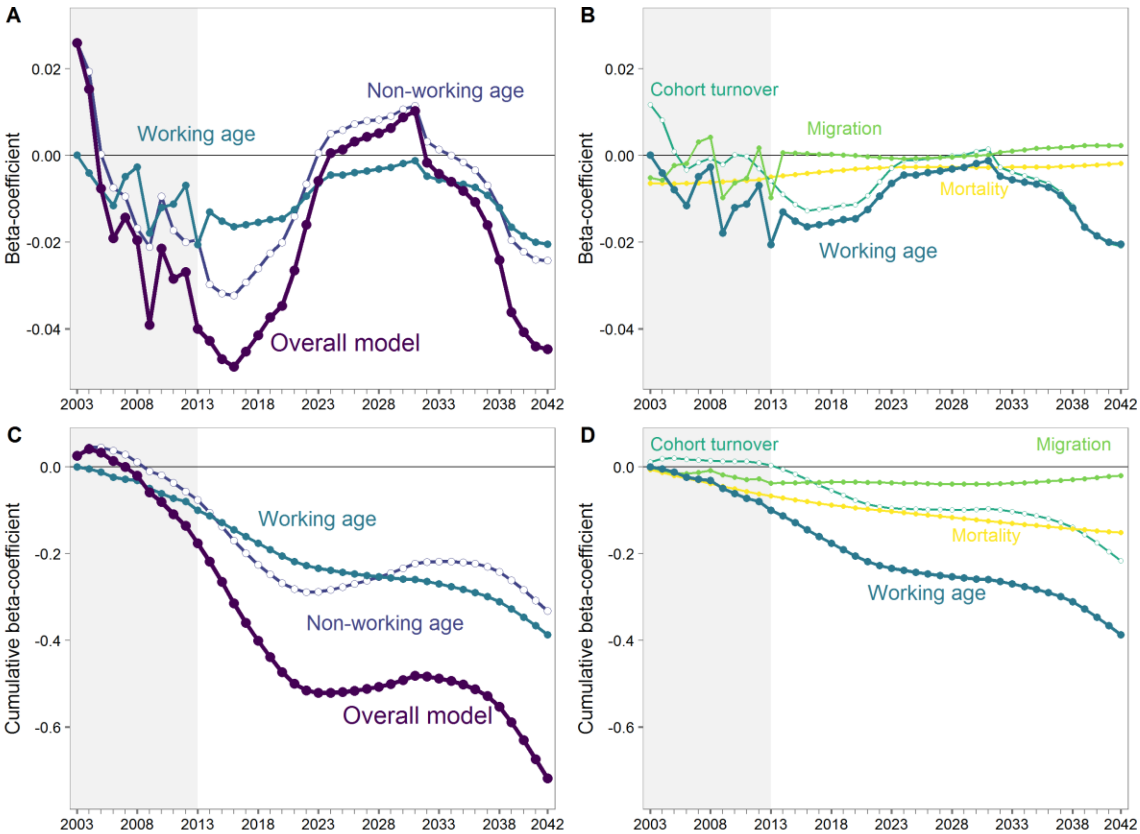
The spatial pattern of changes in the TSR due to cohort turnover (figure 3D) is distinctively similar to what we know about fertility (Frejka and Sobotka 2008) and child migration levels in Europe (Wilson et al. 2013). Interestingly, lots of metropolitan areas have relatively higher increase or lower decrease in the TSR due to cohort turnover, which, probably, means that quite often people leave these areas before turning 65 (see, for example, the development of the population pyramid of London in the Appendix, figure A5). The effect of migration at working ages on the TSR (figure 3E), apart from the mentioned above metropolitan areas regularity, shows some East-West gradient: emigration of working-age population from East-European regions, and especially from Baltic countries, is particularly high. But the most pronounced East-West gradient appears at the map of mortality at the working ages component of the change in the TSR (figure 3F). The prevalence of mortality at ages between 15 and 64 in the regions of Eastern Europe is striking. Even the optimistic convergence-based scenarios of Eurostat population projection do not promise that this divide would vanish in the coming three decades (figure 4F).

Figure 4 illustrates the importance of demographic waves in the development of population structures. This is particularly evident for East-European regions. The downfall of fertility in the 1990s produced a very small generation giving a short-term alleviating effect (demographic dividend), but resulting in a big negative impact of cohort turnover on the TSR 15 years later and a smaller alleviating echo effect about 30 years later. The timing of the effect of migration on the change in the TSR is only visible in the observed part of the study period. The pre- and post- 2008 economic crisis migration shocks are very pronounced (note also that the y-axis scale range is relatively big for the migration component). In the projected part of the study period, according to the converging baseline assumption, migration intensities are extrapolated with reducing variance, which result in a very smooth development of an almost fixed distribution. With such a projection, migration at working ages can hardly have any effect on convergence in ageing (see section 4.3).

