Exploring the role of age structure in regional population change of the Visegrad Group

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Abstract: A caveat of much of the existing demographic literature is that it decomposes population change into the components of fertility, mortality, and migration, treating ageing merely as a consequence of natural change while neglecting the role of age structure in the observed dynamics. This study applies a scenario-based decomposition approach, using counterfactual scenarios for each factor of population change (fertility, mortality, migration, and age structure) to assess their individual contributions. The 37 NUTS-2 units of the Visegrád Group countries (Poland, Czechia, Slovakia, and Hungary) were selected as units of analysis. The research focused on the origins of regional differences and on the explanatory role of age structure. The results indicate that differences at the regional scale cannot be attributed solely to national-level variation, as cross-border groupings also emerge in the cluster analysis. Furthermore, the study demonstrates that initial age structure constitutes an independent and essential explanatory factor of population heterogeneity, both at the national and regional levels.

Keywords: demography, decomposition, Visegrad group, fertility, mortality, net migration, age structure

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Introduction

The Central Eastern European macroregion is a transitional region in many regards. Firstly, after the fall of the Eastern Bloc, the CEE countries transitioned from astate-socialist planned economy to market economy, from the Comecon to the common market of the EU (Svejnar, 2002; Kornai 2006). Secondly, it was one of the first macroregions to enter into the phase of second demographic transition (Sobotka, 2008; Lesthaeghe, 2010). This piqued the interest of many researchers, and for a good reason.

A substantial body of research has examined specific aspects of the demographic transition, including changes in fertility (Rodin, 2011; Sobotka, 2011; Frejka & Gietel-Basten, 2016), mortality (Carlson & Hoffmann 2011; Aburto & Van Raalte, 2018; Jasilionis et al., 2023), and migration (Okólski, 2004; Balaz & Moravčíková, 2017; Strockmeijer et al., 2019) as well as spatially focused studies (Sandu, 2024; Horeczki et al., 2025)

Moreover, many studies undertake the ambitious task of providing a general overview of post-socialist demographic processes (Fihel & Okólski, 2019a; Sobotka & Fürnkranz-Prskawetz 2020; Truskolaski & Bugowski, 2022; Deimantas et al., 2024). Despite their value, these studies share a common caveat: they disaggregate population change only into the components of fertility, mortality, and migration, often treating age structure separately – typically discussing aging mainly as a consequence of fertility and mortality patterns. Yet, as the concept of demographic momentum demonstrates (Keyfitz, 1971; Blue & Espenshade, 2011), populations with similar age-specific mortality and fertility rates but different age structures can exhibit markedly different crude birth and death rates, as well as distinct population dynamics. In contrast, a different approach – scenario-based decomposition – can explicitly reveal the role that age structure plays in observed population changes. Scenario-based decomposition relies on a stationary population model, and utilizes counterfactual scenarios for each factor of population movement (fertility, mortality, migration and age structure), which enables us to assess their individual contribution to the observed population change, including the interaction effects.

The NUTS-2 units of the Visegrád Group (Poland, Czechia, Slovakia, Hungary) were selected as units of analysis. These countries share a lot of similarities in their historical development:

- as emerging feudal kingdoms, they integrated into the Western, Catholic world;
- during the modern period, they became buffer states and were late to join the Industrial Revolution;
- after the Second World War they forcefully reoriented and integrated to the Eastern Bloc;
- they all joined the European Union at the 2004 enlargement.

However, there are also notable differences within the Visegrad Group. Slovakia and Hungary are characterised with a marked West-East slope of socioeconomic development, while this slope is not apparent in Poland and Czechia. Poland is a true polycentric country, with multiple populous regional centres, in accordance with Zipf's law. Czechia also leans toward polycentricity (with strong regional centres Brno and Ostrava besides Prague), while Hungary is a markedly monocentric country, with the second largest city (Debrecen) only 12% of the population of the capital city (Budapest). Hungary has a sizable kin minority outside its borders (most of them in lesser developed countries) which can serve as an immigration pool with no language barriers, while for Czechia, Slovak people may fulfil a similar role due to mutual intelligibility and ties from the Czechoslovakian era.

The four countries of the Visegrad Group comprise 37 NUTS-2 regions (Table 1). Recent adjustments include the division of Central Hungary into Budapest and Pest, as well as the split of the Masovian region into Warsaw metropolitan area and Masovian regional. These changes were primarily motivated by the aim of optimising EU funding absorption ability (Borkowski et al., 2021).

Based on the above, the paper addresses the following research questions:

1. When analysed at the NUTS-2 level, do regional demographic processes primarily reflect national trends, or can cross-country patterns also be observed?
2. What additional insights does scenario-based decomposition provide about the role of age-structure in the population dynamics of the Visegrad Group?

