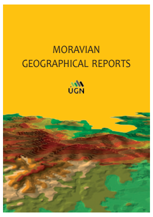

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A retrospective and prospective view of current and future population ageing in the European Union 28 countries

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Abstract

Population ageing in the EU28 is an important twenty-first century phenomenon, affecting virtually every aspect of life in these countries. The results of the latest EUROPOP2018 population forecast indicate that the rate of ageing is accelerating. The aim of this paper is to analyse the current level of population ageing in the EU28, identify spatial differences, and point to likely trends by the middle of this century. For these purposes, we have used a combination of conventional chronological indicators of population ageing and a set of new indicators based on prospective age that allows for a more comprehensive and realistic view of population ageing. We use multivariate statistical methods (factor and cluster analysis) to identify groups of countries with similar population ageing characteristics, using both a retrospective and prospective approach. We decompose changes in selected ageing indicators into the separate effects of changes in the population composition (children under 15, working-age population, elderly). We then identify the effect of major demographic factors (migration, mortality, cohort turnover) for the set of EU28 countries

Key words: *population ageing, prospective age, spatial differences, demographic factors of ageing, population projection, European Union 28 countries*

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1. Introduction

The latest United Nations report on world population (UN, 2017) clearly shows dynamic growth in population ageing in the twenty-first century, with the number and proportion of elderly people increasing in all countries. The ageing phenomenon is unprecedented (UN, 2001). These reports, and changes in the ageing European countries, are generally viewed with negativity, with particular concerns being expressed around the sustainability of public finances, economic growth, and the security of pension systems and social systems (e.g. Cuaresma et al., 2014; Bloom et al., 2010; Börsch-Supan, 2003).

Population ageing is an issue that extends beyond the scientific disciplines that have traditionally investigated it (demography, sociology and economics) and its almost universal presence has led to it being a key social, economic, health care and cultural issue with a wide spectrum of impacts (Lutz et al., 2008a). Several scholars (e.g. Gavrilov and Heuveline, 2003; Lutz et al., 2008a) see population ageing as one of the greatest challenges of the twentieth century. In addition, many (e.g. Lutz et al., 2008ab) claim that the rise in the number of elderly people and as a proportion of the population in the most advanced countries is an irreversible trend that will accelerate.

In recent years, several studies have focused on the level, trends and spatial differences in population ageing (e.g. Atkins and Tons, 2016; Cook and Halsall, 2012; Kashnitsky et al., 2017). A wide range of approaches to population ageing have been adopted, from simple studies using conventional indicators (e.g. Długosz and Kurek, 2006; Káčerová et al., 2012; Káčerová and Ondačková, 2015) to more complex analyses involving various space-time modelling techniques (e.g. Reynaud et al., 2018), cluster analyses (e.g. Bivand et al., 2017) and autocorrelation techniques (e.g. Shiode et al., 2014). Some studies have sought to identify the principal factors determining temporal and spatial changes. Those by Kashnitsky et al. (2017) and Kashnitsky et al. (2019) are perhaps the most complex.

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Other scholars (e.g. Sanderson and Scherbov, 2015b; Spijker, 2015; Basten et al., 2015) have drawn attention to the complex nature of ageing, which is still largely analysed using chronological age-based tools. It is important to note that retrospective approaches, when used to analyse phenomena that are changing significantly, such as mortality, often produce a skewed view of population ageing and, in the absence of a more complex multidimensional approach, may even lead to distorted conclusions that then feed into decision-making processes (see for example, Sanderson and Scherbov, 2007; 2013). Increasingly, analyses of the phenomenon of ageing have tended to focus on the remaining years of life rather than years lived. Some important ageing characteristics, such as retirement, consumption, accumulation of human and tangible capital, health status, morbidity, cognitive abilities, consumer preferences, savings and levels of expenditure on social and health systems, are associated with remaining life expectancy (see e.g. Miller, 2001; Stearns and Norton,2004; Bloom et al., 2003; Sanderson and Scherbov, 2005). With elderly people living longer, these aspects are becoming important at an increasingly older age, and therefore using a chronological definition to set the old-age threshold may not sufficiently capture reality (Sanderson and Scherbov, 2008, p. 2013; Spijker, 2015; Spijker and MacInnes, 2013). This and empirical evidence of the changing characteristics of the elderly population associated with longer life-spans, have led to efforts to apply alternative approaches to conceptualising age and population ageing. These are based on prospective age and look at age in terms of the number of remaining years of life.

It is also important to note that in demography, chronological age and prospective age (and in some studies thanatological age: Riffe et al., 2016; 2017) are only two of six possible ways of viewing time (the others are period, cohort, death cohort and life-span). As Riffe et al. (2016; 2017) point out, the use of various combinations of these temporal indicators greatly expands the possibilities for investigating the temporal dynamics of classical demographic processes and temporal interactions between these events. Studies that adopt a prospective approach to population ageing, such as Basten et al. (2015) and Sanderson and Scherbov (2015a, 2015b), frequently identify quite different levels, dynamics and, in some cases trends, from those using conventional chronological indicators. We therefore assume that accounting for differences in mortality rates could paint a significantly different picture of the level of population ageing in Europe. Generally, we expect to find shifts from younger populations to populations that are chronologically old and older, but with a high mean life expectancy (e.g. Southern European countries). We expect the opposite to happen in countries that appear younger but have relatively high mortality rates (compared to the EU28), which would then feature among the old and very old country categories in Europe.

As life expectancy is expected to increase and there is some degree of convergence in mortality rates (EUROSTAT, 2019), we expect population ageing to become increasingly similar across old and new member states under both the chronological and prospective approaches.

But population ageing is not just affected by mortality rates. Other demographic processes (fertility and migration) play an important role too, especially in relation to changes in age structure and to greater differences in the size of age cohorts. Based on some partial findings at the subnational level (Kashnitsky et al., 2017), we expect age cohort size to be a key factor in ageing.

Following from these hypotheses, the main aim of this paper is to geographically classify EU countries according to their level of population ageing using both a chronological and a prospective approach. This is the first time both approaches, which use established indicators to monitor demographic ageing, have been used for this purpose. In addition to focusing on the current picture (2018), we use the most recent EUROSTAT projection (EUROPOP, 2018) to show how it is likely to change by the mid-twenty-first century. We then identify the main demographic factors in each of the EU member states influencing the expected changes, using selected population ageing indicators.

2. Theoretical framework and the inclusion of a prospective research approach

The phenomenon of population ageing began at some stage in the development of modern and post-modern societies and is now generally thought to be primarily the result of a simultaneous decline in fertility, to persistently very low or even lowest-low levels (Lesthaeghe and Willems, 1999; Kohler et al., 2002), longer life expectancies and numerous post-war generations moving to the top of the age pyramid (Kashnitsky et al., 2017).

The main theories relevant to demographic ageing are as follows.

Theories of demographic transition (Coale, 1973; Coale and Watkins, 1986), and especially the second demographic transition which is now of particular relevance (van de Kaa, 1994; 1997; Lesthaeghe, 2010), attempt to explain changes in reproductive and family behaviours, specifically the decline in fertility rates to low and very low levels associated with delayed parenthood, which are accompanied by a marked fall in the number of childbirths and ageing at the bottom part of the pyramid.

In contrast, the theory of epidemiological transition was originally developed by Omran (1971), and subsequently extended to include fourth and fifth phases, mainly by Olshansky and Ault (1986) and Olshansky et al. (1997). The original theory of epidemiological transition points to a shift in mortality level, associated particularly with causes of death (Robine, 2003). Changes in age-specific morality and the associated increased chances of survival changed the age structure of the population and led to population ageing in the various phases (Omran identified three phases). From around the latter half of the 1960s, Western European countries entered the phase of an onset of delayed degenerative diseases (Robine, 2003). The cardiovascular revolution (Meslé and Vallin, 2000; Yusuf et al., 2001) was an important factor in increasing the probability of living longer, and this contributed to a further relatively rapid fall in old age mortality such that the maximum risk of mortality shifted to an even older age. This led Eggleston and Fuchs (2012) to associate this phase with a longevity transition, and this is closely linked to the rectangularisation of the survival curve and the theory of compression of morbidity (Fries, 1980; Fries et al., 2011). Some scholars, however, have pointed out that the developmental trends in old-age morbidity are not clear-cut, and they have tended to favour a theory of dynamic equilibrium instead (Manton, 1982) or even the expansion of morbidity (Gruenberg, 1977; Kramer, 1980).

As Lutz and Skirbekk (2005) have stated, the current age structure is the result of previous population trends and is a predetermined internal factor of ageing. We should note above all the effect of marked differences in the size of a population cohort. Over a long stretch of time, the large post-war generations of the 'golden age of the family' have been entering retirement age at an increasingly older age. Some European populations also had 'boomer' generations in the 1970s. This cohort turnover, then, continues to be another important aspect of dynamic ageing processes in Europe (Kashnitsky et al., 2017).

The last issue deserving attention is the role played by international migration. Given the specific age profile of migrants, migration can impact on the number and proportion of working-age individuals, both in a positive and negative sense. Ultimately, though, migration has both a direct and an indirect effect on population age structure and has become an important reproductive factor in many European countries (e.g. Sobotka, 2008).

As Ryder (1975) pointed out earlier, followed by Sanderson and Scherbov (2005, 2007) and Lutz et al. (2008b), a chronological approach based on number of years since birth is not a suitable tool for defining the elderly population. In adulthood, most of the characteristics associated with ageing are affected rather by the remaining years of life. Over the long term, old age is associated more with the remaining years of life than with number of years lived (Sanderson and Scherbov, 2010, 2015b). By focusing on chronological age, the assumption is made that the characteristics of the elderly population remain unchanged over time and space. That would mean that there are no between-country differences in the characteristics of the elderly population, and that they have not changed and nor will they change over time. But lower mortality alters the distribution of the age structure of the population and shifts the distribution of potential years of life (Spijker, 2015). In addition, empirical findings reveal that, compared to their predecessors, elderly people in recent days are more educated, more mobile, have better cognitive abilities, declining morbidity, and so on (Sanderson and Scherbov, 2013). In Europe, there are relatively large differences in life expectancy, primarily between the old and new EU28 member states. To a large extent, the differences mirror the well-known East–West mortality gradient (Meslé and Vallin, 2002), which began emerging gradually in the mid-1960s (Vallin and Meslé, 2001). Equally, we should not overlook the significant differences in mean life expectancy between the sexes due to excess male mortality.

The growing need to view ageing in terms of prospective age has led to a series of studies (e.g. Spijker, 2015; Sanderson and Scherbov, 2013, 2016) that seek to define new thresholds for old age and for the elderly population. But it is not the age limit that is the main difference between the conventional chronological approach to ageing and the prospective one, but that the prospective approach also accounts for changes in the characteristics associated with ageing. The prospective age approach takes account of remaining life expectancy and so is consistent because everyone with the same prospective age, regardless of calendar year, population, region and so on, has the same life expectancy and therefore the same number of years of life ahead of them (Sanderson and Scherbov, 2007). Unlike the conventional approach, prospective age reflects changes in mortality and thereby related personal characteristics. Regardless of the population studied, in its space or its time, constant prospective age will always be defined in the same way.

We should not reject conventional approaches but grasp the opportunities offered by prospective ones to extend the research on population ageing. That is the goal here – to take into account both approaches to population ageing in an analysis of current and potential future changes in the level and spatial differentiation of population ageing in the EU.

The results of studies using prospective age to investigate ageing in Europe show that the use of conventional chronological age may significantly distort the level, dynamics and spatial patterns of population ageing (e.g. Klapková et al., 2016; Šprocha et al., 2018; Šídlo et al., 2019). The prospective ageing indicators point to a significantly lower level of ageing in several EU member states, but when conventional instruments are used these states appear to be the oldest ones (e.g. Šprocha et al., 2018; Šídlo et al., 2019). This can be seen at both national and regional levels (Šprocha et al., 2018; Šprocha and Ďurček, 2018).