4.3. Beta-convergence analysis

The results of the beta-convergence modeling for all regions of Europe are shown in figure 5; panels A and B show the components of the first and the second steps of the decomposition of changes in the TSR, respectively. Each point in the plot represents an estimate of the beta-coefficient from the corresponding partial model. Panels C and D show the same model estimates but in a cumulative way, revealing the overall convergence process throughout the study period.

Figure 5: Bi-dimensional decomposition of beta-convergence estimates by (1) component of change in TSR and (2) time



Notes: Each point represents beta-coefficient from the corresponding partial model. The left panels show the first step of TSR growth decomposition; the right panels shows the second step. Panels A and B show beta-convergence estimates for each year separately; panels C and D show the cumulative effect. Observed period marked with a light-grey background.

The dynamics of beta-coefficients from *g* models indicate that there was divergence (positive beta-coefficients) in 2003 and 2004, and then convergence (negative beta-coefficients) for the rest of the observed period with local peaks in 2009 and 2013. The rapid convergence continues till the beginning of the 2020s. From sections 4.1 and 4.2 we know that this period is characterized by the anticipated rapid decrease in the TSR in East-European regions. Then, there is hardly any convergence in the 2020s and early 2030s while East-European regions experience an alleviating echo effect of a relatively smaller generation born to the very small generation of parents born in the 1990s (see, for example, populations pyramids for Romania in the Appendix, figure A6). Finally, fast convergence starts again in the middle of the 2030s when the smaller "echo generation" enters working-ages. In short, most of the regional convergence in ageing in Europe seems to be driven by the dynamics of the TSR in the regions of Eastern Europe.

Thus the overall convergence trend is mainly set by changes in the size of the non-working-age population in the first half of the study period; changes in the size of the working-age population contribute much less to the overall convergence. Though, in the second half of the study period, convergence is mainly driven by the working-age population. In the end, the cumulative contributions of both components are almost equal.

The contribution of ct is very similar to the effect of nw: it contributes to divergence slightly in the beginning of the period and then follow closely the population structure dynamics in Eastern Europe. The impact of mg is quite insignificant throughout the study period due to the mentioned above features of Eurostat regional population projection (section 4.2). The influence of mt is the most stable, which can be explained by the very slow pace of changes in mortality rates and the huge initial differences between Eastern Europe and the rest. It contributes to convergence because both the initial TSR and mortality rates at working ages are higher in East-European regions. By the end of the study period, the cumulative effect of the moderate but stable year-by-year mt contributions accounts for about 40% of the convergence in w.

5. Conclusion and discussion

In this paper we investigate how regional differences in population ageing across Europe developed over the last decade and how they are likely to evolve in the coming three decades. The results show that there was convergence in ageing during the biggest part of the observed period and it is anticipated during the first and the third decades of the projected period.

The speed of convergence depends mainly on the development of the Total Support Ratio in East-European regions in relation to the rest of Europe. Convergence is, by definition, a temporary process. The convergence in ageing among European NUTS-2 regions throughout the 40 years long study period can be explained by the fact that the initial variation in ageing was at a local peak because of the East-European regions that experienced the ending phase of the window of demographic opportunities.

Population structures affect convergence in ageing through cohort turnover and changes in the size of the non-working-age population. Growth of the non-working-age population is responsible for approximately half of the overall convergence in the study period. Of the second half, which is attributed to the effect of growth in the working-age population, cohort turnover is responsible for about 60% of the effect.

Mortality at working ages has the most stable impact on convergence in ageing. It accounts for about 40% of the convergence effect through changes in the size of the working-age population. Interesting in itself, this finding limits the scope for policy options: if policy makers aim at convergence in mortality this may be in conflict with aiming at convergence in population ageing. Even though convergence in ageing may be desirable, the persisting higher mortality in East-European regions is, by no means, a policy option. Yet, this component is likely to contribute significantly to convergence in ageing in the coming decades because improvements in mortality rates go very slowly (Vallin and Meslé 2004).