Code	**Name of the region**	**Code**	**Name of the region**
CZ	*Czechia*	*PL*	*Poland*
CZ01	Prague	PL21	Lesser Poland
CZ02	Central Bohemia	PL22	Silesia
CZ03	Southwest Czechia	PL41	Greater Poland
CZ04	Northwest Czechia	PL42	West Pomerania
CZ05	Northeast Czechia	PL43	Lubusz
CZ06	Southeast Czechia	PL51	Lower Silesia
CZ07	Central Moravia	PL52	Opole
CZ08	Moravia-Silesia	PL61	Kuyavia-Pomerania
HU	*Hungary*	PL62	Warmia-Masuria
HU11	Budapest	PL63	Pomerania
HU12	Pest	PL71	Łódz
HU21	Central Transdanubia	PL72	Świętokrzyskie
HU22	Western Transdanubia	PL81	Lublin
HU23	Southern Transdanubia	PL82	Subcarpatia
HU31	Northern Hungary	PL83	Podlaskie
HU32	Northern Great Plain	PL91	Warsaw metropolitan area
HU33	Southern Great Plain	PL92	Masovian regional
		SK	*Slovakia*
		SK01	Bratislava
		SK02	Western Slovakia
		SK03	Central Slovakia
		SK04	Eastern Slovakia

Table 1. Name and coding of the NUTS-2 regions of the Visegrád group. Source: elaboration of the authors based on the official nomenclature from Eurostat.

Methods and data

Understanding the drivers of population change requires methods that can disentangle the contributions of fertility, mortality, migration, and age structure. Traditional approaches often divide change into natural growth and migration (Fihel & Okólski, 2019b; Sobotka & Fürnkranz-Prskawetz, 2020) or focus on fertility and mortality through regression or decomposition analyses (Chaurasia, 2017; Kulkarni, 2021; Truskolaski & Bugowski, 2022). Retrospective scenario-based analyses have also been used to evaluate demographic impacts (Kippen & McDonald, 2000; Polizzi & Tilstra, 2024). Building on this literature, our study applies a scenario-based decomposition, introduced by Tóth (2025), that combines counterfactual scenarios based on a stationary population model with a decomposition method.

The novelty of this method lies in its ability to separately identify the roles of fertility, mortality, net migration, and initial age structure in observed population change, while ensuring that the sum of their contributions plus interaction effect exactly equals the total change. This framework, rooted in the stationary population model (De Santis & Salinari, 2023; Espenshade et al, 1982; Preston & Coale, 1982), allows us to treat scenario analysis as a decomposition exercise. Importantly, it can capture spillover effects across time (e.g., fertility shaping future cohorts) and across different demographic dimensions (e.g., migration influencing population through immigrants' descendants).

We employ a standard age- and gender-specific cohort-component projection model (Bijak et al., 2008; Potančoková et al., 2021; Tønnessen & Syse, 2023) to simulate population evolution over the study period. Counterfactual scenarios are constructed so that fertility is fixed at replacement level (NRR = 1), mortality is held constant at the rates observed at the beginning of the period, net migration is assumed to be zero, and the initial age structure is replaced by the stationary distribution from female and male life table of the starting year (Preston & Coale, 1982; De Santis & Salinari, 2023). In each scenario, the factor under consideration is modified according to these specific assumptions, while all other factors are kept as observed throughout the period.[3] The stationary population model (Espenshade et al., 1982; Parr, 2023) provides the analytical foundation, combining replacement fertility, constant mortality, zero migration, and stationary age structure to yield zero population growth. This ensures that when combined, the counterfactual scenarios balance out, permitting an additive decomposition.

Each factor's contribution is measured as the difference between the observed outcome and the projection under its respective counterfactual. The decomposition then consists of four terms — fertility, mortality, migration, and age structure — plus a residuum representing interaction effects. For example, when below-replacement fertility coincides with negative net migration, the resulting negative interaction effect stems from two sources: fertility's impact excludes those who emigrated, while migration's impact ignores the difference between observed fertility and replacement-level fertility. Considering this interaction is essential to preserve the mathematical consistency of the decomposition, even though its size is typically modest in our applications.

[3] This is the main difference compared to the method used by Andreev, Vladimíra Kantorová, and John Bongaarts (2013), as they apply a cumulative approach: each time they change a demographic factor to its stationary version, they retain the previously adjusted factors in their stationary form.

By focusing on ratios (e.g., age-specific fertility, mortality, and migration rates) rather than absolute numbers, the method distinguishes demographic behavior from the influence of age structure, which is treated as an independent factor. This is one of the key features that differentiates scenario-based decomposition from direct decomposition. In the latter, population change is broken down into the contributions of net migration and natural change (Fihel & Okólski, 2019b), with the latter sometimes further divided into births and deaths. Implicitly, the counterfactual in direct decomposition is a “no-birth, no-death” scenario, which explains why even very low fertility always appears as contributing positively to population growth, while mortality — regardless of its level — always reduces population size. The different approach leads to different outcomes as we will briefly demostrate in the result section.

The scenario-based decomposition method also links to the concept of population momentum. Whereas classical measures calculate the ratio of a stationary to an actual population (Frauenthal, 1975; Kim & Schoen, 1997), our approach evaluates the retrospective contribution of initial age structure to population change, thereby quantifying momentum within a defined period.

Applications should be interpreted relative to each country’s initial population size. Counterfactuals are partly universal (replacement fertility, zero migration) and partly country-specific (constant initial mortality, age structure from life tables). The scenario-based decomposition thus allows meaningful cross-country comparison. Its limitations include the inability to account for subgroup-specific demographic behaviors, such as fertility and mortality differences between immigrants and natives — a constraint common to counterfactual projection approaches.[4]. Another limitation, as Murphy (2021) highlights, is that results can be sensitive to the chosen base year. To handle this, we conducted the decomposition with an alternative starting point, and the results remained unchanged.

To address the second research question in a quantifiable manner, we used Ward’s hierarchical, agglomerative clustering method, where each merging step leads to the possible smallest increase of within-cluster variance. From the possible options, this method is favourable, because it enables a step-by-step analysis of whether national or cross-border groupings prevail in the earliest and final steps.