Our approach to identifying population ageing indicators follows that of Davies and James (2011), who view spatial inequalities in the level of population ageing as the result of a wider set of demographic, social, economic and political and environmental factors, with differing levels of intensity in different locations. We focus on demographic factors and so base our paper on the latest findings of Kashnitsky et al. (2017, 2019). By identifying the demographic factors behind regional changes in population ageing, we find that the expected convergence in ageing will depend mainly on changes in the age structure of the Eastern European regions. Cohort turnovers play a major role in convergence (Kashnitsky et al., 2017), but changes in the mortality rates of the working-age population are just as important and have the most consistent impact on convergence in ageing (Kashnitsky et al., 2017).

Vallin and Meslé (2004) contend that mortality will significantly contribute to convergence in ageing in the coming decades, as mortality rates have been improving relatively slowly (and continuously) in recent decades. Kashnitsky et al. (2017) have noted that identifying convergence in future population ageing is dependent on the accuracy of the population projection (in their case, Eurostat EUROPOP, 2013). While assumptions about age structure and associated cohort turnover and mortality are generally reliable, there is uncertainty over the validity of assumptions about future migration (Kashnitsky et al., 2017, p. 14). Although the results of their analysis show that working-age migration has almost no effect on convergence in the long run, this can be explained by setting up a convergence scenario for future migration developments in Eurostat's projections, but cannot be considered the most realistic assumption (Kashnitsky et al., 2017). The significance of changes in the working-age component also relates to economic convergence in EU regions (Kashnitsky et al., 2019).

3. Data and methods

For the purposes of this paper, we use a constant chronological age of 65 years for defining old age for the retrospective approach, and for the prospective approach, we use the age at which individuals have a remaining life expectancy of 15 years to establish an old-age threshold that fully captures the main dimensions of population ageing, following Sanderson and Scherbov (2008b). This threshold is empirically derived from the level of mortality rates of countries with the longest life expectancy in the world (Sanderson and Scherbov, 2015a). As there are significant life-span differences between the EU28 member states and the sexes, we incorporate this aspect directly into our calculations (see Tab. 1).

Chronological indicator			Prospective indicator		
Proportion of elderly (prop.65+)	(1)	$\frac{P^{m,c}_{x65+} + P^{f,c}_{x65+}}{P^{m,c}_{0-\omega} + P^{f,c}_{0-\omega}}$	Prospective proportion of elderly (prop.RLE15-)	(5)	$\frac{P^{m,c}_{x(RLE15-)} + P^{f,c}_{x(RLE15-)}}{P^{m,c}_{0-\omega} + P^{f,c}_{0-\omega}}$
Ageing index (AI)	(2)	$\frac{P^{m,c}_{x65+} + P^{f,c}_{x65+}}{P^{m,c}_{0-14} + P^{f,c}_{0-14}}$	Prospective ageing index (PAI)	(6)	$\frac{P^{m,c}_{x(RLE15-)} + P^{f,c}_{X(RLE15-)}}{P^{m,c}_{0-14} + P^{f,c}_{0-14}}$
Old-age dependency ratio (OADR)	(3)	$\frac{P^{m,c}_{x65+} + P^{f,c}_{x65+}}{P^{m,c}_{20-64} + P^{f,c}_{20-64}}$	Prospective old-age dependency ratio (POADR)	(7)	$\frac{P^{m,c}_{x(RLE15-)} + P^{f,c}_{x(RLE15-)}}{P^{m,c}_{20-x(RLE>15)} + P^{f,c}_{20-x(RLE>15)}}$
Average age (AA)	(4)	$\frac{\sum_{x=0}^{\omega} x \cdot (P_x^c + 0.5)}{\sum_{x=0}^{\omega} P_x^c}$	Population average remaining years of life (PARYL)	(8)	$\frac{1}{2} \cdot \sum_{x=0}^{\omega} P_x^c \cdot (e_x^c + e_{x+1}^c)$

Tab. 1: Used chronological and prospective indicators

Notes: $P_{x65+}^{m/f,c}$ is the number of men/women in the country (c) aged 65 and above; $P_{0-\omega}^{m/f,c}$ is the total number of men/women in the country (c); $P_{0-14}^{m/f,c}$ is the number of men/women in the country (c) aged 0–14 years; $P_{20-64}^{m/f,c}$ is the number of men/women in the country (c) aged 20–64 years; $P_{x(RLE15-)}^{m/f,c}$ is the number of men/women in the country (c) at ages with a remaining life expectancy (RLE) of 15 years or less; $P_{20-x(RLE>15)}^{m/f,c}$ is the number of men/women in the country (c) aged from 20 to the age when remaining life expectancy is still greater than15 years; P_x^c is the number of persons in the country (c) aged (x); e_x^c is life expectancy at age (x).

We use basic indicators of ageing, such as the proportion of elderly people and the ageing index, in addition to some more complex indicators. Concerns around population ageing mostly relate to the degree to which the elderly population places a burden on the working-age population. The old-age dependency ratio is used as a rough approximation of this burden. We shifted the lower working-age threshold to 20 years to reflect the growth in amount of time spent in education and training. All three indicators are constructed as prospective indicators: prospective proportion of elderly people; prospective ageing index; and prospective old-age dependency ratio. The last indicator of age structure used in our analysis is average age and the prospective alternative PARYL (population average remaining years of life)[1].

PARYL is essentially the weighted average of remaining years of life. Hersch (1944) assumed that the average person at a certain age (x) has a potential number of years of life identical to the average life expectancy (e_x) at that age. PARYL gives us the average remaining years of life of one "average" member of the observed population. Unlike the preceding indicators of age and population ageing, PARYL values capture the acceleration of ageing. This is a logical property: the greater the number of remaining years of life a person has, indicated by a higher PARYL value, the younger the observed population is on average (Lutz, 2009). Table 1 gives an overview of the indicators used and the methods of calculation.

These indicators were designed for the EU28 member states. The data source is the freely available Eurostat database containing the results of past population forecasts[2]. They were designed for the period from 2018 to 2100. We consider projections beyond 2050 to have accuracy issues, so we use the data for 2018 and for 2050. We consider the baseline scenario only, as it seems the most likely scenario.

Population ageing is a multidimensional phenomenon which, as shown above, can be quantified using various chronological and prospective indicators. As our aim is to create a typology of EU countries based on present and future levels of ageing, we use several multidimensional statistical methods. The input data matrix contained information for the 28 EU member states X their eight selected indicators (Tab. 1) and for two years (2018 and 2050). First of all, we tested the input indicators for mutual linear dependence. Pearson correlation coefficients showed (see Appendix 1) very close linear relations between the pairs of selected indicators for population ageing (in the majority of pairs, the values varied above ± 0.8; for 2018, the range of partial correlations ranged from 0.36 to 0.99, with 43% of the correlations exceeding 0.80; for 2050 the interval was 0.74–0.99, and 86% of the partial correlations were greater than 0.8; almost all partial correlations occur with a 99% significantly high interdependence, which indicates that one of the methods for reducing the covariance of the input variables should be used to create a cluster analysis. The Kaiser-Meyer-Olkin index (KMO) subsequently confirmed the high mutual interdependence of the variables. The values (2018 = 0.72; 2050 = 0.69) indicated that a Principal Components Analysis or Factor Analysis of the input data could be performed; the results of the Bartlett's Test of Sphericity and Measures

[1] Median age and median prospective age are not comparable indicators, and they are not used in this paper

[2] Published since 07/2019 and available at https://ec.europa.eu/eurostat/data/database under Population and Social Conditions – Population Projections – EUROPOP2018 – Population Projections at the National Level; Population data on 1 January by age, sex, and type of projection, Assumptions for life expectancy by age, sex, and type of projection, Assumptions for mortality rates by age, sex, and type of projection, and Assumptions for net migration by age, sex, and type of projection.

of Sampling Adequacy were significant (greater than 0.6 for all variables in the anti-image correlation matrix: for more information, see Mareš et al., 2015). The factors were extracted based on Principal Component Analysis (PCA). The number of factors was determined by evaluation of the solution matrix eigenvalues (Kaiser's rule for an eigenvalue greater than 1). As several factor loadings had high values for both factors (year 2018), the factors had to be rotated to achieve best "fit" with one of the extracted factors. We used orthogonal rotation so the factors remained independent of each other after rotation (Mareš et al., 2015). For this purpose, we used the most commonly applied method, Varimax with Kaiser Normalization.

The values of the extracted joint factors (i.e. the factor scores estimated for each country) meet the mutual independence condition and are therefore suitable inputs for a cluster analysis. The aim is to categorise the EU member states into groups of countries with the most similar population ageing pattern (measured both retrospectively and prospectively), while ensuring as large as possible differences between the groups. To achieve this we maximised intracluster homogeneity using Ward's hierarchical clustering method – the most commonly used method – and Euclidean distances to express the similarity or dissimilarity in population ageing between countries (for more information: see Stankovičová and Vojtková, 2007; Mareš et al., 2015).

Our second aim is to identify the main demographic factors determining the level of population ageing in each EU member country, and changes in that level up to the mid-twenty-first century. We first decomposed the differences between the present and future-level of population ageing, according to the effect of these changes in the elderly population (changes in numerator) on the relevant population in the denominator. This depends on the indicator, for the denominator it is the child population (under 15), working age population (20–64 years), and total population of the country. Each of the ageing indicators represents the rate, so for this purpose we used the two-rate decomposition formula developed by Kitagawa (1955) and then further developed by Das Gupta (1991), among others. If we have two factors α and β, the rate F(α, β) is a function of these factors. If these factors acquire the value a, b in the population in 2050 and A, B in 2018, the differences between these rates can be expressed as:

$$F(a,b) - F(A,B) = \frac{a}{b} - \frac{A}{B} \quad (9)$$

This relation can then be expressed as:

$$F(a,b) - F(A,B) = \frac{1}{2}\left[\left(\frac{a}{b} - \frac{A}{b}\right) + \left(\frac{a}{B} - \frac{A}{B}\right)\right] + \\ + \frac{1}{2}\left[\left(\frac{a}{b} - \frac{a}{B}\right) - \left(\frac{A}{b} - \frac{A}{B}\right)\right] \quad (10)$$

If variables a, A indicate the number of persons aged 65+ (elderly people) in 2050 or 2018, and variables b, B are the relevant age cohorts entered into the calculation of the individual ageing indicators (e.g. children under 15, persons aged 20–64 years, total population) in 2050 or 2018, the first part of the expression on the right side of the equation represents the α-effect, i.e. changes in the elderly population, and the second part the β-effect, i.e. the size of the effect of the change on the relevant age cohort in the denominator of the relevant rate.

If we change the first expression on the right-hand side of the equation (10), we obtain the following:

$$\frac{1}{2}\left[\left(\frac{a}{b} - \frac{A}{b}\right) + \left(\frac{a}{B} - \frac{A}{B}\right)\right] = \frac{1}{2}\left(\frac{1}{b}\right)(a - A) + \\ + \frac{1}{2}\left(\frac{1}{B}\right)(a - A) = \frac{1}{2}(a - A)\left(\frac{1}{b} + \frac{1}{B}\right) \quad (11)$$

According to Kashnitsky et al. (2017), the size of the exposed population $P_{x,x+m}^{t+n}$ in the age cohort $(x,x+m)$, in the year $(t+n)$ can be expressed thus:

$$P_{x,x+m}^{t+n} = P_{x,x+m}^{t} + M_{x,x+m}^{t\to n} + \\ + CT_{(x-1)\to(x+m-1)}^{t\to n} - D_{x,x+m}^{t\to n} \quad (12)$$

where $M_{x,x+m}^{t\to n}$ represents net migration in the age cohort $(x,x+m)$ in the years (t) to (n), $D_{x,x+m}^{t\to n}$ is the number of deceased in the age cohort $(x,x+m)$ in the years (t) to (n) and $CT_{(x-1)\to(x+m-1)}^{t\to n}$ represents the cohort turnover in the years (t) to (n).