Quite surprisingly, migration at working ages assumptions in the Eurostat projections has an almost nonexistent effect on convergence in ageing in the long run. This can be explained by the assumption that there will be convergence in every demographic indicator, which are baseline assumptions of the EUROPOP2013 regional population projections. Interestingly, the contribution of migration at working ages is crucial in explaining the biggest fluctuation of the effect of change in working-age population during the observed period. The most notable is the change of the trend in 2009, which is likely to be caused by sharpened out-migration from East-European regions after the outbreak of the economic crisis; and the preceding local peak of 2004-2005 was, most likely, linked to the increased migration intensities after the biggest EU enlargement. The relative importance of migration during the observed period and the lack of effect in the projected period indicate that convergence in migration flows, as projected by the basic Eurostat scenario, does not lead to convergence in population ageing. Thus if policy makers are aiming for convergence in population ageing one policy option is to attempt to affect the direction of migration flows, i.e. directing net flows of migrants at working ages from regions with a high share of working-age population to regions with a high share of non-working population. If that policy would be effective it would contribute to stronger convergence of ageing than the convergence in the Eurostat scenario.

The relatively big impact of cohort turnover leaves room for policy options, since the size of the impact depends on the age boundaries of 15 and 65 years. If policies aimed at raising the retirement age will be effective, the upper age boundary of 65 should be raised. This will have a positive impact on the level of the TSR. Note that crossing the age margin of 65 may have different implications for different parts of Europe due to varying participation rates after 65 (Sanderson and Scherbov 2007, 2010, 2015). Similarly, with the persistent growth of educational attainment, the lower border of working ages may be raised (Harper 2014). This will have a negative impact on the level of the TSR.

One important question is whether convergence in population ageing contributes to economic convergence. Although, researchers mainly find proofs of the negative effects of accelerating ageing on the economy and on social structures, some demographers call for a calmer evaluation of the consequences of ageing (Lloyd-Sherlock et al. 2012; Van Dalen and Henkens 2011). Moreover, some economists even doubt the negative influence of population ageing on economic development, at least in the beginning of the period of accelerated ageing (Gómez and De Cos 2008). But even if we rely on a negative link between ageing and economic development, most interestingly, in the current state of the variation of regional demographic structures in Europe, convergence in ageing contributes to a slowdown of economic cohesion because East-European regions are now less economically developed but have more favorable population structures (Kashnitsky et al. 2016).

The mentioned limitations leave plenty of room for further research on convergence in ageing. In this paper, we analyzed for the first time the evolution of population structures using beta-convergence modelling and attempted to understand how demographic components of population growth contribute to the convergence process. By focusing on specific features some interesting differences come to the fore. Our results in section 4.2 indicate that employing urban/rural differences can be beneficial for the analysis of convergence in ageing.

6. Acknowledgements

<to be added after the review process>

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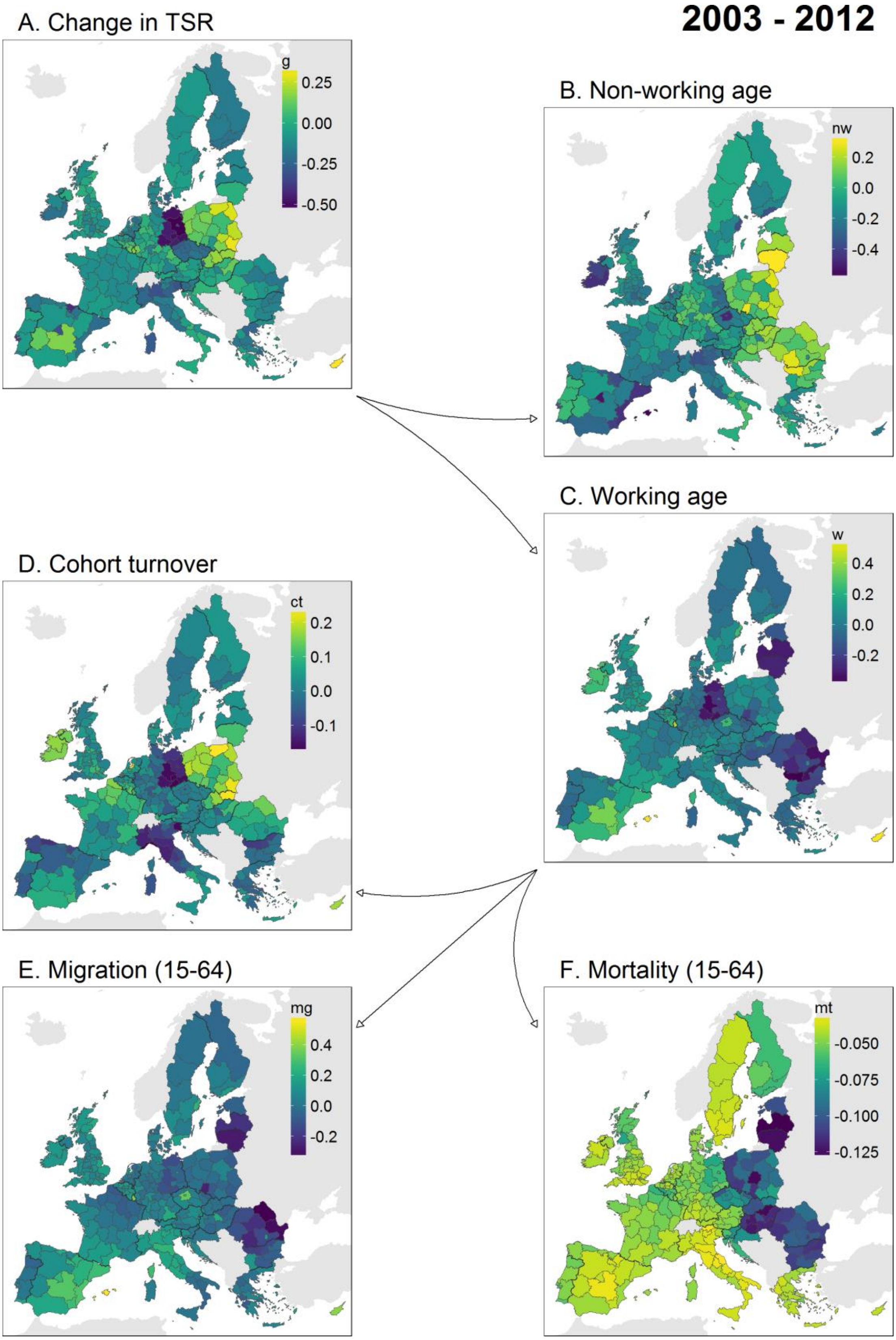
Appendix