One of the downsides of the presented scenario-based decomposition is the steep data requirement. To perform the analysis, the following database was assembled for the 37 NUTS 2 regions, for the years of 2001-2023:

- the age structure of the population by age and sex,
- age specific death rates by sex
- age-specific fertility rates

The database consists of individual age entries up to 95 years, with ages 95 and above combined into a single category.

[4] However, a substantial literature has revealed the assimilation of immigrants and their descendants in fertility and mortality (Antecol & Bedard, 2006; Biddle et al., 2007), though more recent studies reveal considerable heterogeneity in these demographic behaviors (Kulu et al., 2019; Wilson, 2019).

Eurostat served as the primary data source. However, for certain years, age groups and regions of Poland, data is missing from Eurostat and have to been imputed with data from Statistics Poland (GUS). For the imputation of missing data, two approaches were used.

- When it was possible, the missing entries were transferred directly form the corresponding national data tables (e.g. deaths for 7 Polish regions 2004-2012, fertility data for 7 Polish regions 2002-2012). In total, 15 002 entries (4.3% of the total data points) were imputed directly from national data tables. In Appendix I. the related entries are highlighted in yellow.
- When direct imputation was not possible, imputation by proportional distribution was used: missing regional single-year values were imputed by distributing the regional 5-year age-group data according to the available national age-specific proportions. Population of 2001-2013 for 7 Polish regions, deaths of 2001 for all Polish regions, 2002-2003 for 7 Polish regions, and fertility of 2001 of 7 Polish regions were filled in using imputation by proportional distribution. 23454 missing entries (6.7% of the total data points) were filled in using this method, highlighted in red color in Appendix I.

Age-specific migration rates were imputed based on the observed natural movement and change of the population.

Results

Figure 1 presents a summary of the decomposition results at both the national level for the four Visegrad countries and the regional level across their 37 NUTS-2 regions. The counterfactual fertility scenario reveals that fertility levels have the strongest influence on population change among the examined components. In all four countries, TFR remained below the replacement level throughout the period. Czechia recorded the lowest TFR in 2001 (1.15) and the highest in 2021 (1.83). Aside from a brief uptick in the late 2010s, TFR generally fluctuated between the range of 1.2–1.5 births per woman, slightly below the EU average. Variations between the four countries were minimal regarding the impact of fertility on populatin change: the two ends of the spectrum being Czechia with a negative impact of 8.9% on the change in population, and Poland with a negative effect of 11.4%.

In contrast, changes in mortality had a positive impact across all countries. In 2001, life expectancy at birth was significantly lower in each country compared to the EU average (Hungary: 72.5 years; Czechia: 75.3 years). However, over the examined period, a notable catch-up occurred, with life expectancy rising significantly in all countries (Hungary: 76.7 years; Czechia: 79.9 years; EU-27: 81.4 years). The counterfactual mortality scenario suggests that the increase in life expectancy contributed to an approximately 3% surplus in population, with little variation among the four countries.

In contrast to the components of natural population change, the influence of migration differed greatly among the four countries. In Czechia, positive net migration contributed 7.3% — a surplus of 749 thousand people — to the population change during the examined period. In Hungary, the positive effect of migration was moderate (2%, or 244 thousand people), and close to zero in Slovakia. On the other hand, in Poland, net migration contributed negatively to the overall change, amounting to a loss equivalent to 3% of the 2001 population, or 1,138 thousand people.

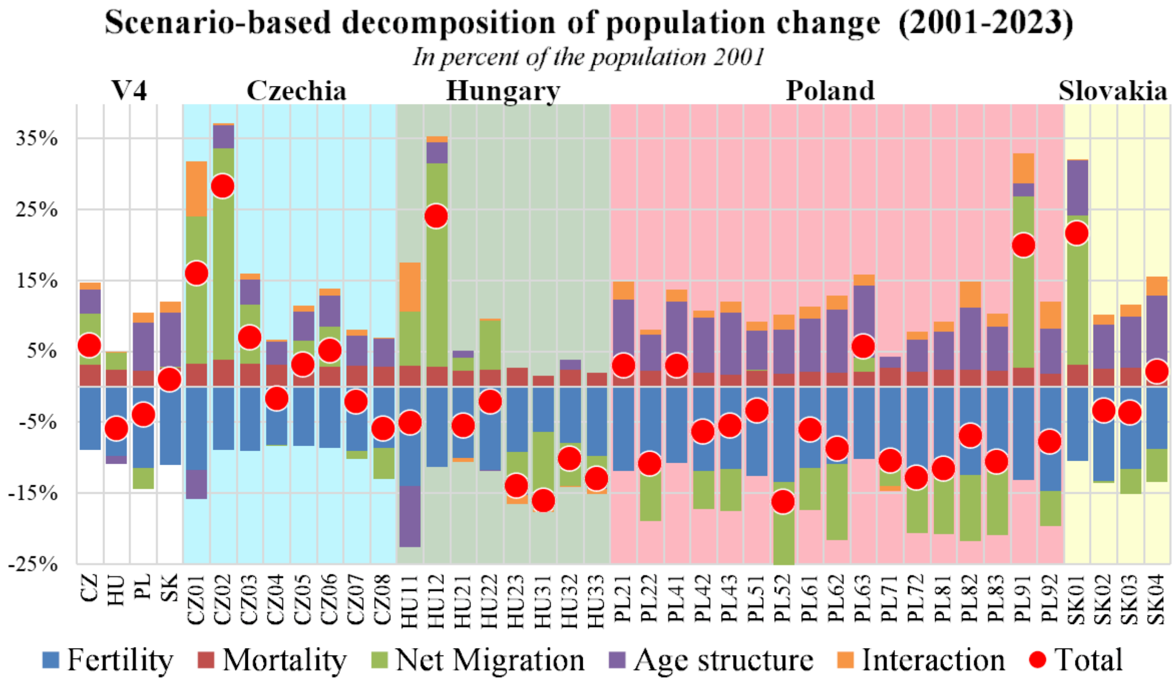

Figure 1. Results of the scenario-based decomposition. Source: Elaboration of the authors, based on data from Eurostat and GUS.