We can define it as the difference between the number joining the control group (e.g. children, working-age, elderly) and the number leaving the cohort. For example, in the OADR decomposition for working-age individuals, it is the difference between the number of people aged 19 to 64. The cohort turnover for the elderly population represents those aged 64 entering the cohort because as there is no cohort above this death or migration are the only routes out of it. The cohort turnover for the child component is the difference between the number of live births, representing entry into the cohort and the number of children aged 14.

Following Kashnitsky et al. (2017), by replacing the (a–A) relation in equation (12) we obtain an expression which enables us to empirically derive migration levels and effect of mortality in the relevant age cohort $(x,x+m)$ and cohort-turnover effect for years (t) and (n) on the change in size of the elderly population:

$$\frac{1}{2}(a - A)\left(\frac{1}{b} + \frac{1}{B}\right) = \frac{1}{2}CT_{(x-1)\to(x+m-1)}^{t\to n}\left(\frac{1}{b} + \frac{1}{B}\right) + \\ + \frac{1}{2}M_{x,x+m}^{t\to n}\left(\frac{1}{b} + \frac{1}{B}\right) - \frac{1}{2}D_{x,x+m}^{t\to n}\left(\frac{1}{b} + \frac{1}{B}\right) \quad (13)$$

By making a similar adjustment to the second part of the right-hand side of the expression (10) measuring the β-effect, we obtain a relation that enables us to identify the effect of the separate demographic factors on changes to the size of the rate denominator, i.e. in our case, the child component, working-age people or total population:

$$\frac{1}{2}\left[\left(\frac{a}{b} - \frac{a}{B}\right) - \left(\frac{A}{b} - \frac{A}{B}\right)\right] = \frac{1}{2}\left(\frac{1}{b} - \frac{1}{B}\right)(a + A) = \\ = -\frac{1}{2}(b - B)\left(\frac{a+A}{bB}\right) = -\frac{1}{2}CT_{(x-1)\to(x+m-1)}^{t\to n}\left(\frac{a+A}{bB}\right) - \\ -\frac{1}{2}M_{x,x+m}^{t\to n}\left(\frac{a+A}{bB}\right) + \frac{1}{2}D_{x,x+m}^{t\to n}\left(\frac{a+A}{bB}\right) \quad (14)$$

4. Results

The factor extraction using PCA and the calculation of eigenvalues (and a scree plot) shows that for the first year (2018), two principal factors were obtained. The first component (factor) accounted for almost 78% of the variance and the second almost 17%. Together the two factors explain more than 94% of the variance in the original input data. The correlations between the factor and factor loadings shows there are two significant groups. The first factor can be labelled a prospective factor and the second a chronological factor, as the latter is saturated with chronological indicators of ageing only. It is clear from the results that more than two thirds of the variation in population ageing in the EU28 can be explained by differences in prospective indicators. They also indirectly show that using mortality rates when designing ageing indicators enables us to obtain a more precise understanding of the spatial differences in population ageing in the EU28 countries than relying exclusively on conventional chronological age-based indicators does.

For 2050, using Kaiser's Rule (an eigenvalue of more than 1), only one factor was identified from the input data. It explained more than 90% of variation and was saturated by all the chronological and prospective indicators (all factor loadings were higher than 0.9). The results of the forecasts and data obtained from Eurostat's EUROPOP2018 show the high level of convergence between the prospective and chronological indicators and accounts for the spatial variation in level of population ageing in the EU28 countries. To some extent, this may be partly because of the expected convergence in mortality rates between the old and new member states. Interestingly, the values of the coefficient of variation (Appendix 2) indicate that between 2018 and 2050, the variation identified by the chronological ageing indicators will intensify (increase in heterogeneity), while the opposite is the case with the prospective indicators. The values of the input indicators can be found in Appendix 2.

Based on squared Euclidean distances and the clustering trajectory for 2018, we can identify three basic groups of EU countries according to their level of population ageing (see Fig. 1). The average values of the monitored/control indicators for these clusters are presented in Table 2.

The first cluster contains the five states with the lowest values for both the chronological and prospective indicators of ageing. This relatively inhomogeneous group consists of Ireland, Luxembourg, Poland, Slovakia and Cyprus. The elderly proportion is smaller in these countries, but not as small as the child component of the population. The final values of the indicators based on this youngest component of the population (ageing index or average age) are not as low. Therefore, comparatively speaking, these states are younger than the others.

At the other end of the spectrum is the second cluster containing six former socialist states – two Baltic states (Latvia and Lithuania), Hungary, Croatia, Romania, and Bulgaria. In 2018, these countries were the oldest, especially under the prospective approach. But when we look at the chronological indicators, we see they are very close to the third group, for which the selected indicators sometimes have lower values. When using the prospective approach, we obtain a more distinct cluster that stands out more from the third group, which could be called the average group because it includes most EU countries (17 countries): all the Western European countries (except Ireland and Luxembourg), all the Northern and Southern European countries (except Cyprus), and some countries in Central Europe, and Estonia, which is the only Baltic state.

The EUROPOP2018 population projection shows ageing will continue and intensify, but also that it will exhibit marked spatial changes. It indicates that by mid-twenty-first century there will be three main groups of countries. The first cluster of member states is the youngest. Most of the countries are in Northern and Western Europe (see Fig. 2). Using the conventional approach, many are older countries. The second cluster is the opposite. The EUROSTAT forecast shows that in 2050 the member states in this cluster will be the oldest states in Europe, using both the chronological and prospective approaches. It contains the oldest populations – Italy, Greece, and Portugal, along with Bulgaria, Croatia, and Lithuania.

The third cluster contains countries with an average level of population ageing under both the prospective and chronological approaches. This cluster is spatially heterogeneous with no distinct geographical pattern. Table 2 presents the average values of the ageing indicators for the clusters identified.

Specifically, the chronological indicators for 2018 show that Ireland, Slovakia, and Cyprus are young countries, while Italy and Greece are old countries. In 2050, the expectation is that Sweden and the United Kingdom will be young, while Greece and Portugal will be old. The prospective indicators for 2018, show that Bulgaria, Latvia, and Lithuania are old countries, while Ireland and Cyprus are young. For 2050, only Sweden stands out under the prospective approach, and Lithuania and Greece have old populations.

As noted in the methodological section, the overall changes in the selected indicators of population ageing can be decomposed into two main effects: change in the elderly population (aged 65+) and change in the population in the denominator (working-age, children, total population).

Indicators	**Cluster 2018**			**Cluster 2050**		
	I	II	III	I	II	III
Prop. 65+	15.3	19.7	19.9	24.2	32.9	29.0
OADR	24.6	32.5	33.6	43.7	65.6	55.7
AI	92.9	131.9	129.2	161.3	264.3	204.8
AA	39.8	42.9	42.6	44.7	49.3	46.9
Prop. RLE-15	9.6	16.1	12.2	12.9	20.0	16.9
POADR	14.2	25.1	18.3	19.4	31.7	26.3
PAI	58.7	107.9	79.5	85.7	160.3	119.0
PARYL	43.0	36.9	41.6	43.8	38.1	40.4
Number of countries	**5**	**6**	**17**	**9**	**6**	**13**

Tab. 2: Average values of indicators for the clusters
Sources: EUROSTAT, 2019; authors' calculations

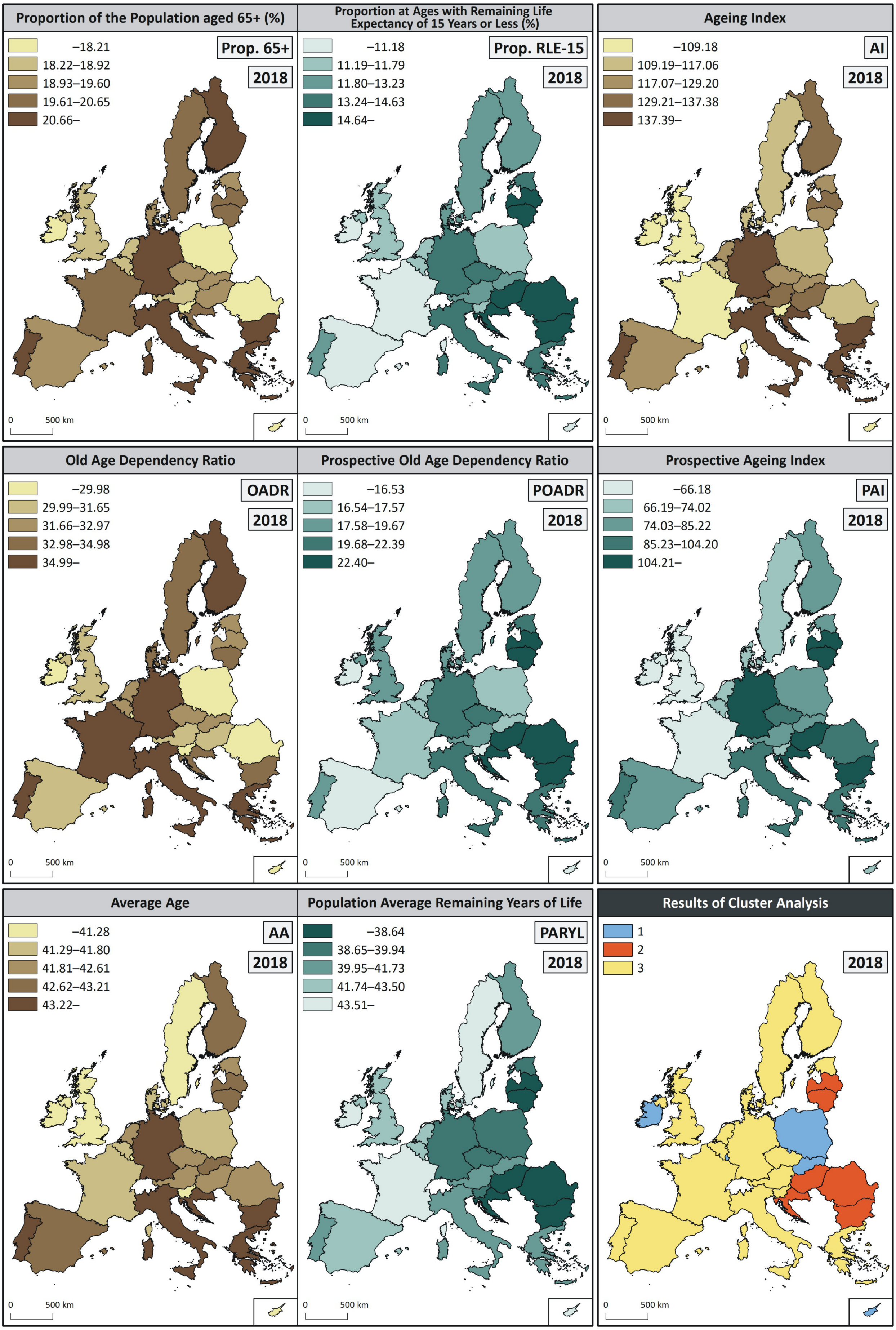

Fig. 1: Clusters of European countries by level of selected chronological and prospective indicators of ageing, 2018
Sources: EUROSTAT, 2019; authors' calculations