Table A1. Summary statistics for the observed period by countries

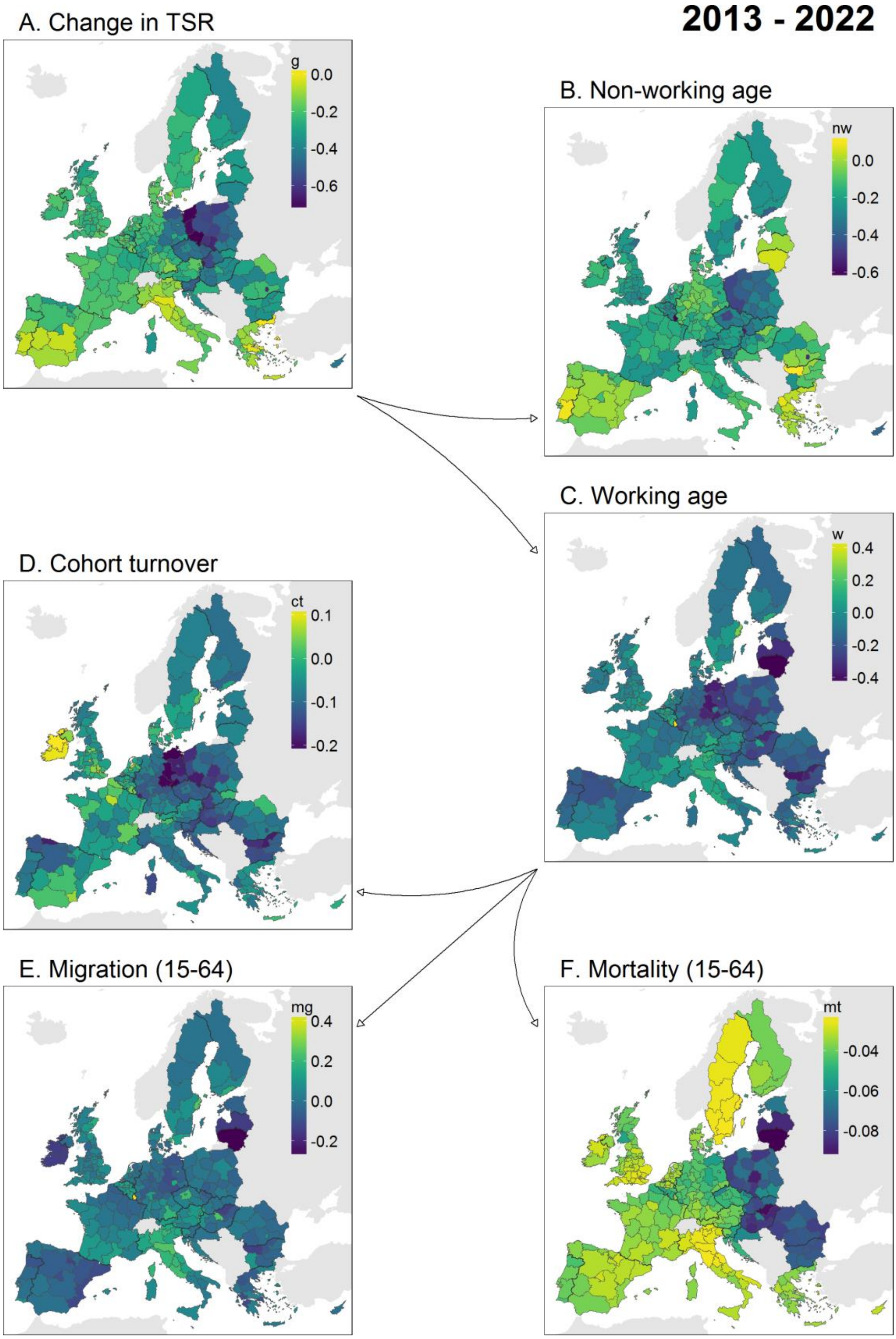
Country	# of NUTS -2 reg.	Total population				TSR	Average TSR growth due to						TSR
		Country	Mean pop. of region	Country	Mean pop. of region		g	nw	w	mt	mg	ct	
		2003	2003	2013	2013	2003	2003-2013						2013
Eastern Europe													
BG	6	7.8	1.3	7.3	1.2	2.14	-0.126	0.090	-0.216	-0.109	-0.061	-0.046	2.02
CZ	8	10.2	1.3	10.5	1.3	2.40	-0.235	-0.241	0.006	-0.084	0.099	-0.009	2.16
HU	7	10.1	1.4	9.9	1.4	2.17	-0.002	0.077	-0.079	-0.117	0.009	0.029	2.17
PL	16	38.2	2.4	38.1	2.4	2.26	0.151	0.130	0.021	-0.098	-0.040	0.159	2.44
RO	8	21.8	2.7	20.0	2.5	2.24	-0.075	0.120	-0.194	-0.105	-0.168	0.078	2.17
SK	4	5.4	1.3	5.4	1.4	2.44	0.069	0.023	0.046	-0.097	0.007	0.137	2.51
Northern Europe													
DK	5	5.4	1.1	5.6	1.1	1.95	-0.143	-0.158	0.015	-0.049	0.045	0.020	1.81
EE	1	1.4	1.4	1.3	1.3	2.10	-0.135	-0.005	-0.130	-0.104	-0.064	0.038	1.97
FI	5	5.2	1.0	5.4	1.1	1.99	-0.161	-0.202	0.041	-0.055	0.074	0.022	1.83
IE	2	4.0	2.0	4.6	2.3	2.05	-0.165	-0.427	0.262	-0.040	0.140	0.162	1.89
LT	1	3.4	3.4	3.0	3.0	2.02	0.020	0.309	-0.289	-0.125	-0.278	0.114	2.04
LV	1	2.3	2.3	2.0	2.0	2.13	-0.124	0.187	-0.310	-0.129	-0.214	0.032	2.01