As discussed in the methodology, one of the key advantages of scenario-based decomposition over other approaches is its ability to explore the role of age structure in population change. The results indeed reveal significant differences between the four countries. In Slovakia and Poland, the populations were considerably younger than the derived stationary age structure at the beginning of the studied peroid, which means that this component had a positive effect on population change. In Poland, the 6.8% contribution translated to an additional 2.6 million people by 2023. In Czechia, the positive contribution was more moderate. Among the four countries, Hungary had the most aged population, exceeding the stationary age structure, and therefore, the initial age structure contributed negatively to population change.

Compared to the national level, NUTS-2 regions exhibit significantly greater variance, even if this is not immediately apparent from the components of natural population movement. At the regional level, fertility rates have remained uniformly below the replacement level. In some peripheral regions (e.g., HU31: Northern Hungary, SK04: Eastern Slovakia), fertility decline lagged behind the national trend, resulting in a comparatively smaller negative contribution from this component (Potančoková, et al., 2008; Őri & Spéder, 2012). At the other end of the spectrum, some metropolitan regions[5] (e.g., CZ01: Prague, HU11: Budapest) exhibit fertility rates that are lower than the national average.

[5] In this paper, we refer to regions encompassing the national capitals and/or their surrounding agglomeration zones as "metropolitan regions." Alternative delimitations – such as the classification of predominantly urban regions, Functional Urban Areas, or NUTS-3 metropolitan areas – could arguably extend the scope of what is considered metropolitan. However, in the present analysis, only the capital city regions display demographic trends that diverge markedly from those of the rest of the country. For this reason, we find the term "metropolitan region" appropriate for the purposes of our research focus.

Since life expectancy has increased in all regions during the examined period, the mortality component contributed positively to population change across all regions. However, some divergence is also observable: life expectancy rose more markedly in metropolitan regions (CZ01: Prague, CZ02: Central Bohemia, HU11: Budapest, HU12: Pest, PL91: Warsaw metropolitan area), and its positive effect on population change was more significant.

As might have been expected, net migration exhibits the highest degree of variance. Migration surpluses are concentrated in metropolitan areas (CZ01: Prague, CZ02: Central Bohemia, HU11: Budapest, HU12: Pest, PL91: Warsaw metropolitan area, SK01 Bratislava), where migration has contributed to population increases of up to 30%. In contrast, most non-metropolitan regions experienced either a net-zero effect from migration or, in some cases, a significant negative contribution — adding more than 10% to population decline in certain regions (e.g., PL52: Opole).

It is particularly notable that age structure also exhibits a high degree of variance. While the contribution of this component — driven by the difference between the observed and stationary age structure at the starting year — was negative for Hungary at the national level, this was only true for Budapest at the regional level, where the population is older due to selective migration to the surrounding Pest County. The same pattern is observable in Prague. Furthermore, significant differences in the role of age structure are evident among non-metropolitan regions as well — a phenomenon most pronounced in Poland.

A key focus of the study is whether demographic trends at the NUTS-2 level primarily reflect national-level differences or whether cross-border patterns also emerge. To provide a clearer picture, the results are also presented in a 3D scatterplot (Figure 2., Appendix II). The others component was omitted, as well as mortality since that shows the least variance. The scatterplot reveals a clear separation between metropolitan regions with high net migration and the rest of the NUTS-2 regions, which appear more closely clustered together. Country-specific groupings are also observable — for example, in the case of Poland.

