A New Approach to Understanding Population Change in Central and Eastern Europe

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Abstract: This study introduces a novel approach to decomposing population change by identifying the separate contributions of fertility, mortality, net migration, and initial age structure using stable population theory. Its strength lies in the additivity of the results: the contributions of these factors, along with the interaction effect, sum to equal the total population change. In addition, identifying the direct impact of initial age structure on population change offers new insights into the drivers of population dynamics. Central and Eastern Europe was one of the regions hit most by population decline between 1990 and 2020; however, it was marked by significant variation across countries. By decomposing population change, we found that the positive impact of the relatively young initial age structure in the CEE region was as large as the population-reducing effect of negative net migration, while the positive impact of mortality improvement offset one-third of the population-reducing effect of low fertility. On the other hand, the initial age structure had a crucial role in explaining differences in country-level population change during the study period.

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Introduction

Identifying the primary drivers of population change is crucial for understanding global and regional demographic trends, especially in an era where concurrent population growth (Cleland and Machiyama 2017; Gu, Andreev, and Dupre 2021) and decline (Gietel-Basten 2023; Lutz 2023; Mason and Lee 2022) pose increasingly complex challenges across various regions of the world. Studies investigating different demographic factors in past population change have utilized diverse methods. A common approach involves decomposing population change into the contributions of net migration and natural change (Fihel and Okólski 2019b; Sobotka and Fürnkranz-Prskawetz 2020), or focusing on natural change by further breaking it down into the effects of fertility, mortality, and age structure. (Chaurasia 2017; Kulkarni 2021). Others have employed various retrospective scenarios to assess the impact of specific demographic factors on population change (Kippen and McDonald 2000; Polizzi and Tilstra 2024) or utilized regression analyses to examine the effects of fertility and mortality (Truskolaski and Bugowski 2022).

The novelty of our method lies in its ability to separately identify the roles of fertility, mortality, net migration, and age structure in population change over a given period. The core of this approach is to apply counterfactual scenarios derived from the stationary population to measure the direct impact of different demographic factors (De Santis and Salinari 2023; Preston and Coale 1982). This ensures that the combined effects of the different factors along with the interaction effect give total population change, which transfers scenario analyses into a decomposition. An advantage of this method is its ability to account for spillover effects over time and across demographic factors in calculating population change. Furthermore, this approach allows for identification of the direct impact of the initial age structure on population change. Separating the role of age structure from other demographic factors is particularly important from the policymaking point of view. Government measures and incentives can influence fertility, mortality, and net migration—however difficult and controversial these efforts sometimes are (Greenhalgh 2009; Short 2024). In addition, these factors strongly depend on current socioeconomic circumstances. In contrast, initial age structure can be considered a demographic inheritance from past population history (Alho and Lassila 2023). This means it is independent of current demographic trends, and especially of government will and actions, so the role of age structure in population change can be considered as path dependency.

Identifying the contribution of different demographic factors to population change is particularly important in Central and Eastern Europe (Deimantas et al. 2024). Firstly, this region is deeply affected by population decline. The total population in CEE which includes the 11 countries that joined the EU after 2000[3] decreased by 8% between 1990 and 2020 (See Figure A1 in Appendix). What makes the situation special is that only 20 countries globally have faced a population decline during this period, and six of the top ten fastest shrinking populations belong to the CEE region. Futhermore, the recent trend can also be considered unique from a historical perspective. Although throughout history some human populations have experienced declines (Johnson and Lichter 2019; Lundquist, Anderton, and Yaukey 2015) most of these were short-term events driven by food shortages, disease, or conflict (LePan 2020; Lutz and Gailey 2020). In contrast, the prolonged population decline in the CEE region, which has persisted for decades, is unprecedented, as none of these traditional factors have played a significant role.

[3] Bulgaria, Croatia, Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, and Slovenia.

Secondly, another aspect that warrants further investigation is the heterogeneity of population change across regions. Despite similar historical backgrounds, significant variation can be observed between countries in terms of population change from 1990 to 2020, with decreases of 29% (Latvia) and increases of 5% (Slovenia)[4]. Although several excellent works (Vanhuysse 2023; Vanhuysse and Perek-Białas 2021) have investigated the roots and nature of the demographic changes in the CEE region, uncertainties remain regarding the weight of different factors. The dominant role of migration in population change compared to natural change in recent decades has been highlighted in previous studies (Fihel and Okólski 2019b; Tomáš Sobotka and Fürnkranz-Prskawetz 2020). However, a broader decomposition that separately examines the role of age structure alongside the contributions of fertility and mortality provides a valuable addition to academic literature.

This research presents a detailed decomposition of the CEE region's population dynamics from 1990 to 2020. Using stable population theory, we decompose country-level population change into the role of fertility, mortality, net migration, and age structure. In addition, we compare CEE countries along the characteristics of their population dynamics. Grouping countries by cluster analyses within the region based on their similarities in driving forces of population change allows for a deeper understanding of the population dynamics in this region.

The paper is structured as follows: First, we introduce the methodologies employed in the study and detail the data sources, Next, we provide a concise overview of the demographic background of surveyed countries between 1990 and 2020. This is followed by a presentation of our primary findings on the country-level decomposition of population change. We then discuss the clustering of regional countries based on the characteristics of their population dynamics. The final section offers our conclusions.

Method and data

Population momentum (Keyfitz 1971; Blue and Espenshade 2011) and stable population theory (Espenshade, Bouvier, and Arthur 1982; Cerone 1987) can be used to explore the mechanisms and interrelationships among the demographic factors influencing population change. Preston and Stokes (2012) focused on age-specific growth rate, Edmonston (2006) employed the stationary population equivalent model (SPE), while others examined the relationship between migration and birth (Alho 2008), or introduced migration-adjusted replacement fertility (Parr 2021; 2023a).

Our approach is closely aligned with the work of Kippen and McDonald (2000), McDonald and Hosseini-Chavoshi (2022), and Polizzi and Tilstra (2024), in utilizing counterfactual scenarios within a standard component model to examine the role of various demographic factors in realized population change.[5] The novelty of our work lies in developing an analytical framework where the direct contributions of different factors to population change, along with the interaction effect collectively sum to the total population change over a given period. This additivity transforms scenario analysis into a decomposition of population change, as demonstrated in the work of Chaurasia (2017) and Kulkarni (2021), though they excluded the role of migration from their analyses. Pullum and Jadhav (2021) also presented a decomposition but their focus was on fertility,

[4] See Table 1

[5] This is similar to Lee and Zhou (2017), who used counterfactual simulations to examine the primary drivers of population aging.

mortality, and migration. This paper studies population change over a given period by decomposing it into the contributions of fertility, mortality, net migration, and the initial age structure.

We employ a cohort-component model (Bijak, Kupiszewska, and Kupiszewski 2008; Tønnessen and Syse 2023; Potančoková, Stonawski, and Gailey 2021) to project the population over the surveyed period. This is a simplified structure of the population projection:

$$P_{t+n} = \sum_x^{\omega} \sum_j^2 \sum_{i=t}^{n+t-1} (P_i^{x,j} f_i^{x,j} - P_i^{x,j} m_i^{x,j} + P_i^{x,j} nm_i^{x,j} + P_t c_t^{x,j}) \quad (1)$$

The equation represents the total population at the time $t + n$, denoted as P_{t+n}, where t is the starting time period, and n is the number of periods over which the population change is calculated. On the right side of the equation, $P_i^{x,j}$ represents the age- and gender-specific population, where x refers to a specific age group, ω is the maximum age of people in the population, j refers to sex. The first term on the right side of the equation represents the role of fertility (f), followed by the contributions of mortality (m), net migration (nm), and the initial distribution of the population across specific age groups (c).

The core of this approach involves constructing counterfactual scenarios for the four demographic factors separately, while ensuring that their combined effect results in zero population change. In each scenario, the factor under consideration is modified according to specific assumptions, while all other factors are kept as observed throughout the period. It is worth emphasizing that we use the observed age-specific ratios for fertility, mortality, and migration rather than the absolute observed numbers. For fertility, the counterfactual scenarios (P_{t+n}^{fert}) assume replacement-level fertility (NRR=1) throughout the entire period. For mortality, scenario (P_{t+n}^{mort}), constant mortality rate at the level observed at the beginning of the period is assumed. In the case of net migration, the zero international migration scenario (P_{t+n}^{nmig}) is assumed.