SE	8	8.9	1.1	9.6	1.2	1.81	-0.070	-0.132	0.062	-0.038	0.080	0.020	1.74
Southern Europe													
CY	1	0.7	0.7	0.9	0.9	2.05	0.327	-0.214	0.541	-0.039	0.404	0.176	2.38
EL	13	11.0	0.8	11.1	0.9	1.91	-0.116	-0.106	-0.010	-0.041	0.037	-0.005	1.79
ES	19	39.9	2.5	44.5	2.8	2.13	-0.123	-0.304	0.180	-0.042	0.226	-0.004	2.00
HR	2	4.3	2.2	4.3	2.1	2.01	0.005	0.008	-0.003	-0.071	0.054	0.014	2.01
IT	21	57.1	2.7	59.7	2.8	1.98	-0.144	-0.165	0.021	-0.037	0.115	-0.056	1.84
MT	1	0.4	0.4	0.4	0.4	2.17	-0.016	-0.143	0.128	-0.046	0.099	0.074	2.15
PT	7	10.0	2.0	10.0	2.0	1.98	-0.130	-0.110	-0.019	-0.052	0.048	-0.015	1.85
SI	2	2.0	1.0	2.1	1.0	2.36	-0.195	-0.211	0.016	-0.068	0.073	0.011	2.17
Western Europe													
AT	9	8.1	0.9	8.5	0.9	2.12	-0.051	-0.115	0.064	-0.048	0.086	0.026	2.07
BE	11	10.4	0.9	11.2	1.0	1.90	0.000	-0.151	0.151	-0.051	0.137	0.065	1.90
DE	38	82.5	2.2	82.0	2.2	2.07	-0.116	-0.054	-0.062	-0.051	0.029	-0.041	1.95
FR	26	60.1	2.7	63.7	2.9	1.81	-0.088	-0.150	0.062	-0.049	0.044	0.066	1.73
LU	1	0.4	0.4	0.5	0.5	2.04	0.187	-0.258	0.445	-0.048	0.390	0.102	2.23
NL	12	16.2	1.3	16.8	1.4	2.07	-0.152	-0.174	0.022	-0.045	0.017	0.050	1.92
UK	37	59.5	1.6	63.9	1.7	1.88	-0.043	-0.154	0.111	-0.046	0.107	0.050	1.84