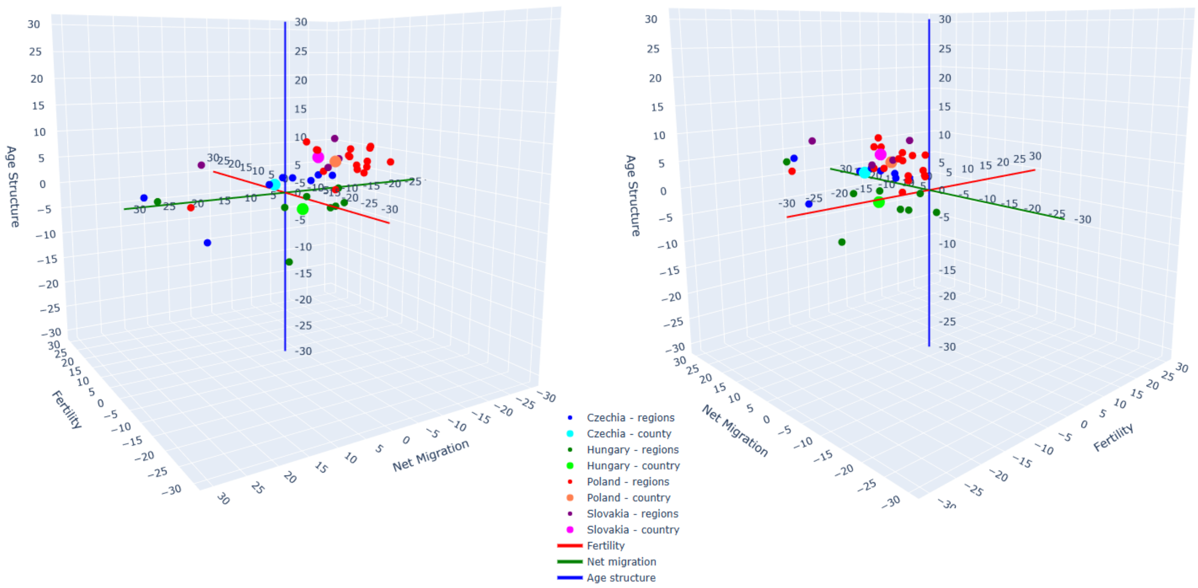

Figure 2. 3D scatterplot of the components of demographic change. (See Appendix II). Source: Elaboration of the authors, based on data from Eurostat and GUS.

Cluster analysis is an appropriate method for quantifying the distance between regions. Mortality, fertility, net migration, and age structure were used as input variables, while the interaction component was omitted from the analysis. The selected hierarchical clustering method — Ward's method — allows for the examination of each individual merging step. Merging is based on squared Euclidean distance. At the initial stage, each NUTS-2 region forms its own cluster consisting of a single unit (indicated in white). The first regions to merge are located within the same country: Lublin and Podlaskie voivodeships, two peripheral regions in eastern Poland. However, by the third step, a cross-border cluster emerges—Western Slovakia and Lower Silesia.

In the subsequent steps of the clustering process, both cross-border and within-country clusters emerged. One cluster includes several regional centres of Poland — Pomerania (Gdańsk), Lesser Poland (Kraków), and Greater Poland (Poznań) — reflecting the country's polycentricity. Another cluster comprises two post-industrial regions undergoing economic transition: Łódz in Poland and Moravia-Silesia in the Czech Republic. This group also includes the Northern Great Plain in Hungary, which similarly represents a crisis-prone area. Additionally, a cluster emerged that includes Central Bohemia and Pest, both metropolitan regions surrounding Prague and Budapest, respectively. These areas function as suburban zones and destinations for outward migration from the capitals.

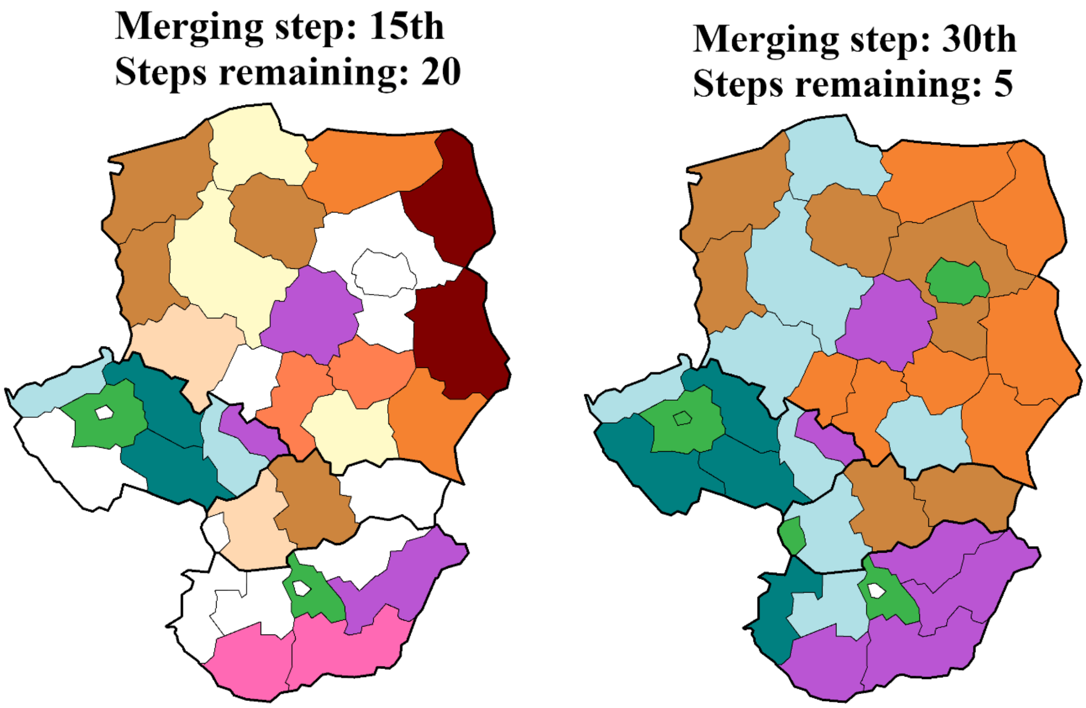

Figure 3. Results of the cluster analysis – cluster configuration at the 15th and 30th merging steps. Source: Elaboration of the authors, based on data from Eurostat and GUS.

The seven-cluster configuration contains two national and five cross-border clusters (Figure 4):

Cluster 1 - metropolitan regions (except Budapest): This cluster is characterised by the huge positive effect of the net migration on population changes. During the following merging steps, the cluster of metropolitan regions remains separate from the other clusters till the very end, providing further support for the initial impression (Figure 2), that the population dynamics of metropolitan regions markedly differ from the rest of the Visegrád Group.