An important aspect of our methodology is creating a counterfactual scenario to assess the impact of the initial age structure on population change. As highlighted by Murphy (2021, p. 215), "a population with an older initial age structure will be relatively insensitive to changes in fertility rates but will be sensitive to mortality changes, whereas the reverse is the case for an initial younger low mortality population." Therefore, it is necessary to control for the initial population structure to isolate the effects of subsequent fertility, mortality and migration. To accomplish this, we use the stationary age structure derived from female and male life table of the starting year (Preston and Coale 1982; De Santis and Salinari 2023) to create the counterfactual scenario (P_{t+n}^{age}) for measuring the impact of the age structure. The remaining variables continue to reflect their observed values.

The stationary population is a specific application of stable population theory with zero population change. It can be achieved through various combinations of demographic parameters (Espenshade, Bouvier, and Arthur 1982; Parr 2023b). However, a distinctive version exists in which age distribution is determined by stationary age structure derived from survival rates. When combined with replacement-level fertility, constant mortality, and zero migration, this maintains a constant population size if applied to a population with the age structure of the life table. This is a key aspect of our methodology, as it ensures that the combination of the counterfactual scenarios also results in zero population change.

To decompose the total population change, we calculate the difference between the population projected under each counterfactual scenario and the observed population at the end of the surveyed period.

$$\Delta P_{t,t+n} = \left(P_{t+n}^{obs} - P_{t+n}^{fert}\right) + \left(P_{t+n}^{obs} - P_{t+n}^{mort}\right) + \left(P_{t+n}^{obs} - P_{t+n}^{mig}\right) + \left(P_{t+n}^{obs} - P_{t+n}^{age}\right) + \varepsilon \quad (2)$$

The first term on the right side of the equation represents the contribution of fertility to population change, followed by the contributions of mortality, migration, and age structure. The final term, the residuum (ε), accounts for the interaction effect. For instance, in a population experiencing below-replacement fertility coupled with negative net migration, a negative interaction effect arises from two sources. First, the effect of below-replacement fertility excludes the missing (emigrated) population in its calculation. Second, the effect of negative migration neglects the differences between observed fertility and replacement-level fertility. Considering the interaction effect is necessary to maintain the mathematical consistency of the decomposition, even though its magnitude is not significant in the context of our investigation (see the section where the results are discussed).

It is worth noting that the measurement of the different factors aligns with the analytical framework: for fertility, mortality, and net migration, we use ratios to exclude the influence of changing age structure, which is measured separately as the fourth demographic factor. In addition to ensuring additivity, the primary advantage of this method is its ability to account for spillover effects when calculating the impact of various demographic factors on population change (Polizzi and Tilstra 2024). On the one hand, it includes spillover effects over time, such as the impact of different fertility levels on subsequent generations. On the other hand, it incorporates spillover effects among different factors; for example, in the case of positive net migration, the offspring of immigrants are also considered when measuring the impact of migration on population change.

It is important to emphasize that this method is also linked to population momentum, particularly to its measurement. When referring to Keyfitz's population momentum, we denote the ratio of the ultimate size of the stationary population to the actual population. This ratio can be calculated using Keyfitz's formula or by a more simplified version proposed by Frauenthal (1975) or Kim and Schoen (1997). The added value of our approach lies in the fact that, while their formulas provide a standardized indicator of the relative size of the ultimate stationary population compared to the actual population, our method calculates the impact of population momentum on population change retrospectively for a given period.

This method is specifically designed to identify the various factors contributing to changes in population size, measured from its initial level at the beginning of a period to its subsequent level at the end. Consequently, when applying this methodology to cross-country comparisons, it is essential to interpret the results with the understanding that population changes are measured relative to each country's starting population. This approach reflects a combination of non-country-specific counterfactual scenarios for fertility (replacement-level fertility) and migration (zero net migration) with country-specific counterfactual scenarios for mortality (constant observed mortality at the beginning of the period) and age structure (derived from the life table). Another characteristic of our method is that it disregards differences in demographic behaviors, including fertility and mortality, among various subgroups of the population, for example, immigrants. This is a limitation that applies to most studies employing counterfactual scenarios for population projections.[6]

Another common limitation of this type of decomposition approach, as highlighted by (Murphy 2021), is that changes to the base year can significantly alter the conclusions. On the one hand, it is reasonable to begin the investigation period for Central and Eastern European countries in 1990, as this marks the regime change which was accompanied by significant political, economic, and sociological transformations. On the other hand, we conducted the decomposition with an alternative starting point, and the results remained unchanged (see Footnote 12).

Among the results, we present a cluster analysis based on the decomposition of the population change in the surveyed countries. Ward's agglomerative clustering is a hierarchical method that merges clusters based on the smallest increase in within-cluster variance at each step (Ward 1963). The method aims to minimize within-cluster variance, resulting in compact and cohesive clusters. It is widely used due to its efficiency in forming well-defined, homogeneous clusters, making it particularly suitable for applications in the social sciences (Murtagh and Legendre 2014).

For decomposing population change, we used age- and gender-specific population, mortality, and fertility data for the period between 1990 and 2020 from EUROSTAT[7] for all countries except Croatia. Due to the lack of suitable data for Croatia, we relied on the World Population Prospects (UN 2024). Since age- and gender-specific migration data are not available for any of the countries, we imputed age- and gender-specific net migration for the surveyed period by deriving it from the official population, mortality, and fertility data.[8]

Background to regional population change

Our research aims to present a comprehensive understanding of population dynamics by identifying the main factors contributing to population change over the first 30 years following the post-Soviet regime change in countries that joined the European Union after 2000. Between 1990 and 2020, this region's population declined from 110.8 million to 102.4 million, a decrease of 7.7% over three decades. However, there were significant differences in the direction and size of population change between countries (See Table 1 and Figure A1 in Appendix). Whilst six countries (Latvia, Lithuania, Bulgaria, Romania, Estonia, and Croatia) experienced a population decrease of between 15% and 30%, others saw a more moderate decrease (Hungary), stagnation (Poland), or even a slight increase (Czechia, Slovakia, and Slovenia). The population change of a country in a given period is the combined effect of fertility, mortality, and migration during that period, plus the initial age structure of the population. In this section, we briefly overview these four demographic factors for the period under investigation.

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[6] A large body of literature has emphasized the assimilation of immigrants' descendants in terms of fertility and mortality (Gordin 1964; Mayer and Riphahn 2000; Biddle, Kennedy, and Mcdonald 2007; Antecol and Bedard 2006). However, recent studies (Kulu et al. 2019; Wilson 2019) have highlighted significant heterogeneity in the behaviors of both immigrants and their offspring.
[7] Downloaded on October 10, 2023.
[8] The measurement errors associated with migration data in the surveyed region (Dańko et al. 2024; Gödri 2018) pose a significant challenge that requires attention. On one hand, we argue that incorporating revisions derived from censuses enhances overall data quality. On the other, since the aim of this paper is to decompose population change as recorded by national statistical offices, we are compelled to use migration data that aligns with their official records.

Fertility

The regime change in post-Soviet countries generated social, economic, and cultural changes on such a scale that major demographic trends changed significantly in just a few years. This can also be seen in the evolution of fertility. By the 1970s and 1980s, a socioeconomic system had become entrenched in the region that limited people's freedom in many areas while strongly encouraging (early) childbearing. Early completion of schooling, job security, easier access to housing for young married couples, full (or close to full) employment, moderate income and wealth inequalities, and in general relatively low levels of economic and existential insecurity all contributed to relatively early family formation and the spread of the two-child family model in the decades before the regime changes (Sobotka 2011). This is also reflected in the evolution of the total fertility rate (TFR). In the two decades preceding regime change, the TFR varied between 1.8 and 2.5 in most countries in the CEE region. The two exceptions were Slovenia and Croatia, where the fertility rate decline preceded other countries and had decreased to around 1.5-1.6 by 1990.

Within a few years of regime change, fertility fell sharply in all Central and Eastern European countries (See Figure A2 in Appendix). The TFR for the region declined from 1.9 in 1990 to 1.2 in 2002, and did not exceed 1.4 in any of the 11 surveyed countries in that year. This was followed by a partial rebound, interrupted only by the Great Recession of 2008-10 and the subsequent European sovereign debt crisis, and by 2019, TFR had recovered to a range of 1.4-1.8. The average TFR from 1990 to 2019 in Central and Eastern Europe was 1.46, and the strong similarities within the region are reflected by the fact that the country-level averages of this period varied between 1.40 and 1.54. It also indicates that fertility behavior was far below the so-called replacement level of fertility[9] in all surveyed countries from 1990 to 2019.