Figure A1: Decomposition of change in TSR between 2003 and 2013



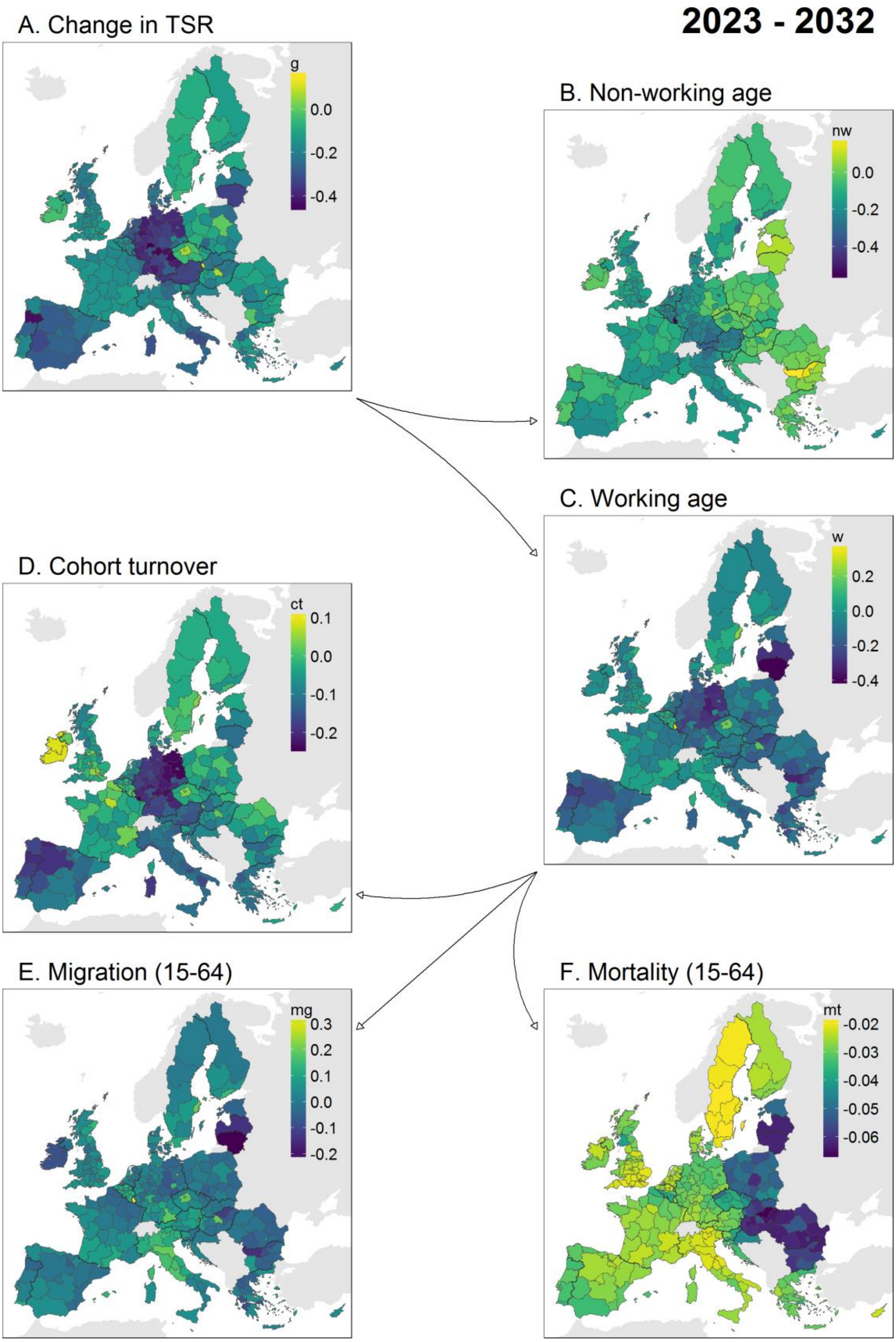
Notes: A – overall change; B – change due to dynamics in non-working-age population; C – change due to dynamics in working-age population; D – change due to cohort turnover; E – change due to migration at working ages; F – change due to mortality at working ages. Color scales are panel specific due to the big difference in variables' distributions.