Cluster 2 – Budapest: While a metropolitan area with a sizable net migration gain, Budapest is divided from the rest of the metropolitan areas by its unfavourable initial age structure contributing negatively to overall change. This phenomenon is unique amongst the clusters, and Budapest remains on its own until the merging step resulting four clusters.

Cluster 3 – Dynamic Czech and Hungarian regions: This cluster contains non-metropolitan regions which boast a sizable net migration surplus due to their successful economic restructuring and proximity to more developed neighbours.

Cluster 4 - Polish regional centres and moderately dynamic regions: This cluster is separated from the former one by its migration balance. Instead migration, a younger age structure contributes positively to the overall population change.

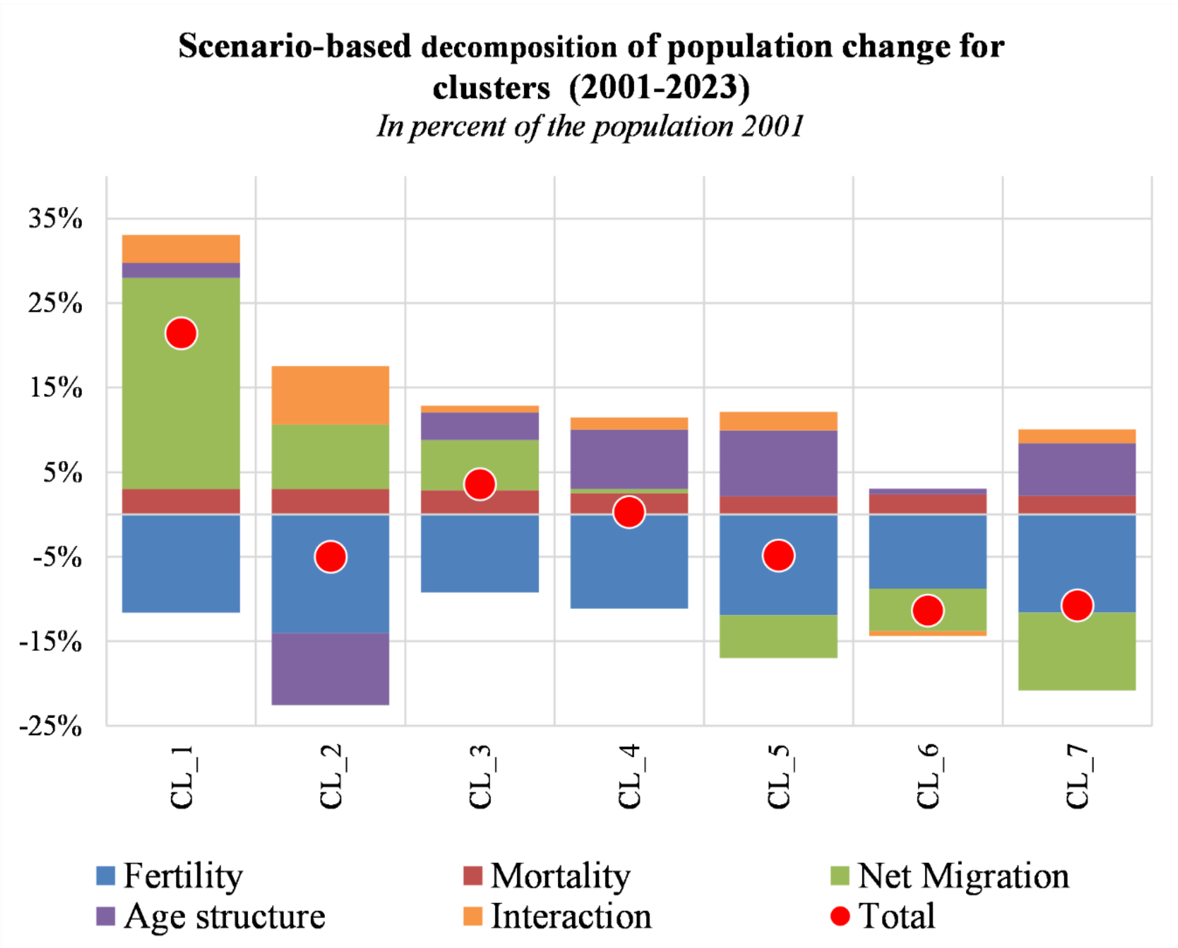

Figure 4. Scenario-based decomposition of the seven-cluster configuration Source: Elaboration of the authors, based on data from Eurostat and GUS.

Cluster 5 - Polish inner peripheries, Central and Eastern Slovakia: In contrast to the clusters presented earlier, migration loss contributes negatively to overall changes in the population. The negative effect of fertility and net migration is only partially offset by favourable age structure, and this cluster is characterised by population loss.

Cluster 6 -lagging regions of Hungary + industrial regions in transition: This region contains the lagging regions in Hungary, as well as two traditional industrial centres (Łódź and Ostrava). Similarly to Cluster 5 and 7, this cluster is also characterised by migration loss, however its effects are not even partially offset by favourable age structure, resulting in a more significant total loss.

Cluster 7 - Polish outer peripheries: This cluster only contains Polish regions from the Eastern part of the country. This cluster will merge with Cluster 5 in the next step. The main difference between these two cluster is that the negative effect of migration on population change is more significant in Cluster 7.