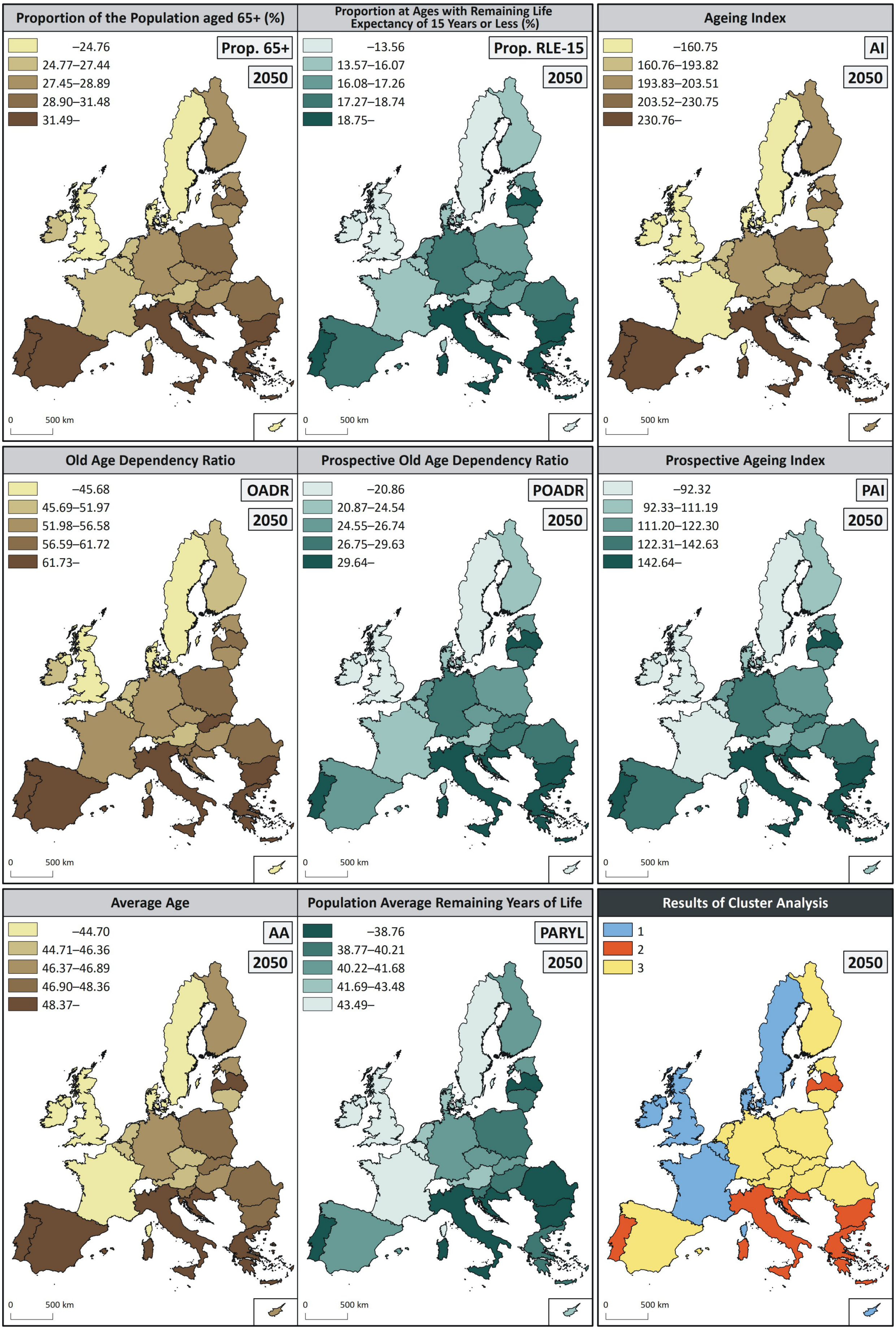

Fig. 2: Clusters of European countries by level of selected chronological and prospective indicators of ageing, 2050
Sources: EUROSTAT, 2019; authors' calculations

Figures 3–5 show that, according to the EUROPOP2018 population forecast, by the mid-twenty-first century, the share of the elderly population will have grown, and the elderly component will outweigh the child component, and that in all EU countries the elderly population will place an increasing burden on the working-age population. These changes will occur most rapidly in Southern Europe (except Malta and Cyprus), and in several former Eastern Bloc countries (Slovakia, Poland and Slovenia, in particular). The opposite will be true in Northern Europe and in some Western European countries.

As the number of elderly people in the population is expected to increase in all member states, the effect of change in the elderly component will be to raise the values of the ageing control indicators. The strength of the effect will differ geographically. It will be stronger in the countries currently identified as the youngest (Slovakia, Poland, Ireland, Luxemburg, Cyprus), and in some states that our analysis identifies as the oldest (Spain, Portugal). The effect of the change in the elderly section of the population will be weakest in the Balkans and Baltic states and the north of Europe, and in Germany and Hungary.

As the results of the internal decomposition of the elderly component in each EU member state shows, cohort turnover is the principal factor along with improved mortality, and thus mortality effect. The migration effect will be minimal for this age group (see Appendix 3).

Only eight EU member states can expect the number of working-age individuals to rise by 2050. Most are located in the north west, but Malta and Cyprus in the south are included as well (see Fig. 3). This will mitigate the effect of a growing elderly component; it is also why these countries have the lowest forecasted rise in OADR (except Ireland). The opposite will occur in the EU member states in the Balkans, the Baltic states and certain Southern European and Eastern European countries. The decomposition of demographic factors shows that cohort turnover (the strongest effect will be in southern and south eastern EU countries) accounts for these changes and, in the Balkan and Baltic states, this trend is exacerbated by (e-)migration. All EU member states are expected to see a continued improvement in mortality and convergence, and changes in mortality will compensate for the reduction in the working-age component. Its effect will be strongest in the former socialist member states, where mortality tends to be worse than in other EU countries (Fig. 3 and Appendix 3).

Although EUROPOP2018 forecasts a slight rise in fertility (except in France), most member states have low fertility over the long-term[3], and when combined with the fall in the reproductive population[4], this will contribute to an overall decrease in the number of children in the EU. EUROPOP2018 forecasts that by mid-twenty-first century, the opposite phenomenon could occur in eight member states. As a result, the effect of change in the child component could mitigate the growth in the ageing index in these countries (see Fig. 4 and Appendix 4). The opposite situation will probably occur due to the ongoing low fertility and the cohort shift in the reproductive population (see footnote 4), particularly in members states in Southern Europe and the Balkans and Lithuania.

Changes in the child component and expectations of positive net migration in member states will counteract the rise in ageing index values (Appendix 4). This also applies to the improved mortality among children. The cohort-turnover effect will be the main factor in the majority of members states (except in the afore-mentioned eight countries) contributing to the increase in ageing index values.

In addition to the anticipated rise in the number of elderly people in all EU28 member states, as analysed above, the trend in total population will be reflected in the changing proportion of elderly people (see Fig. 5 and Appendix 5). Except for the Czech Republic, the population is expected to decrease in all former socialist EU members states between 2018 and 2050. The old member states in Southern Europe (except Malta and Cyprus) and Germany and Finland are expected to see a negative population trend. Thus, the overall population trend will balance out the growing proportion of the elderly component in the population. The opposite will occur in the remaining member states, where the effect of the expected growth of the population will mitigate growth in the share of elderly people in the population.

5. Discussion and conclusions

Having identified differences in the mean longevity of the elderly population in the EU28 member states and the continuously lengthening life-span, we can agree with Sanderson and Scherbov (2008) that using chronological age to set the value of the old-age threshold no longer accurately captures the main characteristics of population ageing. Over time and space, the old age threshold cannot simply be seen in fixed terms as the number of years lived. The number of years of remaining life is a much more important indicator in regard to ageing. The results of our analysis confirm this contention. When prospective indicators are used, the spatial distribution and level of population ageing differ. The Principal Components Analysis showed that prospective indicators better explain current variation in ageing across the EU28. No less important are questions relating to other practical issues affecting or associated with population ageing. For example, it is especially important to account for longer life-spans and the threshold of old age when setting pension age. As the OECD (2017) analysis shows, OECD countries tend to raise the pension age by a certain number of years to a new fixed threshold (fixed to 60–67 years, most commonly at 64 or 65 years). A more progressive approach to pension age reform, however, has been adopted in Denmark, Finland, Italy, the Netherlands, and Portugal (and until recently Slovakia), where the increase in pension age has been pegged to mean life expectancy (OECD, 2017).

[3] In all member states, total fertility is less than 2 children per woman and, according to EUROPOP2018, will remain so. In 11 countries it is less than 1.5 children per woman, and forecasted absolute fertility growth will be around 0.02 to 0.27 in 2050 (except in France, where it will drop slightly).

[4] According to EUROPOP2018, across the EU28 the number of women of reproductive age ranges from over 112 million to slightly over 100 million. Growth in the reproductive base is expected in only eight countries (ranked according to relative growth between 2018 and 2050: Luxemburg, Sweden, Malta, United Kingdom, Ireland, Belgium, Denmark and Cyprus). By contrast, in the southern member states, the Balkan and Baltic member states and in some former socialist countries in Central Europe, the 1970s boomer generations will be entering post-reproductive age and will be replaced by the smaller generations from the 1990s and the first two decades of the new millennium, which will contribute to a marked decrease (of 25–35%) in the reproductive base.

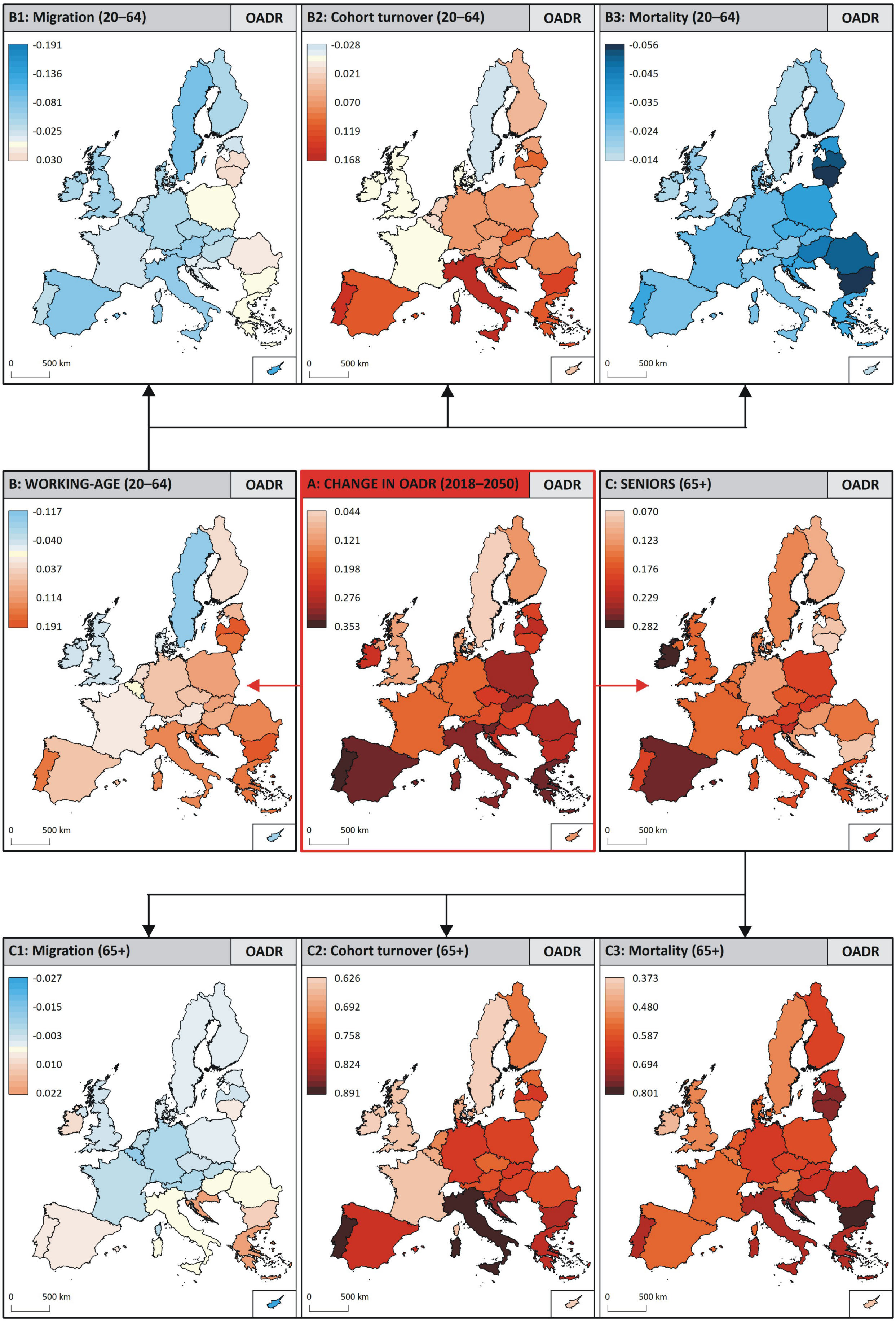

Fig. 3: Decomposition of the Old-Age Dependency Ratio (OADR) between 2018 and 2050
Sources: EUROSTAT, 2019; authors' calculations