Figure A2: Decomposition of change in TSR between 2013 and 2023



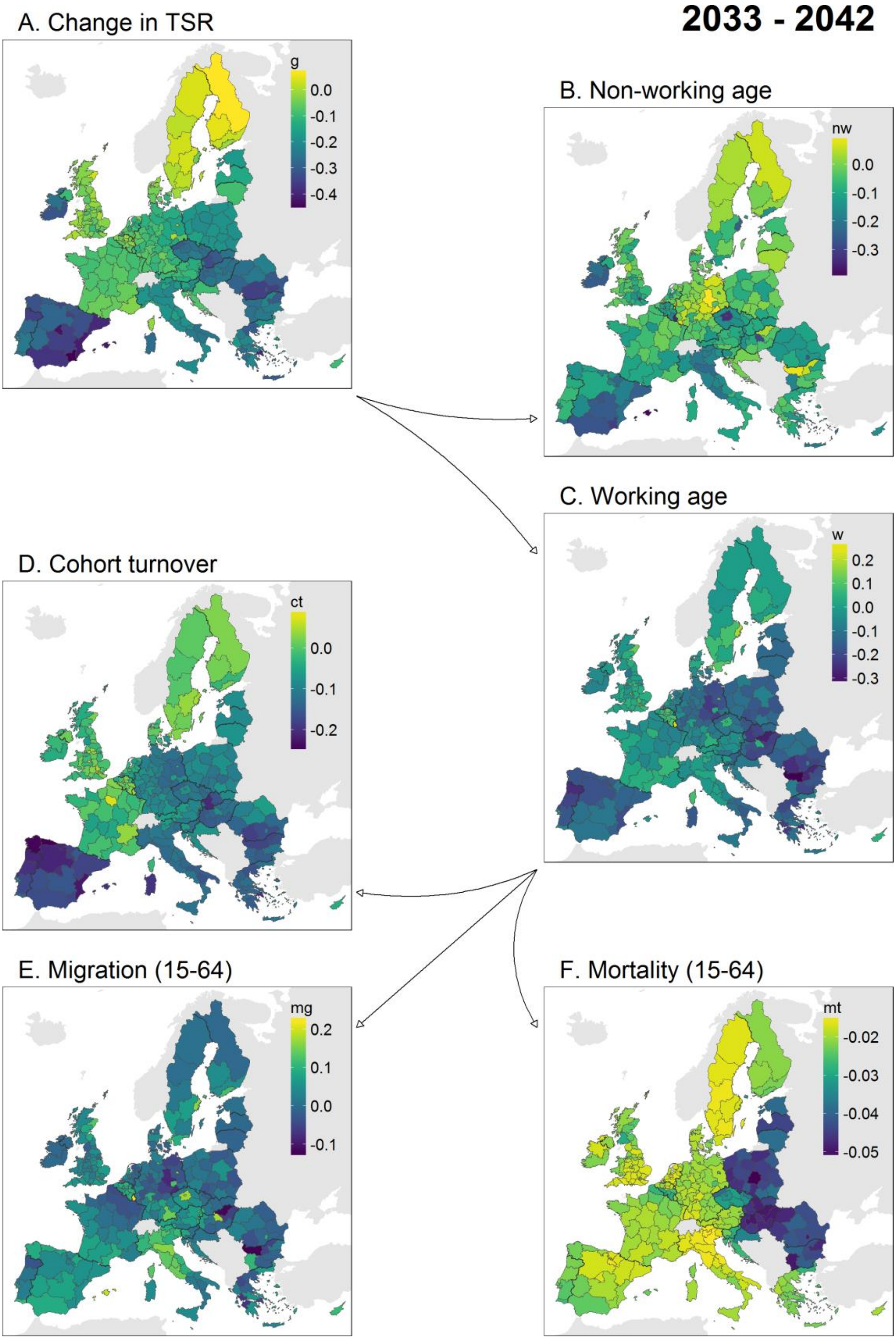
Notes: A – overall change; B – change due to dynamics in non-working-age population; C – change due to dynamics in working-age population; D – change due to cohort turnover; E – change due to migration at working ages; F – change due to mortality at working ages. Color scales are panel specific due to the big difference in variables' distributions.