The literature typically explains fertility trends along several dimensions (Sobotka 2011; Sobotka and Prskawetz 2020). First, the economic downturn following regime change played a significant role in the rapid decline in fertility. The relative stability and predictability of the earlier period quickly disappeared, and with the arrival of political freedom, economic decline and uncertainty emerged. As part of the transformation crisis, entire sectors almost disappeared in the region, full employment was gone, wage inequality increased, and unemployment and inflation soared (Kornai 1994; Kolodko 2001). Living standards deteriorated further due to fiscal adjustments, which in many cases also affected the generous family support system that had built up in the past.[10] At the same time, income inequalities within society widened (Novokmet 2021), especially on the basis of educational attainment. All this played a significant role in the remarkable decline of TFR in the 1990s in Central and Eastern Europe. In addition, deterioration in economic conditions due to the Great Recession and the European sovereign debt crisis was also an important driver of the temporary fertility decline in the early 2010s.

However, understanding fertility behavior merely based on the trend of TFR is misleading in our case, as all countries in the region experienced a significant postponement of childbearing after regime change (Frejka and Gietel-Basten 2016). The average age at birth for women increased

[9] Total fertility rate that corresponds to replacement level fertility for zero migration in Central and Eastern Europe declined from 2.11 to 2.07 between 1990 and 2019. While alternative replacement-level fertility indicators incorporate varying assumptions, such as those discussed by Parr (2021), this study utilizes the conventional measure that assumes zero net migration.

[10] Although the weight of family support, especially cash-based financial aid, has increased in several countries over the past decade, it has tended to affect rather the timing of childbearing and has a minor impact on birth numbers in the long term. (Lutz, Sobotka, and Zeman 2024; Sobotka and Prskawetz 2020).

significantly, from 25.5 in 1990 to 28.9 in 2011, and then rose further at a slower pace to 29.6 until 2019. The economic difficulties and uncertainty discussed above are only some of the factors that contributed to this delay. The expansion of education after regime change both provided protection against labor market risks and postponed the age of marriage and family formation. According to the theory of the second demographic transition (van de Kaa 1987) the post regime change increase in educational attainment may be linked to values such as individual freedom, self-fulfilment, and the pursuit of personal goals coming to the fore, and this too may have contributed to the postponement of having children (Doblhammer and Spéder 2024; Fihel and Okólski 2019a).

Table 1. Key Variables of Population Change in the CEE Region (1990–2020)

	Population 1990 (Million)	Population 2020 (Million)	Population change (%)	TFR (average of 1990-2019)	Change in life expectancy at birth from 1990 to 2019 (years)	Cumulative net migration from 1990 to 2019*	Median age in 1990
Bulgaria	8,8	7,0	-20,7	1,42	3,9	-7,5	36,5
Croatia	4,8	4,0	-17,8	1,50	5,9	-11,4	35,4
Czechia	10,4	10,7	3,2	1,44	7,8	4,5	35,1
Estonia	1,6	1,3	-15,4	1,54	9,1	-9,4	34,2
Hungary	10,4	9,8	-5,8	1,44	7,1	4,4	36,1
Latvia	2,7	1,9	-28,5	1,46	6,1	-17,4	34,6
Lithuania	3,7	2,8	-24,4	1,54	5,0	-18,9	32,4
Poland	38,0	38,0	-0,2	1,47	7,3	-2,2	32,2
Romania	23,2	19,3	-16,7	1,48	5,7	-11,9	32,6
Slovakia	5,3	5,5	3,2	1,46	6,7	-0,5	31,2
Slovenia	2,0	2,1	5,0	1,40	7,7	4,1	34,0
CEE Region	110,8	102,4	-7,7	1,46	6,6	-4,7	33,4

**In percent of the population in 1990*

Source: EUROSTAT

Taking into account this postponement, it can be concluded that the significant fall and then partial recovery in fertility rates is partly due to changes in the timing of childbearing in Central and Eastern European countries. This is supported by the picture drawn by the tempo-adjusted TFR (Lutz, Sobotka, and Zeman 2024) and the fact that completed fertility rate has been declining steadily[11] in the countries studied over the last decades. Together, these points indicate that, on the one hand, there has been a significant decline in fertility from 1990 to 2019 in the region. On the other hand, the dramatic decline in the fertility rate in the first decade and a half after the regime change was fueled partly by a shift in the timing of childbearing. Accordingly, the rebound in the subsequent period is largely the result of catching up associated with the earlier postponement, with no significant overall improvement in actual fertility.

Mortality

While persistent below-replacement fertility led to population decline across all countries in the region from 1990 to 2019, substantial mortality improvements had the opposite effect, increased population with moderate variation between countries (See Figure A3 in Appendix). Regime

[11] Source: Human Fertility Database

change brought the same significant changes in mortality trends in Central and Eastern Europe but with greater differences between countries compared to fertility, particularly in terms of timing. In most of the surveyed countries, a mortality crisis began in the mid-1960s, leading to decades of stagnation or only modest gains in life expectancy at birth—and, in many cases, a decline in life expectancy for men. (Meslé 2004; Carlson and Hoffmann 2011; Meslé and Vallin 2017). This was because socialist countries had not made strides in reducing cardiovascular mortality comparable to those seen in Western Europe. Additionally, the burden of "man-made" deaths—those linked to lifestyle factors like smoking, alcohol consumption, poor nutrition, and external causes such as suicide—had grown substantially (Bobak and Marmot 1996; Tóth 2021).

Although substantial improvements in mortality emerged across all surveyed countries following regime change, the timing of the shift from mortality crises to a period of increasing life expectancy varied among them (Scheiring, Irdam, and King 2019). Most navigated regime change without experiencing significant mortality losses, and increases in life expectancy began shortly afterwards in Czechia, Slovakia, Poland, Hungary, and Slovenia, while in Romania and Bulgaria these gains emerged somewhat later, in the late 1990s (Cornia and Paniccià 2000; Parr, Li, and Tickle 2016). The situation was different in the Baltic countries, where political and socio-economic transitions led to a sharp decline in life expectancy at birth by 3–4 years, lasting until 1994 (Billingsley 2011; Jasilionis et al. 2011). This was followed by a strong rebound; however, life expectancy at birth did not return to its 1990 level until the end of the decade. In Croatia, the improvement in mortality was interrupted by a nearly two-year decline in life expectancy at birth in 1991, caused by the fatalities of the Croatian War of Independence. However, the trend resumed its upward trajectory following that period (Bozicević et al. 2001).

Although the timing of its inception varied slightly among countries, the subsequent period leading up to the COVID-19 pandemic was characterized by significant mortality reduction in most countries. This improvement is generally associated with reduction of infant mortality and increased life expectancy among older adults, though some countries also experienced a significant decline in mortality among middle-aged individuals (Aburto and van Raalte 2018).

In terms of cause of death, mortality related to cardiovascular diseases has declined significantly (Zatonski, McMichael, and Powles 1998; Bandosz et al. 2012; Fihel and Pechholdová 2017), lagging behind Western European trends by a few decades. Additionally, there has been some improvement in cancer mortality rates and a substantial reduction in deaths from external causes (Wéber et al. 2023). These trends are partly attributable to the adoption of advanced technologies and developments in former socialist countries following regime change, which have greatly enhanced the effectiveness of health interventions and of medications. Concurrently, a major lifestyle shift has occurred, with reductions in smoking and alcohol consumption alongside an increased focus on healthy eating and regular exercise (Jasilionis, Meslé, and Vallin 2023; Sobotka and Fürnkranz-Prskawetz 2020). As a result of this, life expectancy at birth in the CEE region increased from 70.6 to 77.2 between 1990 and 2019. Estonia saw the greatest improvement, with a 9.1-year increase, while Bulgaria experienced the smallest gain, with a modest increase of 3.9 years. In all other countries, life expectancy rose by between 5.0 and 7.8 years. Country-level variation within the region, which is more pronounced among men, is largely driven by differences in reducing cardiovascular mortality and decreasing the incidence of deaths from external causes (Jasilionis, Meslé, and Vallin 2023).