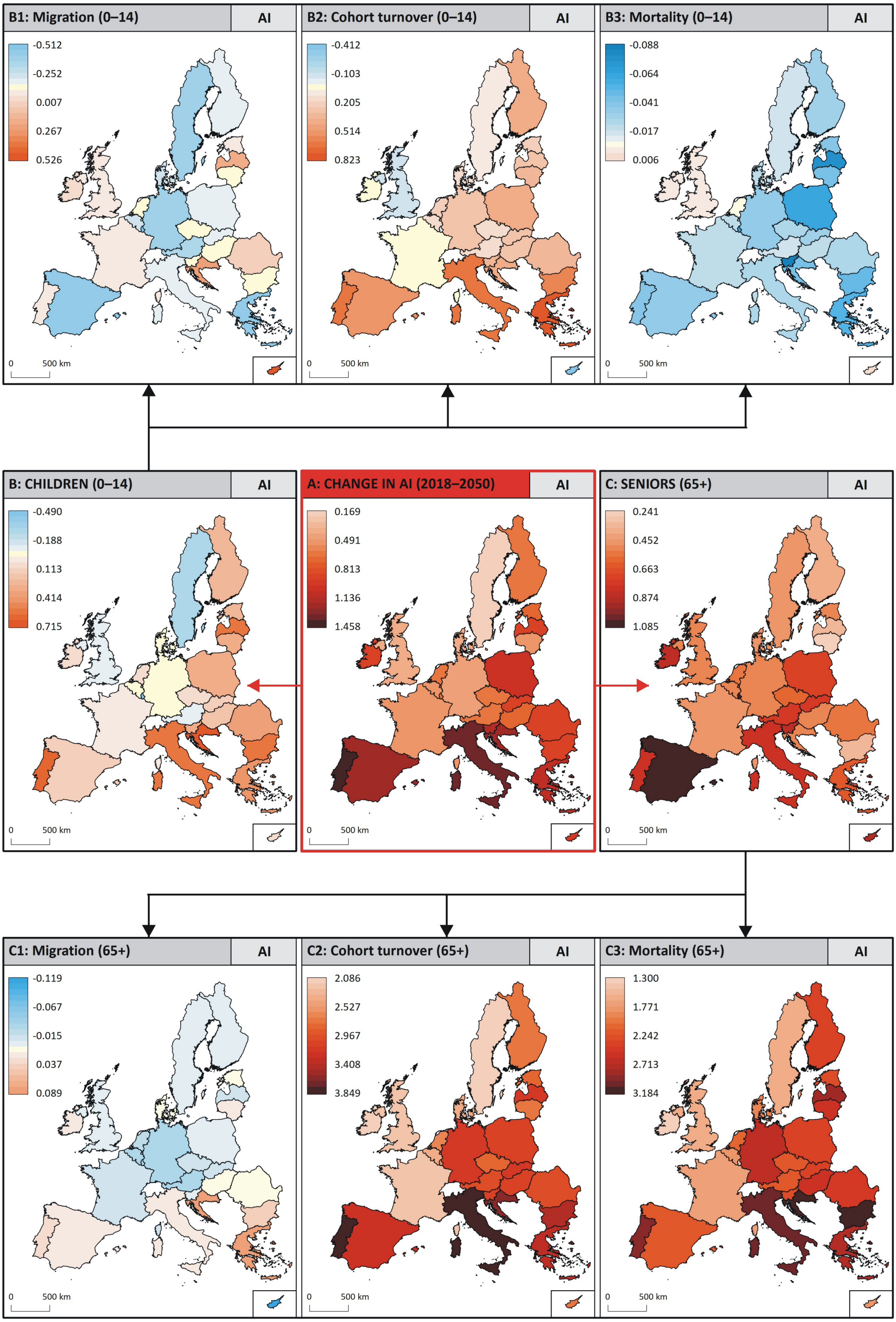

Fig. 4: Decomposition of the Ageing Index (AI) between 2018 and 2050
Sources: EUROSTAT, 2019; authors' calculations

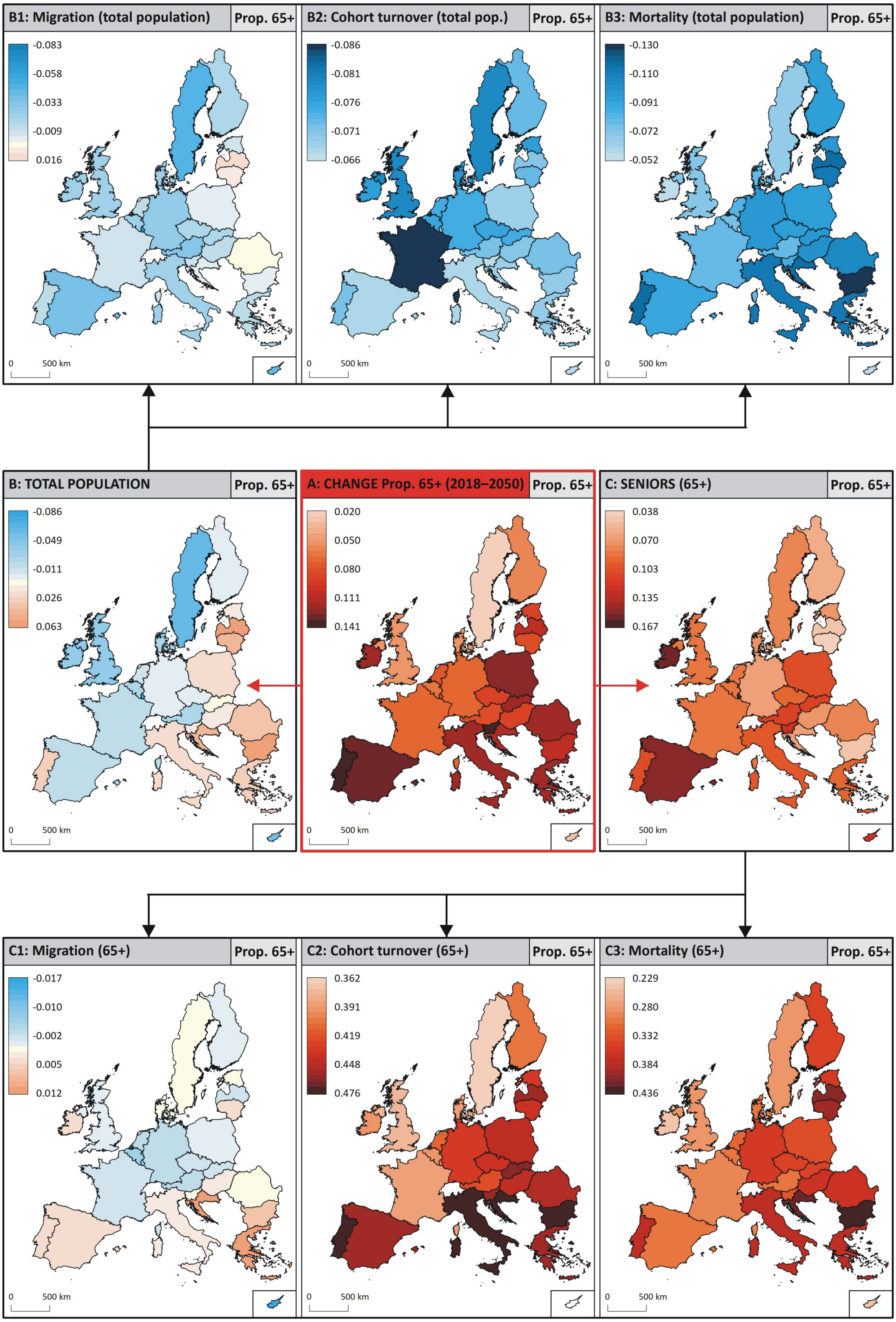

Fig. 5: Decomposition of the proportion of elderly (65+) between 2018 and 2050
Sources: EUROSTAT, 2019; authors' calculations

Our study confirms, as have other European and non-European studies (e.g. Basten et al., 2015; Lutz et al., 2008b; Sanderson and Scherbov, 2013; 2015a; 2016; Scherbov et al., 2016; Šprocha et al., 2018), that when the level of population ageing is measured using conventional chronological-age indicators, the resulting picture can differ from when a prospective approach is used. In fact, the more detailed analyses of the development trends in these studies indicate a more rapid rate of change and obtain contrasting values for the individual indicators. As a result, the more rapid the change in life expectancy, the slower the rate of change in the characteristics of population ageing. This could even lead to a situation where the rapid increase in mean life expectancy of the elderly population contributes to a slowing of population ageing or even its reversal, and thus to the youthing of the population (see for example: Sanderson and Scherbov, 2005, 2013, 2015). Our results confirm the results of several other studies (e.g. Sanderson and Scherbov, 2013; Spijker, 2015; Basten et al., 2015) that demonstrated that using the traditional retrospective approach based on chronological age, considerably limits the information obtained, and provides an incomplete and in many ways distorted picture of population ageing. By combining prospective age and chronological age, we obtain a richer analytical framework that provides more comprehensive insights into population ageing in both dimensions.

When both approaches are used, there are relatively large differences in population ageing levels among the EU member states (see Šprocha et al., 2018; Šídlo et al., 2019). Combining the conventional retrospective and the newer prospective indicators of ageing enables us to identify several groups of countries according to current and future levels of population ageing. When incorporating the prospective approach, the current picture of population ageing in EU member states differs in some ways from that presented in some studies (e.g. Długosz and Kurek, 2006; Káčerová et al., 2012; Káčerová and Ondačková, 2016). It indicates that ageing is taking place in some former socialist countries as well as in the southern and some northern Europe countries. This confirms existing knowledge (e.g. Šprocha et al., 2018; Šídlo et al., 2019) that these countries and regions have the highest mortality rates within the EU. Conversely, particularly in the north and south of Europe, the prospective indicators of ageing show a significantly lower level of population ageing.

With the projected continued lengthening of life-spans and an increasing convergence in mortality rates, not just between the old and new member states but also between the sexes, we may well see population ageing stabilising or converging. Similarly, Kashnitsky et al. (2017) have shown mortality has a stabilising effect on the convergence of population ageing. According to their research, mortality rates are slowly improving and there are relatively large differences in initiation levels in the former Eastern and Western bloc countries. This is related to a paradox that Kashnitsky et al. (2017) have pointed out. If we focus on implementing policy measures to improve mortality (especially in relation to the higher mortality rates in the former Eastern Bloc), which is presumably socially desirable, this will accelerate ageing, but that will not necessarily lead to convergence in population ageing. To some extent, this can also be seen by examining the coefficient of variation. The prospective indicators (which are far more dependent on changes in mortality in old age) show that by 2050 heterogamy will have fallen, while the chronological indicators show that the coefficient of variation rises in all cases. Despite this inconclusive finding, we can state that some major spatial differences are likely to remain.

A spatial analysis of the differences in population ageing based on a combination of chronological and prospective indicators shows that, for 2018 and 2050, three main groups of EU member states can be identified. The youngest of these contains countries such as Poland, Slovakia, Ireland, Luxembourg, and Cyprus. In the first two countries, this is mainly because of the significantly below average values of the chronological indicators of ageing, while the prospective values are also lower for the other three. The oldest countries are joined by the Balkan EU member states, Hungary and two Baltic states (Latvia and Lithuania) mainly on the basis of the prospective indicators. We should also point out, however, that the populations of these countries do not look any more favourable in terms of chronological age.

The forecasted trend in population ageing could mean that by the mid-twenty-first century a number of Northern and Western European countries may be some of the youngest in the EU28, while Southern European countries (Italy, Portugal, Greece) along with Croatia, Bulgaria and Lithuania, will be the oldest according to both the chronological and prospective views.