Figure A3: Decomposition of change in TSR between 2023 and 2033



Notes: A – overall change; B – change due to dynamics in non-working-age population; C – change due to dynamics in working-age population; D – change due to cohort turnover; E – change due to migration at working ages; F – change due to mortality at working ages. Color scales are panel specific due to the big difference in variables' distributions.

Figure A4: Decomposition of change in TSR between 2033 and 2043



Notes: A – overall change; B – change due to dynamics in non-working-age population; C – change due to dynamics in working-age population; D – change due to cohort turnover; E – change due to migration at working ages; F – change due to mortality at working ages. Color scales are panel specific due to the big difference in variables' distributions.

Figure A5: Population pyramids of London in 2003, 2013

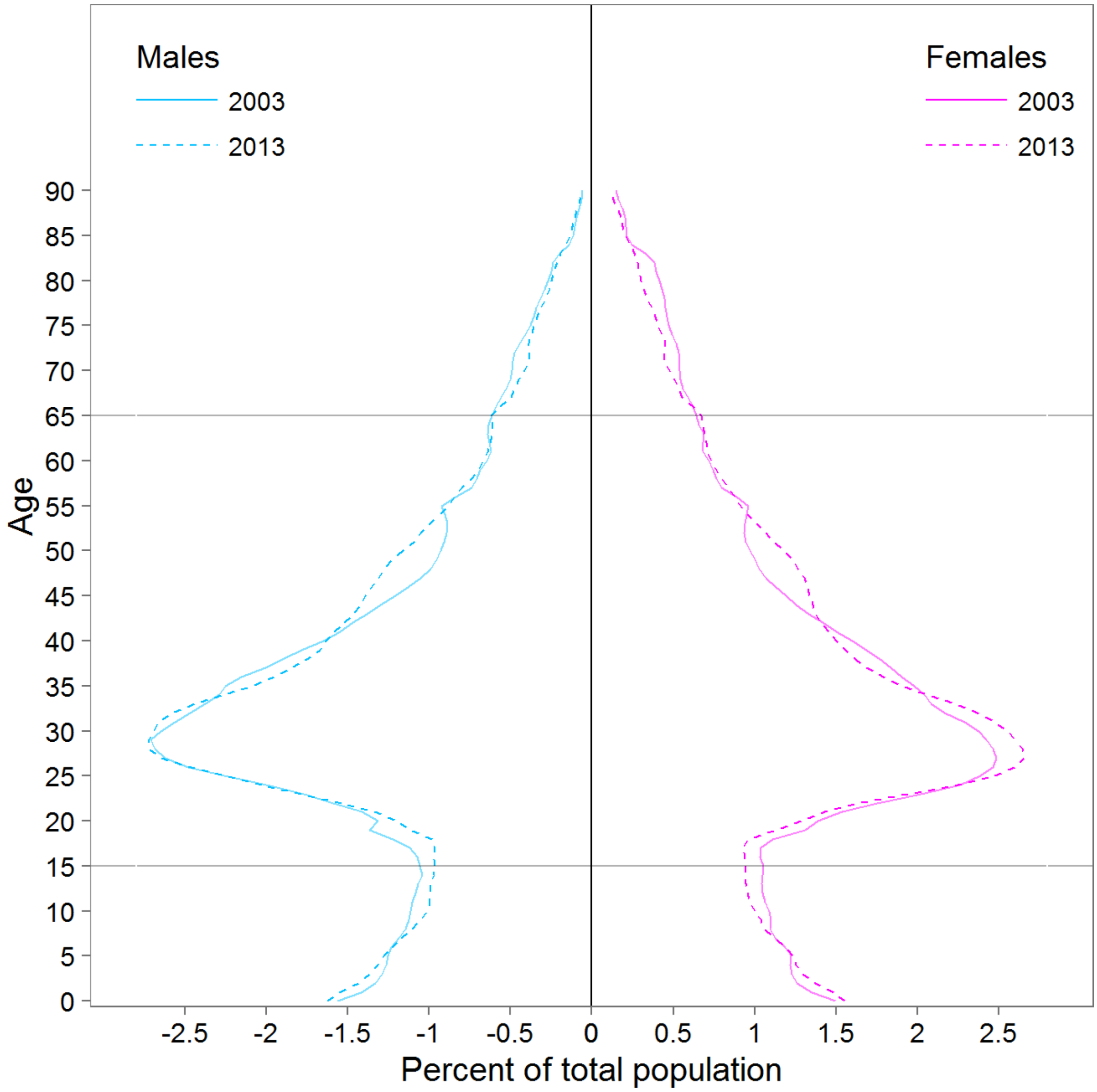


Figure A6: Population pyramids of Eastern Europe in 2003, 2013, 2023, 2033, 2043