Migration

Compared to fertility and mortality trends, since 1990 there have been even greater differences in net migration within the region (Kahanec and Zimmermann 2010; Inglis, Li, and Khadria 2020). If we sum the annual number of net migrants for each country from 1990 to 2019 and then compare this 30-year cumulative net migration to the initial 1990 population, the results range from –18.9% in Lithuania to +4.5% in Czechia among the 11 countries surveyed (See Figure A4 in Appendix). Treating the entire CEE region as a single geographical unit, cumulative net migration between 1990 and 2019 was -4.7% of the initial population, indicating that, despite country-level differences, 5.1 million more people left the region than arrived.

Ethno-national motivations were among the primary drivers of international migration[12], especially in the first decade following regime change in several CEE countries (Fihel and Okólski 2019b; Fox 2003). This influence is partly reflected in the share of the foreign-born population, which reached 4% across the CEE region by the end of the surveyed period, with Estonia, Croatia, Latvia, and Slovenia notably seeing double-digit percentages.

As the role of ethno-national motivation gradually diminished, east-west labor migration for employment gained prominence, boosted by the accession of the CEE countries to the European Union (in 2004, 2007, and 2013) and the subsequent opening of foreign labor markets to workers from the region. Higher wages, relative prosperity, higher quality of public services, and better infrastructure in Western Europe attracted many to take advantage of the opportunities offered by migration (Vanhuysse 2023; Cuaresma et al. 2012). Using the aspirations-capabilities framework, Fihel and Kaczmarczyk (2023) highlight the importance of factors such as the lifting of labor market restrictions, strong demand in the secondary sector of labor markets, and the influence of migration networks and the migration industry in shaping individuals' capabilities. Among aspiration factors, they emphasize labor market failures and the substantial aspirational gap created by increased levels of educational attainment in migrants' countries of origin. As a result of this, between 2005 and 2014 the number of migrants from the 'new' post-2004 EU member states residing in the 15 'old' member states at least doubled. In some countries, however, the increase was significantly higher—particularly in the UK, where it rose thirteen-fold (King and Okólski 2019). The other main destinations were Germany, Austria, Spain, and Italy, shaped by factors such as geographic proximity, historical ties, and the timing of labor market liberalizations following EU enlargement, all of which influenced migration flows (Baláž and Karasová 2017).

By 2017, the number of Central and Eastern European emigrants living abroad had reached 13.8 million, representing 13.4% of the population in their countries of origin (World Bank 2019). Regional differences (Kahanec and Zimmermann 2016) are reflected in the varying shares of people from each country living abroad. This share ranged from 18% to 23% in Croatia, Lithuania, Latvia, Bulgaria, and Romania, while, at the lower end, it was between 6% and 7% in Hungary, Slovakia, and Slovenia in 2017. These numbers also suggest that, even in countries with positive net migration, the outflow of migrants was not negligible. However, it was balanced by inflow migration, which was partly driven by return migration (Kahanec, Zaiceva, and Zimmermann 2010) and immigration from non-EU countries. The latter plays a significant role in the marked shift in international migration trends during the final years of the surveyed period. This shift was characterized by a decline in emigration, an unprecedented rise in inflows from non-European

[12] For example, Hungarians living in neighboring countries migrated to Hungary after the regime change.

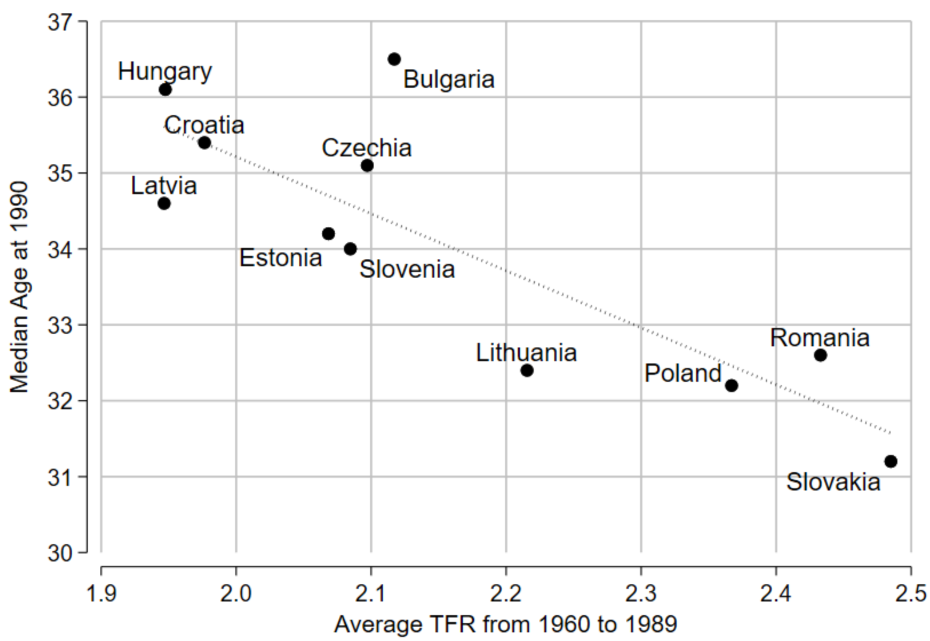
countries, and positive net migration in countries that had previously experienced decades of net outflow, such as Poland, Estonia, and Lithuania (Fihel and Kaczmarczyk 2023).

Age structure

Using age-specific indicators for mortality, fertility, and net migration enhances comparability across populations and provides deeper insights into surveyed trends. However, since these indicators do not account for the age distribution within a population, separately examining the age structure is essential for accurately understanding the drivers of population change in a given country. This means that in addition to the factors discussed previously (fertility, mortality, and migration), changes in population size over the three decades following regime change are also influenced by the initial age structure of each country's population.

Taking all 11 countries into account, the median age in Central and Eastern Europe was 33.4 years in 1990, with notable variation between countries. The lowest median age in the region, at 31.2 years, was observed in Slovakia in 1990, but Poland, Lithuania, and Romania were also relatively young nations, with median ages below 33 years. The oldest country was Bulgaria, with a median age of 36.5 years, though Hungary, Croatia, and Czechia also had median ages above 35 years.

Figure 1. Median Age in 1990 and Average Total Fertility Rate from 1960 to 1990



Source: EUROSTAT, UN WPP (2024)

The age structure of a population at a given time is determined by the fertility, mortality, and migration patterns of the previous period. While the mechanisms by which these factors influence age structure are complex, Lee and Zhou (2017, p. 296) emphasize that "fertility decline, particularly to low levels, is largely responsible for past and current population aging, regardless of mortality trends." This is consistent with our findings, as we identified a clear negative association (Corr: -0.84) between the average total fertility rate from 1960 to 1989 and the median age in 1990 (Figure 1). Among the surveyed countries, the median age in Bulgaria in 1990 was higher than expected based on fertility trends from the previous period. This may partly be due to the fact that, on average, between the early 1970s and mid-1980s, Bulgaria had the highest life expectancy at birth in Central and Eastern Europe. In contrast, significant Russian immigration to the Baltic countries during the communist era played a role in shaping their age structures. A large portion of the immigrants were young adults seeking job opportunities, which helps explain the relatively young age structure in these countries compared to their fertility levels (Taagepera 1981).

Decomposition of population change

Population change over a given period is determined by fertility, mortality, migration, and the initial age structure, as described in Equation (1). Isolating the effects of these demographic factors allows us to quantify the population change attributable to differences between the observed and counterfactual scenarios for each specific factor, while holding all other factors constant at their observed values. We present in Figure 2 the impact of various demographic factors in the percentage of the initial 1990 population, aligning it with the analytical framework of the decomposition method.