The internal decomposition of the population component changes on population ageing shows that the elderly population is growing in all EU member states. This is likely to increase, especially in populations now seen as the youngest in the EU. The most important factors in all EU member states will be improved mortality rates and cohort turnover. According to the results of the EUROPOP2018 forecast, most member states will see a decline in the working-age population. This will mainly be driven by the cohort-turnover effect (for similar results: see Kashnitsky et al., 2019) and, to a lesser extent, by the emigration effect (particularly in the Balkan EU member states and the Baltic states). Similarly, in most EU member states, cohort turnover will be a major factor in the projected decline of the child component.

The populations of the EU28 member states have aged considerably, especially in recent decades, and undoubtedly rank among the oldest in the world. All projections show this trend will continue in the coming decades, and in many cases it will become more dynamic. Despite the complexity and national overlaps, the analytical perception of age and ageing remains largely unchanged. At a time when the characteristics of the elderly population, however, are changing so dramatically, the prevailing conventional approach based on chronological age cannot satisfactorily answer all our questions.

In conclusion, developing new approaches which focus not only on the number of years lived but also on the number of years of remaining life, will deepen our knowledge of population ageing. It is becoming a major factor in fully understanding and creating relevant, sustainable and meaningful public policy measures in response to the challenges this twenty-first century demographic phenomenon presents for the EU28.

Nonetheless, it is essential that we draw attention to the limitations of prospective indicators. As a number of studies (e.g. Sanderson and Scherbov, 2005, 2013, 2015; Basten et al., 2015; Spijker, 2015) have noted, the most important problem is that the old-age threshold is arbitrarily set using the threshold of remaining years of life. This is considered too broad, and those captured by the threshold still show relatively large differences in some ageing-related characteristics. This applies to both international comparisons and to comparisons of two periods many years apart. In international comparisons, in particular, the use of constant prospective age with a remaining years of life threshold, may not take sufficient account of the differences in population ageing between countries that have markedly different working-age and post-working-age mortality levels. As Balachadran et al. (2017) have shown, in populations with high child and working-age mortality, it is much harder to reach an average life expectancy of 15 years than in countries with more favourable mortality rates. It is therefore important to include a prospective old-age threshold in wide-ranging international comparisons. For example Balachadran et al. (2017) suggest the original prospective old-age threshold should be adapted by taking into consideration the differentials of reaching an RLE of 15 years, due to variations in adult survival between countries and over time (Balachadran et al., 2017). Moreover, the general nature some of these simpler prospective indicators has been criticised on the grounds that some population components (e.g. working-age population) do not reflect current real conditions. By combining demographic, economic, health, social and other data we can obtain multidimensional indicators of ageing that reflect reality as closely as possible (see Spijker, 2015). The disadvantage is the large amount of input data required, not just to assess the current situation but future trends as well, and that factor can make them relatively impossible to use, as was our case. Nonetheless, using a prospective approach to analyse ageing can broaden our understanding of current and future trends in population ageing, which are an important phenomenon in most countries.

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References

ATKINS, M., TONTS, M. (2015): Exploring Cities through a Population Ageing Matrix: a spatial and temporal analysis of older adult population trends in Perth, Australia. Australian Geographer, 47(1): 65–87. Doi: 10.1080/00049182.2015.1110087.

BALACHANDRAN, A., DE BEER, J., JAMES, K. S., VAN WISSEN, L., JANSSEN, F. (2019): Comparison of Population Aging in Europe and Asia Using a Time-Consistent and Comparative Aging Measure. Journal of Aging and Health. Doi: 10.1177/0898264318824180.

BASTEN, S., SCHERBOV, S., SANDERSON, W. C. (2015): Remeasuring Ageing in Southeast Asia. Asian Population Studies, 11(2): 191–210. Doi: 10.1080/17441730.2015.1052201.

BIVAND, R. S., WILK, J., KOSSOWSKI, T. (2017): Spatial association of population pyramids across Europe: The application of symbolic data, cluster analysis and joint-count tests. Spatial Statistics, 21, Part B: 339–361. Doi: 10.1016/j.spasta.2017.03.003.

BLOOM, D. E., CANNING, D., GRAHAM, B. (2003): Longevity and life-cycle savings. Scandinavian Journal of Economics. 105(3): 319–338. Doi: 10.1111/1467-9442.t01-1-00001.

BLOOM, D. E., CANNING, D., FINK, G. (2010): Implications of population ageing for economic growth. Oxford Review of Economic Policy, 26(4): 583–612. Doi: 10.1093/oxrep/grq038.

BÖRSCH-SUPAN, A. (2003): Labor market effects of population aging. Labour, 17(1): 5–44. Doi: 10.1111/1467-9914.17.specialissue.2.

COALE, A. J. (1973): The Demographic Transition Reconsidered. In: International Population Conference, Liége, 1973(1): 53–72. Liége: International Union for the Scientific Study of Population.

COALE, A. J., WATKINS, S. C. [eds.] (1986): The Decline of Fertility in Europe. Princeton, New Jersey: Princeton University Press.

COOK, I., HALSALL, J. (2012): Aging in Comparative Perspective – Process and Policies. London, Springer.

CUARESMA, J. C., LÁBAJ, M., PRUŽINSKÝ, P. (2014): Prospective ageing and economic growth in Europe. The Journal of the Economics of Ageing, 3: 50–57. Doi: 10.1016/j.jeoa.2014.05.003.

DAS GUPTA, P. (1991): Decomposition of the difference between two rates and its consistency when more than two populations are involved. Mathematical Population Studies, 3(2): 105–125. Doi: 10.1080/08898489109525329.

DAVIES, A., JAMES, A. (2011): Geographies of Ageing: Social Processes and the Spatial Unevenness of Population Ageing. Farnham, Ashgate.

DŁUGOSZ, Z., KUREK, S. (2006): Demographic ageing in European Union countries. In: Komornicki, T., Czapiewski, K. Ł. [eds.]: Europe XXI – Regional Periphery in Central and Eastern Europe (pp. 185–197). Warsaw, IGiPZ PAN.

EGGLESTON, K. N., FUCHS, V. R. (2012): The New Demographic Transition: Most Gain in Life Expectancy Now Realized in Late Life. Journal of Economic Perspectives, 26(3): 137–156.

EUROSTAT (2019): Population projections at national level [online]. Eurostat [cit. 18.09.2019]. Available at: http://ec.europa.eu/eurostat/data/database

FRIES, J. F. (1980): Aging, Natural Health, and the Compression of Morbidity. The New England Journal of Medicine, 303(3): 130–135.

FRIES, J. F., BRUCE, B., CHAKRAVARTY, E. (2011): Compression of morbidity 1980–2011: a focused review of paradigms and progress. Journal of Aging Research 2011. Article ID 261702, 10 p. Doi: 10-4061/2011/261702.

GAVRILOV, L. A., HEUVELINE, P. (2003): Aging of Population. In: Demeny, P., McNicoll, G. [eds.]: The Encyclopedia of Population (pp. 32–37). New York, Macmillan Reference USA.

GRUENBERG, E. M. (1977): The failures of success. The Milbank Quarterly, 55(3): 3–24.

HERSCH, L. (1944): De la démographie actuelle à la démographie potentielle. Melange des Études Economiques Offertes à William Rappard. Genčve, Librairie de l´Université.

KÁČEROVÁ, M., ONDAČKOVÁ, J., MLÁDEK, J. (2012): A comparison of population ageing in the Czech Republic and the Slovak Republic based on generation support and exchange. Moravian Geographical Reports, 20(4): 26–38.

KÁČEROVÁ, M., ONDAČKOVÁ, J. (2015): The Process of Population Ageing in Countries of Visegrad Group (V4). Erdkunde, 69(1): 49–68.

KASHNITSKY, I., DE BEER, J., VAN WISSEN, L. (2017): Decomposition of regional convergence in population aging across Europe. Genus, 73(1): 2. Doi: 10.1186/s41118-017-0018-2.

KASHNITSKY, I., DE BEER, J., VAN WISSEN, L. (2019): Economic convergence in ageing Europe. Tijdschrift voor Economische en Sociale Geografie, 0(0): 1–17, Doi: 10.1111/tesg.12357.

KITAGAWA, E. M. (1955): Components of a Difference Between Two Rates. Journal of the American Statistical Association, 50(272): 1168–1194. Doi: 10/ggfgpj.

KLAPKOVÁ, M., ŠÍDLO, L., ŠPROCHA, B. (2016): Koncept prospektivního věku a jeho aplikace na vybrané ukazatele demografického stárnutí. Demografie, 58(2): 129–141.

KOHLER, H.-P., BILLARI, F. C., ORTEGA, J. A. (2002): The emergence of lowest-low fertility in Europe during the 1990s. Population and Development Review, 28(4): 641–680.

KRAMER, M. (1980): The rising pandemic of mental disorders and associated chronic diseases and disabilities. Acta Psychiatrica Scandinavica, 62 (Suppl. 285): 282–297. Doi: 10.1111/j.1600-0447.1980.tb07714.x.

LESTHAEGHE, R. (2010): The unfolding story of the second demographic transition. Population and Development Review, 36(2): 211–251. Doi: 10.1111/j.1728-4457.2010.00328x.

LESTHAEGHE, R., WILLEMS, P. (1999): Is low fertility a temporary phenomenon phenomenon in the European Union? Population and Development Review, 25(2): 211–228. Doi: 10.1111/j.1728-4457.1999.00211.x

LUTZ, W. (2009): The Demography of Future Global Population Aging: Indicators, Uncertainty, and Educational Composition. Population and Development Review, 35(2): 357–365. Doi: 10.1111/j.1728-4457.2009.00282.x.

LUTZ, W., SANDERSON, W. C., SCHERBOV, S. (2008a): Global and Regional Population Ageing: How Certain Are We of its Dimensions? Population Ageing, 1(1): 75–97. Doi: 10.1007/s12062-009-9005-5.

LUTZ, W., SANDERSON, W. C., SCHERBOV, S. (2008b): The coming acceleration of global population ageing. Nature, 451(7179): 716–719. Doi: 10.1038/nature06516.

LUTZ, W., SKIRBEKK, V. (2005): Policies Addressing the Tempo Effect in Low-Fertility Countries. Population and Development Review, 31(4): 699–720. Doi: 10.1111/j.1728-4457.2005.00094.x.

MANTON, K. G. (1982): Changing Concepts of Morbidity and Mortality in the Elderly Population. The Milbank Memorial Fund Quarterly. Health and Society, 60(2): 183–244. Doi: 10.2307/3349767.

MAREŠ, P., RABUŠIC, L., SOUKUP, P. (2015): Analýza sociálněvědních data [nejen] v SPSS. Brno, MUNI.

MESLÉ, F., VALLIN, J. (2000): Transition sanitaire: Tendances at perspectives. Médecine/science, 16(11): 1161–1171.

MESLÉ, F., VALLIN, J. (2002): Mortality in Europe: The Divergence Between East and West. Population, 57(1): 157–197.

MILLER, T. (2001): Increasing longevity and Medicare expenditures. Demography 38(2): 215–226. Doi: 10.1353/dem.2001.0018.

OLSHASKY, S. J., AULT,A. B. (1986): The fourth stage of the epidemiologic transition: the age of delayed degenerative diseases. Milbank Quarterly, 64(33): 355–391.

OLSHANSKY, S. J., CARNES, R., ROGERS, G. et al. (1997): Infectious Diseases: New and Ancient Threats to World Health. Population Bulletin, 52(2): 1–52.

OMRAN, A. R. (1971): The epidemiological transition: a theory of epidemiology of population change. Milbank Memorial Fund Quarterly, 49(4): 509–538. Doi: 10.1111/j.1468-0009.2005.00398.x.

REYNAUD, C., MICCOLI, S., LAGONA, F. (2018): Population Aging in Italy: An Empirical Analysis of Change in the Ageing Index Across Space and Time. Spatial Demography, 6(3): 235–251. Doi: 10.1007/s40980-018-0043-6.

RIFFE, T., CHUNG, P. H., SPIJKER, J., MACINNES, J. (2016): Time-to-death patterns in markers of age and dependency. Vienna Yearbook of Population Reasearch 2016, 14: 229–254. Doi: 10.1553/populationyearbook2016s229.