After the overview of the seven clusters, we can conclude that neither mortality, nor fertility turned out to be a distinctive dimension, and clusters are mostly differentiated based on the contribution of age structure and migration to the change of population.

As we could see, with a few exceptions, age structure played a favourable role in the change of population, thus underlining the significance of population momentum. However, positive divergence from stationary age structure is a temporary, non-stable component of population momentum, which weakens through time, as the population is getting closer to stationary age structure (Espenshade et al., 2011). Examining the contribution of age structure with dividing it into two time period (2001-2011 and 2012-2023) reveals its diminishing effect (Figure 5.) The results indicate that the positive contribution of age structure was much higher in the first half of the examined period, and later significantly reduced. In Czechia and Hungary, age structure still had a positive contribution in the first period, but as the actual age structure caught up with the stationary age structure, this advantage disappeared, and the more aged society started to exert a negative effect on the overall change of population.

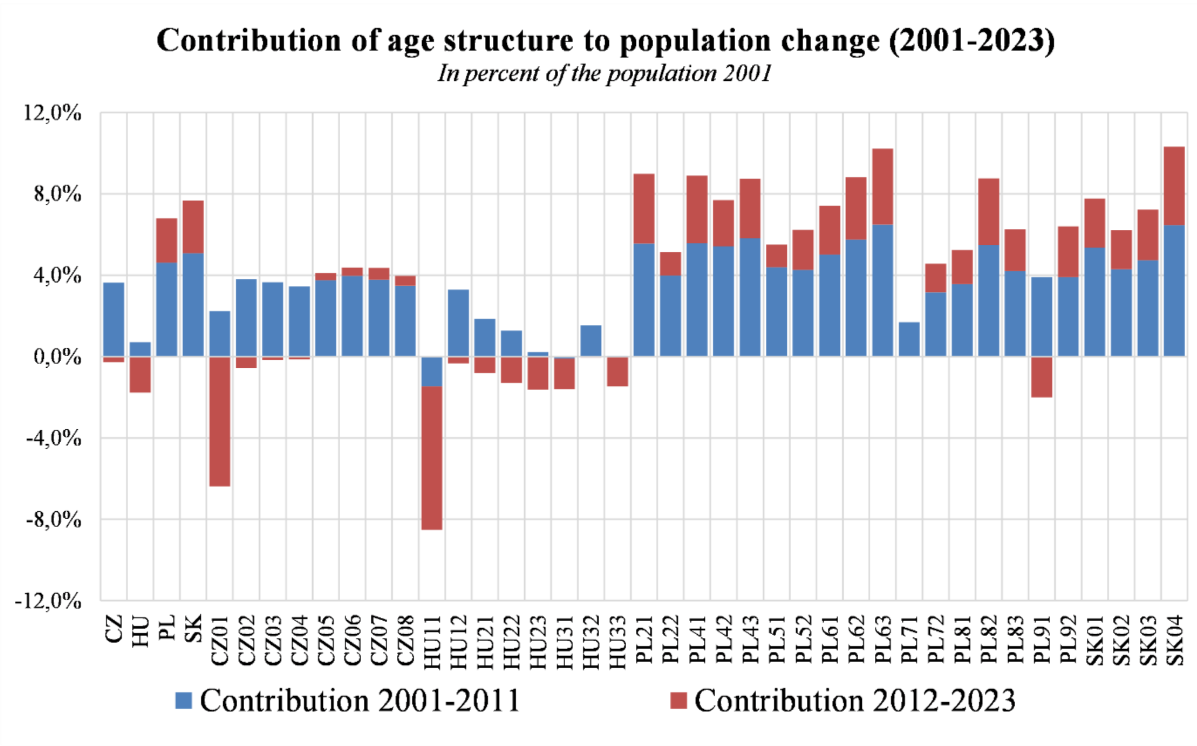

Figure 5: Contribution of age structure to population change, divided into two periods. Source: Elaboration of the authors, based on data from Eurostat and GUS.

Scenario-based decomposition provides additional insights compared to the commonly used direct decomposition method. Applying direct decomposition to the same country-period setting (Appendix IV) helps illustrate the key differences between the two approaches. In direct decomposition, because it measures changes relative to a "No Birth, No Death" baseline, fertility (births) consistently contributes positively and mortality (deaths) negatively to population change. In addition, this method tends to obscure changes that occur over the study period, as well as spillover effects across time and between demographic components — for example, how variations in fertility influence subsequent generations. Moreover, in direct decomposition, the effect of age structure is implicitly embedded within the number of births and deaths. In contrast, scenario-based decomposition uses age-specific rates, allowing for a more explicit identification of the contribution of the initial age structure to population change.

Conclusions

This study has examined regional population change across the Visegrád Group (Czechia, Hungary, Poland, and Slovakia) over the period 2001–2023, a macroregion where demographic processes remain deeply shaped by the legacies of transition and ongoing integration into the European Union. Investigating population dynamics at the NUTS-2 level enables the identification of patterns that are often obscured at the national scale, providing new insights into the heterogeneity of demographic change within and across these countries. Such an approach is particularly relevant in light of the persistent challenges posed by low fertility, population ageing, and unequal migration trends.

The analysis was guided by two main questions: first, whether regional demographic trajectories primarily reflect national-level dynamics or whether cross-border similarities can also be identified; and second, what additional understanding can be gained by explicitly quantifying the role of age structure. To this end, we combined a scenario-based decomposition framework that separately identifies the contributions of fertility, mortality, migration, and initial age structure, with hierarchical cluster analysis to capture cross-regional similarities in the drivers of demographic change.