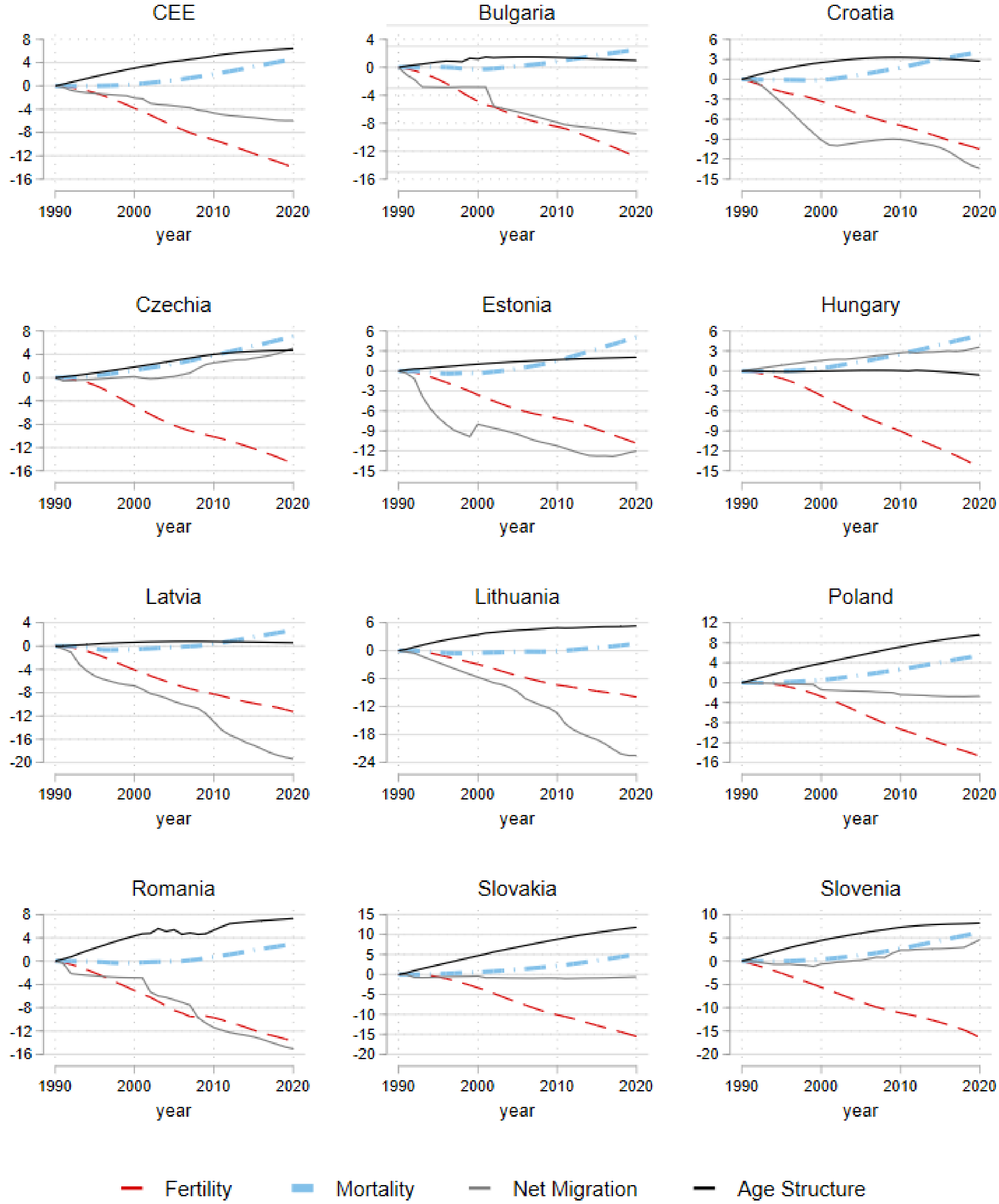
The fertility trend in Central and Eastern Europe from 1990 to 2020 was generally similar across countries, and, except for the very early years, it remained well below replacement-level fertility throughout most of the period. Consequently, the impact of fertility on population change proved to be similarly negative and significant across the region. (Figure 2). Taking Central and Eastern Europe as a single region, low fertility resulted in a 14% decrease in the population by 2020. This implies that, had fertility remained at replacement level (NRR = 1) throughout the period, the region's population in 2020 would have been higher than the observed population by approximately one-sixth (16 million) of its initial size in 1990. The population-reducing effect of fertility increased in the first decade following regime change, after which it remained relatively constant with small variations, averaging an annual decrease of 0.5% of the initial population over the surveyed period.

The most significant negative impacts were observed in Slovenia and Slovakia, where low fertility led to a 16% percent decline in the initial population. In contrast, the lowest impact was recorded in Lithuania, with a decline of 10%, followed by Croatia, Estonia, and Latvia with 11%. These differences are primarily driven by variations in observed fertility, reflecting the fact that the highest average TFRs were recorded in Lithuania, Estonia, and Croatia. Another factor that modifies the impact of fertility is the spillover effect. In this context, it means, for example, that countries with more negative net migration tend to experience smaller population reductions due to low fertility, as the fertility behavior of emigrants does not influence the future population. Conversely, countries with positive or modestly negative migration with a TFR around the regional average, such as Poland, Slovakia, or Czechia (see Table 1), experienced a relatively higher population reduction due to low fertility.

Following the end of the mortality crises in the latter half of the 20th century, Central and Eastern Europe experienced unprecedented improvements in mortality, which had a significant impact on population change. Assuming all other factors remained constant, the 6.6 year increase in life expectancy across the region led to a 5% increase (5 million people) in the population by 2020, relative to the initial population (Figure 2). Since the mortality crisis had a deteriorating effect in the Baltic countries even during the 1990s, the impact of mortality change on the population in the whole region remained negligible during the first decade following regime change. During the 2000s, the annual average impact of mortality change on the population rose to 0.2% of the initial population, further increasing to 0.3% in the 2010s.

Figure 2. The cumulative effect of fertility, mortality, net migration, and age structure on population change from 1990 to 2020

(in percent of the population in 1990)



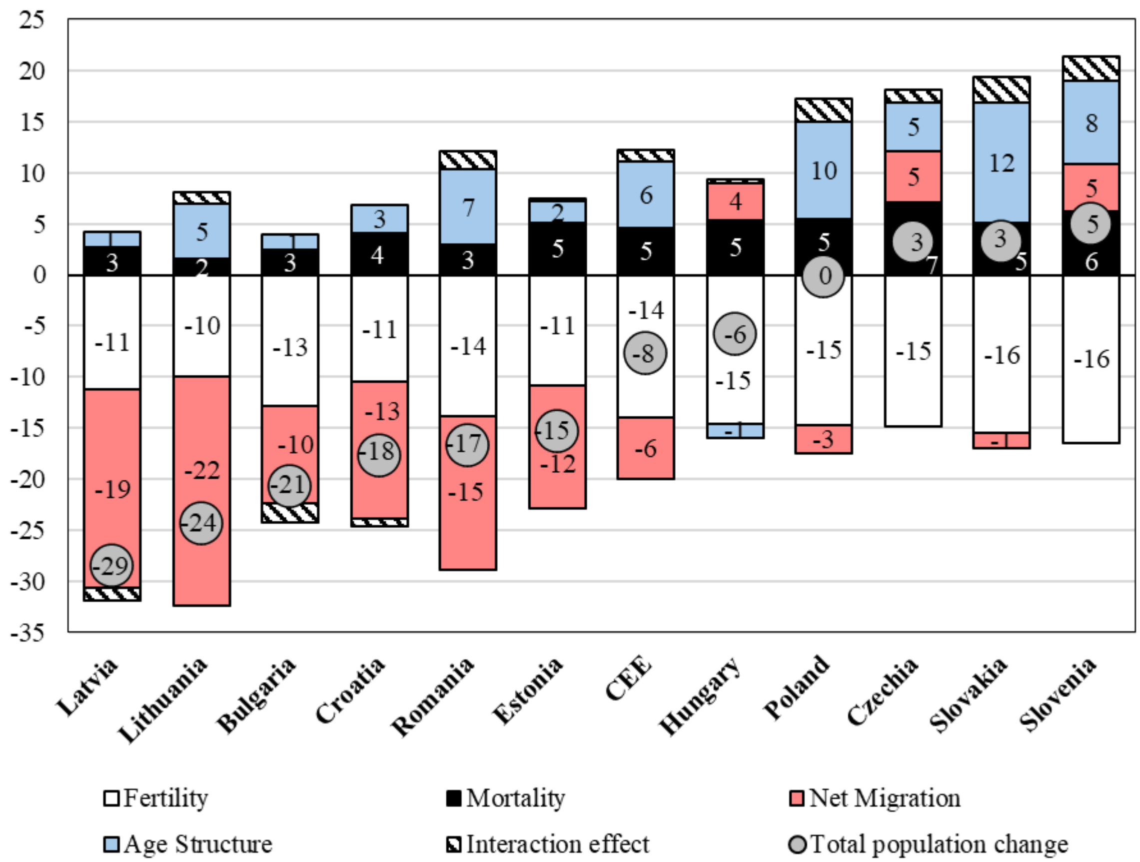
Source: Own calculations

However, the effect of mortality change varied significantly across the region. The most substantial population increases attributable to mortality improvements were observed in Czechia (+7%) and Slovenia (+6%), as these countries experienced some of the largest increases in life expectancy between 1990 and 2020. The smallest contributions to population increase were observed in Lithuania (+2%), Bulgaria (+3%), Latvia (+3%), and Romania (+3%). This reflects the relatively modest gains in life expectancy, particularly in Bulgaria. It also reflects that significant negative net migration and younger population age structures mitigated the population growth effects of similar mortality improvements through the spillover effect, explaining the relatively smaller impacts in the other three countries.