RIFFE, T., SCHÖLEY, J., VILLAVICENCIO, F. (2017): A unified framework of demographic time. Genus, 73(7): Doi: 10.1186/s41118-017-0024-4.

ROBINE, J.-M. (2003): Epidemiological transition. In: Demeny, P., McNicoll, G., Kaplan, H. [eds.]: Encyclopedia of Population. Volume 1: 307–310. Macmillan Reference.

RYDER, N. (1975): Notes on stationary population. Population Index, 41(1): 3–28.

SANDERSON, W. C., SCHERBOV, V. (2005): Average Remaining Lifetimes Can Increase as Human Populations Age. Nature, 435(7043): 811–813. Doi: 10.1038/nature03593.

SANDERSON, W. C., SCHERBOV, V. (2007): A New Perspective on Population Aging. Demographic Research. 16: 27–58. Doi: 10.4054/DemRes.2007.16.2.

SANDERSON, W. C., SCHERBOV, V. (2008): Rethinking Age and Aging. Population Bulletin, 63(4): 3–16.

SANDERSON, W. C., SCHERBOV, V. (2010): Remeasuring Aging. Science, 329(5997): 1287–1288. Doi: 10.1126/science.1193647.

SANDERSON, W. C., SCHERBOV, V. (2013): The Characteristics Approach to the Measurement of Population Aging. Population and Development Review, 39(4): 673–685. Doi: 10.1111/j.1728-4457.2013.00633.x.

SANDERSON, W. C., SCHERBOV, A. (2015a): Faster Increases in Human Life Expectancy Could Lead to Slower Population Aging. PLOS ONE 10(4), e0121922. Doi: 10.1371/journal.pone.0121922.

SANDERSON, W. C., SCHERBOV, A. (2015b): Are We Overly Dependent on Conventional Dependency Ratio? Population and Development Review, 41(4): 687–708. Doi: 10.1111/j.1728-4457.2015.00091.x.

SANDERSON, W. C., SCHERBOV, A. (2016): A unifying framework for the study of population aging. Vienna Yearbook of Population Research 2016(14): 7–39.

SHIODE, N., MORITA, M., SHIODE, S., OKUNUKI, K. (2014): Urban and rural geographies of aging: a local spatial correlation analysis of aging population measures. Urban Geography, 36(4): 608–628. Doi: 10.1080/02723638.2014.905256.

SOBOTKA, T. (2008): The rising importance of migrants for childbearing in Europe. In: T. Frejka et al. [eds.] Childbearing Trends and Policies in Europe. Demographic Research, 19: 225–248. Doi: 10.4054/DemRes.2008.19.9.

SPIJKER, J. (2015): Alternative Indicators of Population Ageing: An Inventory. Working Papers, 4/2015, Vienna Institute of Demography.

SPIJKER, J., MACINNES, J. (2013): Population ageing: the time bomb that isn't? British Medical Journal, 347: f6598.

STANKOVIČOVÁ, I., VOJTKOVÁ, M. (2007): Viacrozmerné štatistické metódy s aplikáciami. Bratislava, Iura Edition.

STEARNS, S. C., NORTON, E. C. (2004): Time to include time to death? The future of health care expenditure predictions. Health Economics, 13(4): 315–327. Doi: 10.1002/hec.831.

ŠÍDLO, L., ŠPROCHA, B., KLAPKOVÁ, M. (2019): Regional differences in population ageing in Europe viewed through prospective indicators. Erdkunde, 73(3): 225–240, Doi: 10.3112/erdkunde.2019.03.06.

ŠPROCHA, B., ĎURČEK, P. (2018): Prospektívny prístup pri regionálnej analýze procesu populačného starnutia na Slovensku. Geographia Cassoviensis, XII (2): 212–223.

ŠPROCHA, B., ŠÍDLO, L., KLAPKOVÁ, M., ĎURČEK, P. (2018): Nové prístupy k hodnoteniu procesu populačného starnutia a ich aplikácia v prípade Slovenska a Európy. Geografický časopis, 70(4): 351–371. Doi: 10.31577/geogrcas.2018.70.4.19.

UN [United Nations] (2001): World Population Ageing. Department of Economic and Social Affairs, Population Division. New York, United Nations.

UN [United Nations] (2017): World Population Ageing. Department of Economic and Social Affairs, Population Division. New York, United Nations.

VALLIN, J., MESLÉ, J. (2001): Trends in mortality in Europe since 1950: age-, sex- and cause-specific mortality. In: Vallin, J., Meslé, F., Valkonen, T. [eds.]: Trends in mortality and differential mortality (pp. 31–184). Population studies No. 36, Strasbourg, Council of Europe Publishing.

VALLIN, J., MESLÉ, J. (2004): Convergences and divergences in mortality. A new approach to health transition. Demographic Research, Special Collection 2, Article 2: 11–44.

VAN DE KAA, D. J. (1994): The Second Demographic Transition Revisited: Theories and Expectations. In: G. C. N. Beets et al. (eds.).Population and Family in the Low Countries 1993: 81–126. Lisse, Zwets and Zeitlinger.

VAN DE KAA, D. J. (1997): Options and sequences: Europe's demographic patterns. Journal of the Australian Population Association, 14(1): 1–30.

YUSUF, S., S. REDDY, S. ÔUNPUU, ANAND, S. (2001): Global Burden of Cardiovascular Diseases: part I: General Considerations, the Epidemiologic Transition, Risk Factors, and Impact of Urbanization. Circulation, 104(22): 2746–2753.

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		Prop. 65+	OADR	AI	AA	Prop. RLE-15	POADR	PAI	PARYL
Prop. 65+	Pearson CC	1.000	.977**	.896**	.902**	.651**	.612**	.692**	−.475*
	Sig. (2-tailed)		*0.000*	*0.000*	*0.000*	*0.000*	*0.001*	*0.000*	*0.011*
OADR	Pearson CC	.992**	1.000	.791**	.803**	.580**	.558**	.578**	– 0.362
	Sig. (2-tailed)	*0.000*		*0.000*	*0.000*	*0.001*	*0.002*	*0.001*	*0.058*
AI	Pearson CC	.918**	.869**	1.000	.968**	.646**	.577**	.799**	−.567**
	Sig. (2-tailed)	*0.000*	*0.000*		*0.000*	*0.000*	*0.001*	*0.000*	*0.002*
AA	Pearson CC	.921**	.867**	.984**	1.000	.699**	.633**	.818**	−.630**
	Sig. (2-tailed)	*0.000*	*0.000*	*0.000*		*0.000*	*0.000*	*0.000*	*0.000*
Prop. RLE-15	Pearson CC	.926**	.926**	.797**	.825**	1.000	.994**	.954**	−.927**
	Sig. (2-tailed)	*0.000*	*0.000*	*0.000*	*0.000*		*0.000*	*0.000*	*0.000*
POADR	Pearson CC	.895**	.907**	.735**	.766**	.995**	1.000	.921**	−.908**
	Sig. (2-tailed)	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*		*0.000*	*0.000*
PAI	Pearson CC	.937**	.901**	.957**	.960**	.923**	.882**	1.000	−.911**
	Sig. (2-tailed)	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*		*0.000*
PARYL	Pearson CC	−.825**	−.780**	−.807**	−.862**	−.863**	−.831**	−.880**	1.000
	Sig. (2-tailed)	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	

Appendix 1: Correlation matrix of input variables, EU-28, 2018 and 2050 (shaded grey)
*Notes: ** Correlation is significant at 0.01 (2-tailed); * Correlation is significant at 0.05 (2-tailed)*
Sources: EUROSTAT, 2019; authors' calculations

Country	Prop.65+	OADR	AI	AA	Prop. RLE-15	POADR	PAI	PARYL
2018								
Belgium	18.7	31.8	110.2	41.6	11.4	17.2	67.0	42.8
Bulgaria	21.0	34.9	147.5	43.7	18.6	29.6	130.5	35.4
Czech Republic	19.2	31.7	122.1	42.2	13.8	20.9	87.7	39.6
Denmark	19.3	33.2	116.2	41.5	11.9	18.1	71.4	42.0
Germany	21.4	35.5	158.5	44.4	14.4	21.4	106.6	39.7
Estonia	19.6	32.9	120.1	42.2	13.5	20.5	82.5	39.9
Ireland	13.8	23.5	66.4	37.7	8.2	12.8	39.5	46.4
Greece	21.8	37.1	151.3	44.1	13.9	20.8	96.4	40.3
Spain	19.2	31.5	128.4	43.2	11.1	16.1	74.5	42.4
France	19.7	35.1	108.5	41.5	10.8	16.6	59.5	43.8
Croatia	20.1	33.4	138.9	43.2	15.5	23.8	106.8	38.1
Italy	22.6	38.0	168.9	45.2	13.9	20.4	103.9	40.6
Cyprus	15.9	25.5	97.8	39.5	8.8	12.7	54.3	45.1
Latvia	20.1	33.7	127.4	42.9	16.5	26.1	104.4	36.5
Lithuania	19.6	32.6	130.9	42.9	15.8	24.6	105.0	37.2
Luxembourg	14.3	22.4	88.8	39.9	8.6	12.3	53.2	44.3
Hungary	18.9	30.8	130.2	42.5	15.4	23.7	106.0	37.1
Malta	18.8	30.1	135.2	41.8	9.1	12.7	65.7	43.7
Netherlands	18.9	32.0	117.2	41.8	11.3	17.0	70.5	42.4
Austria	18.7	30.2	129.4	42.6	12.2	17.9	84.6	41.7
Poland	17.1	27.3	112.3	41.4	11.4	16.6	74.7	39.5
Portugal	21.5	36.3	155.4	44.2	13.2	19.5	95.2	40.0
Romania	18.2	29.9	116.3	41.9	14.8	23.0	94.6	37.3
Slovenia	19.4	31.8	129.2	43.2	12.0	17.5	79.6	40.6
Slovakia	15.5	24.3	99.4	40.6	11.2	16.5	72.0	39.9
Finland	21.4	37.5	132.4	42.7	12.2	18.3	75.3	41.6
Sweden	19.8	34.7	111.8	41.2	12.0	18.5	67.5	43.7
UK	18.2	31.3	101.9	40.7	11.5	17.6	63.9	43.2
Coefficient of variation	**11.2**	**12.9**	**18.0**	**3.8**	**19.8**	**22.1**	**25.4**	**6.8**
2050								
Belgium	25.2	46.9	161.7	44.7	14.2	21.9	90.9	43.5
Bulgaria	31.6	62.4	236.7	48.2	20.1	32.3	150.5	37.0
Czech Republic	28.5	55.0	189.0	46.0	16.8	26.4	111.3	40.7
Denmark	24.4	44.9	157.5	44.5	14.9	23.3	96.1	43.4
Germany	28.3	53.5	202.3	46.8	17.6	27.7	126.0	41.2
Estonia	28.5	54.8	194.2	46.7	16.7	26.1	113.6	40.4
Ireland	25.6	48.2	157.5	44.4	12.8	19.4	78.8	44.1
Greece	33.8	69.3	261.8	49.0	19.7	31.3	152.5	39.7
Spain	32.4	64.4	253.3	48.6	17.5	26.7	136.2	40.8
France	26.6	52.2	160.1	44.7	14.6	23.1	87.5	44.5
Croatia	31.6	60.7	261.9	49.0	19.1	29.6	158.6	37.4
Italy	34.8	69.9	303.2	50.6	20.7	32.3	180.1	38.6
Cyprus	23.1	37.8	197.2	46.4	11.5	15.9	98.5	41.7
Latvia	28.7	56.6	182.7	46.2	18.1	29.6	115.5	39.4

Appendix 2: Ageing indicators for 2018 and 2050
Sources: EUROSTAT, 2019; authors' calculations