The results reveal that demographic developments at the NUTS-2 level cannot be reduced to national differences alone. While country-specific groupings were visible, the cluster analysis also identified clear cross-border clusters. Examples include the grouping of Polish and Czech post-industrial regions together with several lagging Hungarian regions, as well as the cluster formed by suburban zones around Prague and Budapest. Metropolitan regions consistently stood apart from other clusters due to their strong migration surpluses, whereas in other clusters, younger age structures played a decisive role in shaping population outcomes. Overall, the clustering results show that both migration and age structure were the main forces differentiating regions, whereas fertility and mortality contributed far less to regional divergence.

The study further demonstrates that initial age structure constitutes an independent and essential explanatory factor of population heterogeneity, at both the country and regional levels. Younger populations, particularly in Poland and Slovakia, benefitted from demographic momentum that amplified growth, while Hungary's more aged structure exerted a drag on population change. A striking case is provided by metropolitan regions such as Prague and Budapest, where the relatively old age composition partly offsets the otherwise strong population-increasing effect of net migration. Conversely, peripheral or younger regions clustered together across borders due to similar age-structural advantages, underlining that population momentum — just as much as migration — explains regional divergence. Fertility remained below replacement throughout the period, while mortality improvements contributed modestly and consistently to population growth. Taken together, these findings show that regional population change in the V4 between 2001 and 2023 was shaped not only by fertility, mortality, and migration, but also decisively by age structure. Importantly, however, the positive contribution of favourable age structures proved temporary, decreasing between 2001–2011 and 2012–2023, which highlights the fleeting nature of demographic momentum as populations converge toward older stationary age distributions.

From a policy perspective, these results suggest that while migration remains the most direct lever to mitigate regional population decline, strategies cannot overlook the independent role of age structure. Regions currently benefitting from youthful populations will gradually lose this advantage, making it crucial to anticipate the erosion of demographic momentum. At the same time, the relative disadvantage of ageing metropolitan regions highlights the need for policies that address both selective migration patterns and the long-term challenges of demographic ageing.

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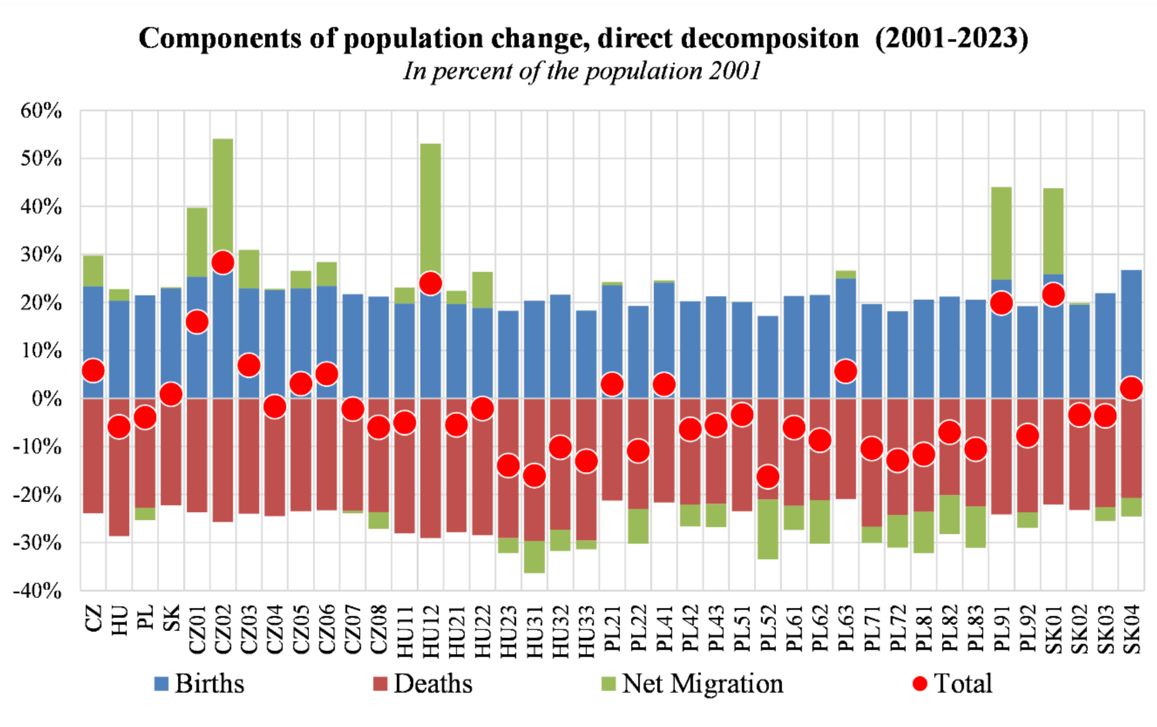
Appendix I. Data table for scenario-based decomposition after imputation of missing entries. Source: Eurostat and GUS. See attachment.

Appendix II. 3D scatterplot of the components of demographic change. Source: Elaboration of the authors, based on data from Eurostat and GUS. See attachment.

Appendix III. Results of the cluster analysis, GIF of the merging steps. Source: Elaboration of the authors, based on data from Eurostat and GUS. See attachment.

Appendix IV: Components of population change based on direct decomposition. Source: Elaboration of the authors, based on data from Eurostat and GUS.



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