One advantage of this approach is that it allows a direct comparison between the population reduction caused by low fertility and the opposing effect of mortality improvement. This is particularly important, as public and academic debates on strategies to halt population decline typically focus on fertility and, occasionally, migration. However, we found that the increase in life expectancy was able to offset one-third of the population reduction caused by low fertility in Central and Eastern Europe between 1990 and 2020 (Figure 3). In Estonia and Czechia, this ratio is close to 50%, providing evidence that improvements in mortality — by increasing efficiency and affordability of healthcare, better nutrition, and more active lifestyles — can significantly mitigate the impact of other population-reducing factors, such as low fertility.

Figure 3. Decomposition of population change from 1990 to 2020

(in percent of the population in 1990)



Source: Own calculations

Net migration was a particularly significant factor shaping population dynamics from 1990 to 2020. Its impact on the region's overall population change was -6%, suggesting that the population of Central and Eastern Europe would have been 7 million larger by 2020 in the absence of migration into and out of the region. The impact was more pronounced during the first two decades following regime change and diminished significantly in the later years of the survey period, as net migration turned positive in countries like Estonia and Poland, which had previously experienced substantial net migration outflows.

Migration is also one of the most significant factors contributing to country-level variation in population change after regime change. The largest population decline due to it was observed in Lithuania (-22%) and Latvia (-19%), countries where around one-fifth of the initial population was missing by 2020 because of net migration. Only three countries—Czechia (+5%), Slovenia (+5%), and Hungary (+4%)—experienced a migration inflow that exceeded outflow by 2020, contributing to population growth in Czechia and Slovakia and moderating the extent of population decrease in Hungary.[13]

The impact of migration on population change is primarily driven by the direct effect of net migration; however, spillover effects can cause slight deviations in this case, too. For instance, while Hungary and Czechia experienced similar totals for positive net migration, the effect of net migration on population was slightly greater for Czechia. This difference can be attributed to the combined effects of the younger age structure of immigrants and the older age structure of emigrants, both shaped by the motivations of migration. These dynamics contributed to a higher number of children being born to immigrants in Czechia. Alternatively, the longer the period under consideration, the more emigrants and immigrants pass away, widening the gap between cumulative annual migration since the start of the surveyed period and its impact on the population.

One advantage of this decomposition method is that it allows the role of initial age structure in population change to be identified separately. Reflecting the region's relatively young age distribution, we found that the initial age structure in 1990 contributed to a 6% increase in the population of Central and Eastern Europe by 2020. This means that if the age structure in the CEE region had been identical to that of a stationary population, 7 million fewer people would have lived there in 2020. It is worth emphasizing that the positive impact of the age structure on population change was substantial enough to fully offset the equally large negative impact of net migration, highlighting the importance of age structure in understanding population change.

In addition to the overall impact of initial age structure, its variation plays a significant role in explaining country-level differences in population change. The largest impacts were observed in Slovakia (+12%) and Poland (+10%). Hungary was the only country with a negative impact (-1%), and there were only small positive impacts in Latvia (+1%) and Bulgaria (+1%).[14]

[13] The level shifts observed in some countries (e.g., Bulgaria, Romania, Croatia, Estonia) are in most cases attributable to annual changes in migration following the census. These can be regarded as revisions to the estimated population figures from the previous census.

[14] In the case of Romania, there was a brief period during which the impact of age structure on population change fluctuated around a slightly declining trend (see Figure 2). This results from the combination of significant differences in subsequent cohorts and high age-specific migration rates. Following the abortion ban in 1966, the number of births nearly doubled between 1966 and 1967, rising from 265,000 to 510,000. This had a long-term impact on Romanian age structure, causing a significant deviation from stationary age structure in the corresponding cohorts. The difference in cohort size, combined with the same migration rate we applied, caused a brief fluctuation in the impact of the age structure.

The impact of the initial age structure in a given country is assessed by comparing the observed age structure with the stationary age structure in 1990. The observed age structure reflects the country's historical patterns of fertility, mortality, and migration, while the stationary age structure is based solely on the prevailing mortality conditions in 1990. To understand the cross-country variation in the differences between observed and stationary age structures, it is useful to compare the variation in both dimensions. The country-level variation in median age is substantially greater for the observed age structure compared to the stationary age structure. Consequently, the impact of age structure on population change is primarily driven by the observed age structure, mainly through the proportion of women in reproductive ages and the share of older generations. This explains why the contribution of the initial age structure to population change was largest in countries with the youngest age structures in 1990 (Slovakia and Poland), driven in part by the relatively high total fertility rates (TFR) between 1960 and 1990. On the other hand, the impact of age structure on population change was moderately positive (Bulgaria and Latvia) or even slightly negative (Hungary) in countries with relatively older age structures in 1990, reflecting the low TFR of previous decades.

However, the difference in stationary age structure, which is determined by surviving ratios (Ryder 1975; Heuveline 2023; Santis and Salinari 2024), also influences the results. For instance, this explains the differences in the impact of age structure between Slovenia (+8%) and Estonia (+2%), despite having similar median ages in 1990 (34.0 and 34.2, respectively). Higher surviving ratios, associated with higher life expectancy, resulted in an older stationary age structure in Slovenia, leading to a larger gap between observed and stationary median age and a larger positive impact of initial age structure on population change.

The interaction effect (residual) ranged from -2% to 3%, fluctuating around zero. It tended to be positive in countries with small negative or positive net migration (with some exceptions), while it was generally negative in countries with more substantial negative net migration. This reflects the difference between the observed and stationary values of the various demographic factors and their relative contributions to overall population change.

Comparing the influence of different factors on population change at the country level reveals several key conclusions (Figure 3). Fertility and mortality, in general, had a smaller role in explaining differences in population dynamics. What makes a difference are migration and initial age structure. The former has already been highlighted by (Fihel and Okólski 2019b; Tomáš Sobotka and Fürnkranz-Prskawetz 2020), while measuring the impact of age structure and presenting its significant contribution to regional differences in population change, to the best of our knowledge, expands our understanding of the topic.[15]

Another key finding that underscores the role of initial age structure in population dynamics is that, without its influence, not only the entire CEE region but also all 11 individual countries would have experienced a population decrease from 1990 to 2020. The largest decline would have occurred in Lithuania (-30%) and Latvia (-29%) if observed age structure of the population in 1990 had been identical to that of the stationary population, while the smallest decreases would have been in