Appendix 2: continuation

Country	Prop.65+	OADR	AI	AA	Prop. RLE-15	POADR	PAI	PARYL
...								
2050								
Lithuania	30.7	59.9	221.0	48.4	20.4	33.1	146.9	37.6
Luxembourg	22.5	39.2	152.4	44.2	11.2	16.2	75.6	44.4
Hungary	28.2	53.4	199.7	46.5	17.2	27.0	122.0	39.2
Malta	24.4	41.8	192.3	46.6	12.0	17.0	94.5	42.3
Netherlands	26.6	49.6	182.5	45.8	16.2	25.4	111.6	42.4
Austria	27.2	50.4	195.1	46.4	15.5	23.5	110.8	41.9
Poland	29.7	57.3	215.4	47.4	16.2	24.8	117.5	39.5
Portugal	35.1	71.6	301.2	50.5	20.2	31.6	173.4	38.2
Romania	29.9	58.7	208.3	47.2	17.9	28.4	124.4	38.6
Slovenia	31.3	62.6	221.8	47.8	17.5	27.3	123.7	40.3
Slovakia	29.7	56.7	218.7	47.4	16.8	25.7	123.7	38.9
Finland	27.5	51.1	199.0	46.8	15.2	23.0	110.2	41.7
Sweden	21.8	39.1	128.7	42.7	11.8	18.0	69.7	45.6
UK	23.7	43.4	144.3	43.7	13.1	20.2	80.1	44.3
Coefficient of variation	**12.9**	**17.3**	**21.5**	**4.2**	**17.5**	**19.9**	**24.7**	**5.9**

Country	Change in OADR	Change in OADR due to		Change in working-age population due to			Change in elderly due to		
		Working-age	Elderly	Migration 20–64	Cohort turnover	Mortality 20–64	Migration 65+	Cohort turnover	Mortality 65+
Austria	0.202	0.011	0.191	– 0.065	0.054	– 0.022	– 0.007	0.733	0.535
Belgium	0.151	– 0.004	0.155	– 0.043	0.015	– 0.023	– 0.010	0.701	0.535
Bulgaria	0.275	0.191	0.085	0.006	0.130	– 0.056	0.011	0.874	0.801
Croatia	0.273	0.152	0.121	– 0.005	0.122	– 0.035	0.021	0.849	0.749
Cyprus	0.123	– 0.077	0.199	– 0.124	0.033	– 0.014	– 0.027	0.626	0.400
Czech Rep.	0.233	0.068	0.166	– 0.038	0.075	– 0.031	– 0.002	0.782	0.614
Denmark	0.117	– 0.019	0.135	– 0.042	0.000	– 0.023	0.002	0.685	0.552
Estonia	0.219	0.081	0.138	– 0.020	0.064	– 0.037	0.002	0.777	0.641
Finland	0.136	0.030	0.106	– 0.038	0.043	– 0.024	0.000	0.734	0.628
France	0.171	0.011	0.160	– 0.015	0.000	– 0.027	– 0.003	0.725	0.562
Germany	0.180	0.058	0.122	– 0.043	0.074	– 0.027	– 0.007	0.770	0.642
Greece	0.322	0.153	0.169	0.007	0.115	– 0.031	0.022	0.859	0.712
Hungary	0.226	0.095	0.131	– 0.026	0.074	– 0.046	0.003	0.784	0.657
Ireland	0.247	– 0.035	0.282	– 0.046	– 0.007	– 0.018	0.008	0.702	0.428
Italy	0.318	0.134	0.184	– 0.059	0.168	– 0.025	0.004	0.878	0.698
Latvia	0.228	0.159	0.070	0.030	0.074	– 0.054	0.007	0.805	0.742
Lithuania	0.273	0.186	0.086	0.026	0.108	– 0.052	– 0.002	0.836	0.748
Luxembourg	0.168	– 0.105	0.273	– 0.141	0.018	– 0.018	– 0.006	0.652	0.373
Malta	0.117	– 0.117	0.234	– 0.191	0.058	– 0.017	0.016	0.678	0.460
Netherlands	0.176	0.025	0.151	– 0.020	0.025	– 0.021	– 0.004	0.726	0.571
Poland	0.300	0.112	0.188	– 0.002	0.078	– 0.036	0.000	0.790	0.602
Portugal	0.353	0.157	0.196	– 0.029	0.153	– 0.033	0.006	0.891	0.701
Romania	0.288	0.142	0.146	0.011	0.081	– 0.050	0.003	0.822	0.678
Slovakia	0.324	0.104	0.220	– 0.005	0.075	– 0.034	0.001	0.792	0.574
Slovenia	0.308	0.101	0.208	– 0.039	0.112	– 0.028	– 0.003	0.844	0.634
Spain	0.329	0.058	0.271	– 0.079	0.112	– 0.025	0.007	0.824	0.559
Sweden	0.044	– 0.096	0.140	– 0.086	– 0.028	– 0.018	0.001	0.642	0.503
UK	0.121	– 0.038	0.158	– 0.057	– 0.003	– 0.022	0.000	0.667	0.508

Appendix 3: Summary statistics for the decomposition of the Old-Age Dependency Ratio (OADR) between 2018 and 2050
Sources: EUROSTAT, 2019; authors' calculations

Country	Change in AI	Change in AI due to		Change in children due to			Change in elderly due to		
		Children	Elderly	Migration 0–14	Cohort turnover	Mortality 0–14	Migration 65+	Cohort turnover	Mortality 65+
Austria	0.657	– 0.122	0.780	– 0.340	0.201	– 0.017	– 0.027	2.986	2.180
Belgium	0.515	– 0.020	0.536	– 0.214	0.176	– 0.018	– 0.036	2.423	1.852
Bulgaria	0.892	0.556	0.335	– 0.111	0.620	– 0.047	0.045	3.469	3.179
Croatia	1.230	0.715	0.515	0.246	0.426	– 0.043	0.089	3.611	3.184
Cyprus	0.994	0.108	0.886	0.526	– 0.412	0.006	– 0.119	2.782	1.777
Czech Rep.	0.669	0.068	0.601	– 0.144	0.189	– 0.023	– 0.008	2.836	2.227
Denmark	0.413	– 0.061	0.475	– 0.250	0.170	– 0.018	0.006	2.401	1.933
Estonia	0.742	0.245	0.497	– 0.052	0.257	– 0.040	0.007	2.791	2.302
Finland	0.666	0.270	0.396	– 0.192	0.433	– 0.029	0.001	2.731	2.337
France	0.516	0.023	0.493	– 0.072	0.075	– 0.020	– 0.009	2.233	1.732
Germany	0.438	– 0.061	0.499	– 0.368	0.275	– 0.032	– 0.028	3.157	2.631
Greece	1.105	0.444	0.661	– 0.432	0.823	– 0.053	0.085	3.357	2.781
Hungary	0.694	0.177	0.518	– 0.114	0.269	– 0.022	0.013	3.103	2.599
Ireland	0.911	0.056	0.855	– 0.025	0.080	– 0.001	0.024	2.131	1.300
Italy	1.344	0.535	0.808	– 0.165	0.677	– 0.023	0.017	3.849	3.057
Latvia	0.553	0.313	0.241	– 0.110	0.381	– 0.041	0.023	2.780	2.563
Lithuania	0.901	0.571	0.330	0.177	0.316	– 0.077	– 0.008	3.195	2.857
Luxembourg	0.637	– 0.438	1.075	– 0.512	0.011	– 0.063	– 0.026	2.568	1.467
Malta	0.571	– 0.490	1.061	– 0.474	– 0.046	– 0.030	0.072	3.075	2.086
Netherlands	0.653	0.096	0.556	– 0.143	0.235	– 0.005	– 0.016	2.668	2.096
Poland	1.031	0.294	0.736	– 0.173	0.405	– 0.063	0.000	3.092	2.356
Portugal	1.458	0.628	0.830	– 0.051	0.639	– 0.040	0.027	3.776	2.973
Romania	0.920	0.380	0.540	0.019	0.334	– 0.026	0.011	3.033	2.504
Slovakia	1.192	0.321	0.872	– 0.136	0.369	– 0.088	0.005	3.139	2.272
Slovenia	0.927	0.144	0.783	– 0.160	0.275	– 0.029	– 0.010	3.183	2.390
Spain	1.249	0.164	1.085	– 0.437	0.569	– 0.032	0.026	3.297	2.239
Sweden	0.169	– 0.286	0.455	– 0.394	0.095	– 0.013	0.002	2.086	1.634
UK	0.424	– 0.097	0.521	– 0.050	– 0.046	0.001	– 0.001	2.192	1.670

Appendix 4: Summary statistics for the decomposition of the Ageing Index (AI) between 2018 and 2050
Sources: EUROSTAT, 2019; authors' calculations

Country	Change in Prop. 65+	Change in Prop. 65+ due to		Change in Total population due to			Change in elderly due to		
		Total population	Elderly	Migration	Cohort turnover	Mortality	Migration 65+	Cohort turnover	Mortality 65+
Austria	0.085	– 0.025	0.111	– 0.033	– 0.072	– 0.079	– 0.004	0.424	0.309
Belgium	0.066	– 0.022	0.087	– 0.021	– 0.075	– 0.075	– 0.006	0.395	0.302
Bulgaria	0.105	0.059	0.046	– 0.001	– 0.070	– 0.130	0.006	0.476	0.436
Croatia	0.115	0.048	0.067	0.000	– 0.069	– 0.117	0.012	0.471	0.416
Cyprus	0.072	– 0.051	0.123	– 0.039	– 0.066	– 0.054	– 0.017	0.386	0.247
Czech Rep.	0.093	0.000	0.093	– 0.016	– 0.076	– 0.092	– 0.001	0.437	0.343
Denmark	0.051	– 0.025	0.076	– 0.023	– 0.078	– 0.076	0.001	0.386	0.311
Estonia	0.089	0.013	0.077	– 0.008	– 0.076	– 0.097	0.001	0.431	0.355
Finland	0.061	0.002	0.059	– 0.018	– 0.073	– 0.093	0.000	0.407	0.348
France	0.070	– 0.016	0.086	– 0.008	– 0.086	– 0.078	– 0.002	0.388	0.301
Germany	0.069	0.000	0.068	– 0.024	– 0.074	– 0.099	– 0.004	0.433	0.361
Greece	0.120	0.030	0.090	– 0.013	– 0.070	– 0.113	0.012	0.456	0.377
Hungary	0.092	0.018	0.074	– 0.013	– 0.071	– 0.102	0.002	0.444	0.372
Ireland	0.117	– 0.041	0.158	– 0.019	– 0.076	– 0.054	0.004	0.394	0.240
Italy	0.122	0.023	0.099	– 0.023	– 0.068	– 0.114	0.002	0.473	0.376
Latvia	0.086	0.048	0.038	0.007	– 0.073	– 0.114	0.004	0.438	0.403
Lithuania	0.111	0.063	0.047	0.016	– 0.071	– 0.118	– 0.001	0.459	0.410
Luxembourg	0.082	– 0.085	0.167	– 0.068	– 0.070	– 0.052	– 0.004	0.400	0.229
Malta	0.056	– 0.086	0.142	– 0.083	– 0.071	– 0.068	0.010	0.412	0.280
Netherlands	0.077	– 0.008	0.085	– 0.013	– 0.074	– 0.080	– 0.002	0.408	0.321
Poland	0.126	0.020	0.106	– 0.003	– 0.069	– 0.092	0.000	0.447	0.341
Portugal	0.136	0.031	0.104	– 0.012	– 0.072	– 0.115	0.003	0.475	0.374
Romania	0.117	0.037	0.081	0.005	– 0.072	– 0.104	0.002	0.452	0.373
Slovakia	0.141	0.015	0.126	– 0.005	– 0.067	– 0.087	0.001	0.454	0.329
Slovenia	0.119	0.005	0.114	– 0.017	– 0.075	– 0.097	– 0.001	0.464	0.348
Spain	0.132	– 0.018	0.150	– 0.038	– 0.068	– 0.089	0.004	0.456	0.310
Sweden	0.020	– 0.059	0.079	– 0.045	– 0.080	– 0.066	0.000	0.362	0.284
UK	0.054	– 0.035	0.089	– 0.023	– 0.080	– 0.068	0.000	0.377	0.287

Appendix 5: Summary statistics for the decomposition of Proportion of Elderly (65+) between 2018 and 2050
Sources: EUROSTAT, 2019; authors' calculations