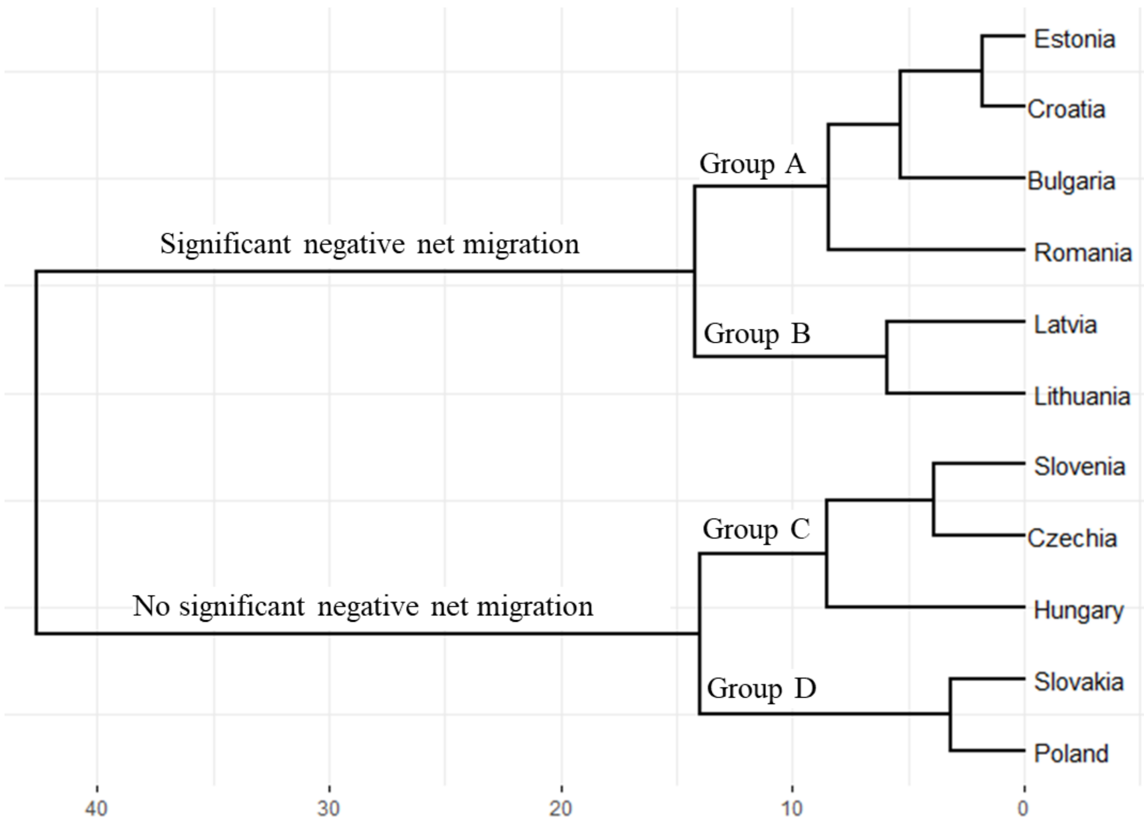
[15] As a robustness test, we performed the same decomposition using 1992 as the starting point instead of 1990. The results showed minimal changes, and the key messages remained consistent. For instance, in the case of the CEE region, population change decreased from 8% to 7%, driven by a decline in the impact of migration from -6% to -5%, while the impacts of fertility (-14%), mortality (5%), and age structure (6%) remained unchanged.

Czechia (-2%) and Slovenia (-3%). Without the impact of initial age structure, the population in Central and Eastern Europe would have decreased by 14% from 110 million to 95 million between 1990 and 2020.

Regional Country Groupings

The decomposition of population change highlights the diverse combinations of factors driving population dynamics, enabling the grouping of surveyed countries based on similarities in these patterns. This categorization offers valuable insights for selecting countries to compare with the demographic trends of a given country. Using Ward's agglomerative clustering, we identified groups of countries based on the patterns that shaped population change from 1990 to 2020 (Ward 1963).

Figure 4. Cluster analysis based on the contribution of fertility, mortality, net migration, and age structure to population change from 1990 to 2000



Source: Own calculations

The most important factor dividing the 11 surveyed countries into two categories is migration (Figure 4). The Baltic countries, along with Croatia, Bulgaria, and Romania, experienced significant population loss (-12% to -22% of the initial population) due to it. At the same time, the negative impact of net migration was moderated or even positive in the remaining five countries (-3% to 5%). However, in addition to migration, fertility also contributes to this division. In countries with significant negative net migration, the negative impact of fertility on population change tends to be lower (-10% to -14%), while this negative effect was larger in countries with no significant negative net migration (-14% to -16%). Both groups can be further divided into subgroups based on similarities and differences in the role of various factors in population change.

Among the countries with significant negative net migration, we can identify Estonia, Croatia, Bulgaria, and Romania as Group A, where the negative impact of net migration was more moderate (-12% to -15%), compared to Group B, consisting of Latvia and Lithuania, where the negative effect of net migration was more pronounced (-19% to -22%). This difference played an important role, as the total population decline in Group A ranged from -15% to -21%, while in Group B it was even larger, ranging from -24% to -29%.

Among the countries without significant negative net migration, we can also form two subgroups. Group C contains Slovenia, Czechia, and Hungary, with positive net migration and relatively large variation in the role of age structure (-1% to 8%). In contrast, Slovakia and Poland formed Group D, characterized by a larger positive impact of age structure (10% to 12%) and a moderate but negative impact of net migration on population change. As shown in the cluster analysis (Figure 4) and the previous graph (Figure 3), the patterns driving population change are remarkably similar in Estonia and Croatia, as well as in Slovakia and Poland.

Conclusion

While shrinking population increasingly affects more and more countries around the world, there is a significant geographical concentration in this respect. Most states that have already experienced considerable population decline are post-Soviet countries (Coleman and Rowthorn 2011; Newsham and Rowe 2023) however, within this area, the population loss is also significant in Central and Eastern Europe. Although we have limited experience with the consequences of long-lasting population decline, we can identify several risks and opportunities linked to the process (Gietel-Basten 2023; Mason and Lee 2022). From an economic point of view, it may lead to significant societal adjustment costs during the transition from larger to smaller population numbers (Kiss et al. 2021; Van Dalen and Henkens 2011); it may additionally change the distribution of well-being across subpopulations (Gál, Vanhuysse, and Vargha 2018) and accompany changes in the geographical distribution of the population (Kóczy 2012; Deimantas et al. 2024). On the other hand, population decline can bring economic benefits regarding higher female labor force participation and can mitigate human-induced climate change (Götmark, Cafaro, and O'Sullivan 2018; Jarzebski et al. 2021; Lutz 2023). These considerations underscore the importance of understanding population change, particularly in regions most affected by this issue.

The aim of our research is to present a new approach to decomposing population change and to apply this method in order to gain deeper insights into population dynamics in Central and Eastern Europe. The decomposition relies on scenario analyses conducted using the cohort-component model, with counterfactual scenarios grounded in stable population theory. This approach enables us to identify contributions of fertility, mortality, net migration, and initial age structure separately to population change. Its advantage lies in the additivity of the results: the impacts of the different factors along with the interaction effect sum up to the total change, transforming simple scenario analyses into a comprehensive decomposition. In addition, this method accounts for spillover effects, illuminating the long-term consequences of changing demographic factors (such as fertility or migration) on the size and composition of future generations.

The population of Central and Eastern Europe declined by 8% between 1990 and 2020, with significant country-level variation ranging from -29% to +5% of the initial 1990 population. Few found that this population loss in the whole CEE region was driven by a 14% decline due to low fertility and 6% decline due to negative net migration. However, these effects were partially offset by a 5% improvement in mortality and a 6% contribution from initial age structure relative to the population in 1990. This demonstrates that the positive impact of improved mortality could offset a significant portion of the population-reducing effect of low fertility. One of our main findings is that initial age structure played a crucial role in population change across the entire region. This is demonstrated by the fact that without the impact of age structure, not only the entire CEE region but also all 11 individual countries would have experienced a population decrease from 1990 to 2020. Using our new decomposition method, we demonstrated that the heterogeneity across the CEE region is more complex than previously assumed. While migration is a key factor explaining differences in population change, the initial age structure also plays a crucial role and must be considered for a comprehensive understanding.

Our results provide valuable insights for public policymaking from multiple perspectives. Many countries concerned about actual or expected population decline focus their efforts on slowing down or even reversing this trend, primarily by implementing a wide range of pro-natalist measures to increase fertility (Björklund 2006; Sobotka, Matysiak, and Brzozowska 2019; Spéder, Murinkó, and Oláh 2020). We highlighted that reducing mortality can significantly contribute to population growth or help mitigate population decline. Therefore, governmental investment in improving the efficiency and accessibility of the healthcare system, promoting healthy lifestyles, and strengthening mental and physical well-being not only benefits individuals but also helps offset the population-reducing effects of other factors (see Polizzi and Tilstra 2024).

While our results highlight the importance of reducing mortality in addressing population decline, they also underscore the need for policymakers to recognize the limitations of governmental measures. The age structure of a population is determined by historical fertility, mortality, and migration trends, and can thus be regarded as a form of demographic inheritance (Alho and Lassila 2023). Using a novel approach to decomposing population change, we demonstrated that this demographic inheritance has a significant impact on population dynamics. In conclusion, we showed that exogenous factors, which public policy cannot influence, play a crucial role in shaping population change. From another perspective, since the age structure embodies the consequences of past demographic trends and influences future demographic outcomes, its role in population change can be regarded as path dependency.

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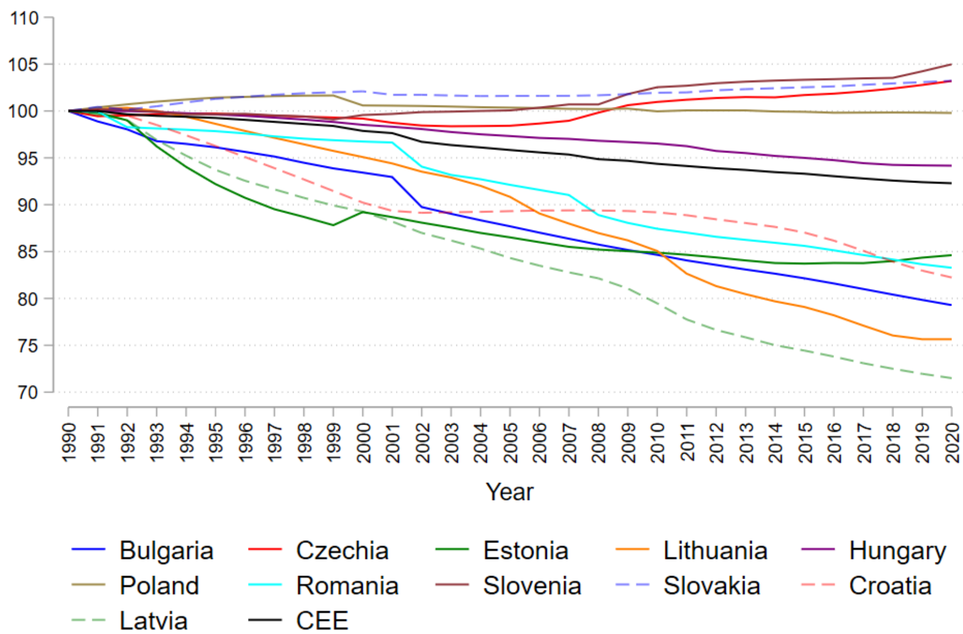
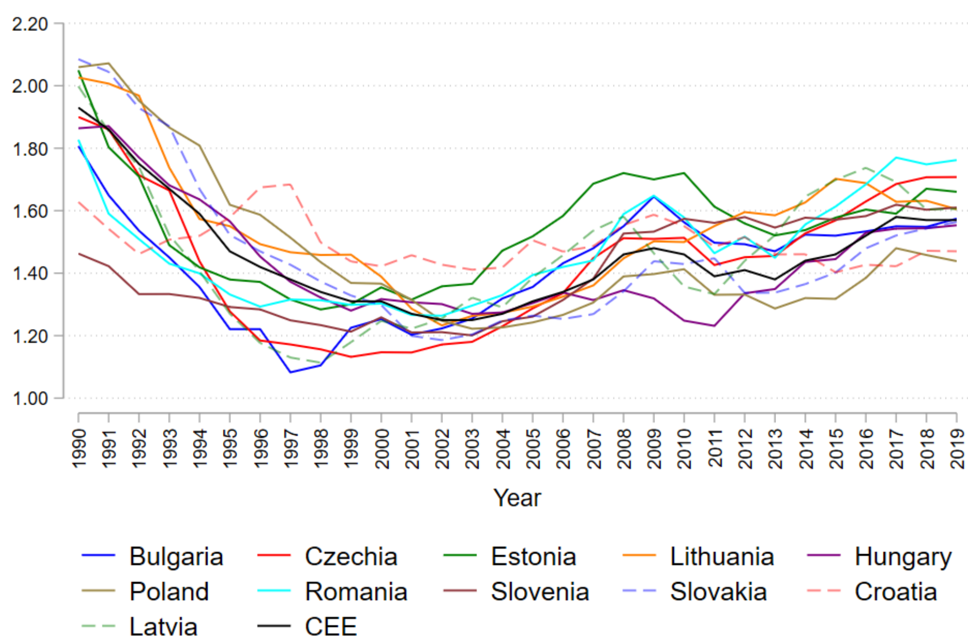
APPENDIX

Figure A1. Population changes from 1990 to 2020 (1990=100)



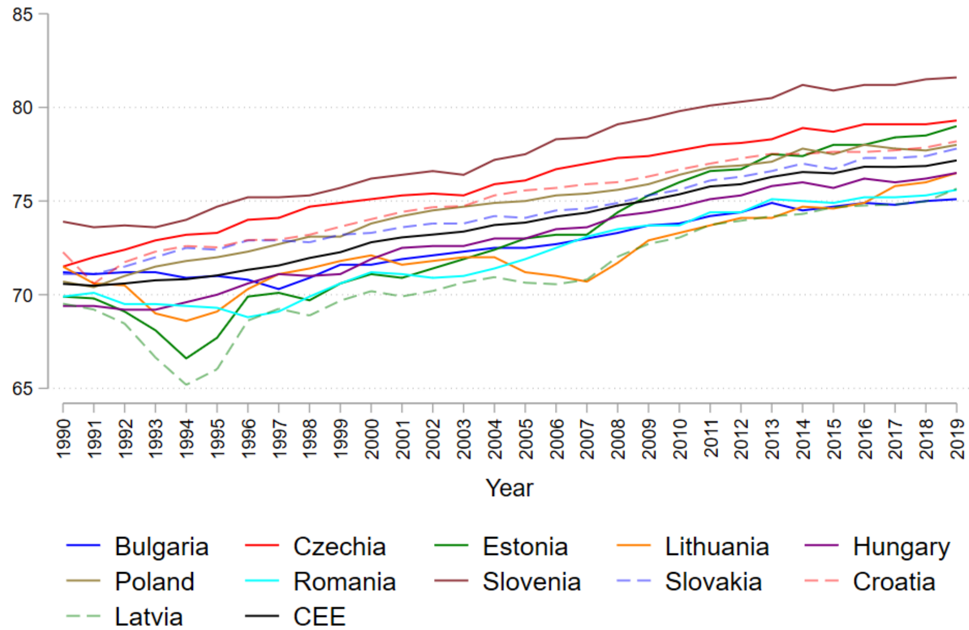
Source: EUROSTAT

Figure A2. Total Fertility Rate in Central and Eastern Europe (1990-2019)



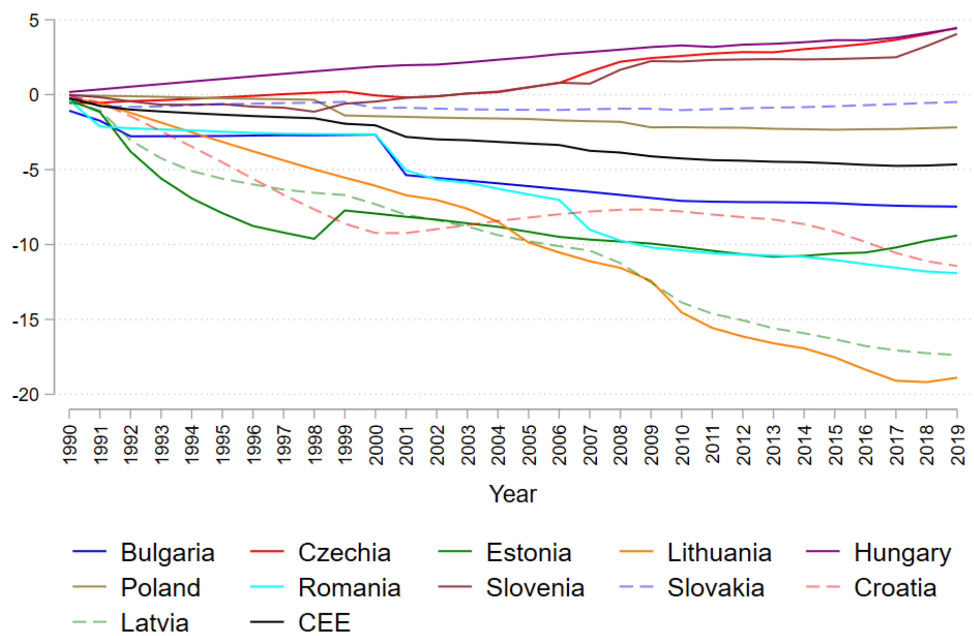
Source: EUROSTAT

Figure A3. Changing Life Expectancy in Central and Eastern Europe (1990-2019)



Source: EUROSTAT

Figure A4. Cumulative net migration from 1990 to 2019 (In percent of the population in 1990)



Source: Own calcuation based on EUROSTAT