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GEOSCAPE

# A spatiotemporal analysis of ageing trends in Slovakia and their societal implications

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## Abstract

This study examines the changing age structure in Slovakia and ageing process, analyzing district-level data from 2001, 2010, and 2020. The research highlights significant ageing trends across most Slovak districts. These demographic changes have profound implications, including potential labor shortages, increased demand for healthcare and social services, social isolation, pension system strain, and shifting housing needs towards older adults. Understanding these trends and regional variations is vital for effective planning and provision of education, social services, and healthcare for diverse age groups in Slovakia. Our research underscores the complexity of implementing effective measures to mitigate the consequences of demographic ageing, given the regional disparities in ageing intensity. This study offers valuable insights for optimal planning. The challenges identified, such as financing social and healthcare systems and supporting vulnerable groups, are not unique to Slovakia but are shared by many countries undergoing similar demographic transitions. By examining Slovakia's approach, we contribute to the broader discourse on demographic ageing and highlight the need for future research to focus on comparative studies between regions and countries. This will help identify best practices and innovative solutions that can be adapted to various socio-economic contexts, fostering international collaboration and informed policy-making to address the global impact of ageing populations.

**Highlights for public administration, management and planning:**

- Changes in the proportions of age groups have taken place in Slovakia. This will have many economic, social, health, cultural and political consequences and will increase the economic burden on the productive age group.
- The representation of the main age groups is regionally differentiated and adaptation to the different developments in the proportions of these age groups in different regions is crucial for decision-making processes at the level of local authorities and public administration.
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- An important factor in the changes in the age structure is the speed of these changesand its spatial differentation. Some districts (e.g. Bratislava I and III) had low growth dynamics in the post-productive age group, other (e.g. Bratislava IV, Dunajská Streda, Banská Bystrica, Poprad, Košice II, III and IV) are characterised by a dynamic ageing trend.

**Keywords**

Age structure, Population aging, Districts of Slovakia, Ossan triangle

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## 1 Introduction

Changes in population development lead to natural changes in age structure and demographic aging. Addressing the challenges and opportunities of population ageing is crucial for both academic researchers and policymakers due to its far-reaching implications for societies worldwide. These changes can significantly affect the social, economic, and political situation in each country. The effects can be advantageous or disadvantageous, contingent on particular modifications in the population composition.

The increase in life expectancy and demographic aging were initially viewed as a positive outcome, however, economic implications have since been recognized. Nevertheless, the extension of human life expectancy can be considered one of the most remarkable achievements of the 20$^{th}$ and 21$^{st}$ centuries (Piscová et al. 2015). Population ageing is a result of two primary trends: the rise in life expectancy and the decline in fertility rates. It is typically associated with an improved quality of life and decreased mortality intensity, and is directly linked to advancements in healthcare and population health (Mládek et al. 2018).

Changes in age structure have a significant impact on various aspects of society, including the overall quality of life, labor resources, aggregate demand, consumption, and social policy as noted by Heczko (2013). Research into demographic trends helps to predict future societal changes and inform policy decisions. For instance, studies on the demographic transition in various countries illustrate how shifts in birth and death rates impact population structures (Bloom et al. 2010). These shifts have profound implications for labor markets, economic growth, and social services.

The ageing population increases the demand for healthcare services, driving research into age-related diseases, healthcare infrastructure, and innovative care models. The World Health Organization (WHO) has emphasized the need for healthcare systems to adapt to the growing number of elderly individuals. Research focuses on chronic diseases, geriatric care, and the development of age-friendly health services. Innovative approaches, such as telemedicine and integrated care models, are being explored to improve healthcare delivery for the elderly (WHO 2015). It is essential to monitor these transformations as they can lead to modifications in social and economic organisation, increased demand for healthcare and social support, and altering needs of individuals across their lifetime and successive generations (De Mello 2021; Cristea et al. 2020).

Ageing affects social structures, including family dynamics, intergenerational relationships, and community cohesion. Scholars study these changes to understand how societies can adapt and thrive. For example, the shift towards smaller family units and the increasing number of single-person households among the elderly require new social policies and support systems. Population ageing has positive impacts on society, such as augmented participation in community life, amplified knowledge and expertise, or more significant intergenerational solidarity (Smrčka & Arltová 2012).

Ageing affects labor supply, productivity, and economic growth. Research in this area focuses on the potential economic consequences and explores strategies to mitigate negative effects. Studies highlight the need for policies that support older workers, promote lifelong learning, and encourage delayed retirement. Additionally, the impact of ageing on public finances, particularly pension systems, is a critical area of research, guiding reforms to ensure sustainability (OECD 2023). To guarantee the sustainable functioning of the national economy, it is necessary to prepare for its social and economic impact ahead of time, as only then can measures be comprehensive, conceptual, and effective.

As a country in Central Europe, Slovakia is experiencing demographic shifts that mirror trends seen across many developed nations. By examining Slovakia, researchers and policymakers can gain insights into the broader regional and global challenges and opportunities associated with an ageing population. Slovakia's population is ageing rapidly due to declining birth rates and increasing life expectancy. This shift is leading to a higher proportion of elderly individuals within the population. According to the census, the proportion of the population aged 65 and over has risen from 13.4% in 2001 to 17.9% in 2021. This trend is predicted to persist over the next few decades, with the proportion of the elderly expected to reach 25% by 2050. Slovakia has been grappling with regional disparities for a considerable time, particularly when compared to the capital and its environs, as well as the northern and eastern regions of the nation. These differences persist across several levels, including demographic variations (Škrovánková 2017). Slovakia exhibits considerable spatial disparities in its population distribution, with most inhabitants being clustered in the western region of the nation.

The Bratislava region and other areas in western Slovakia exhibit a higher population density and proportion of young people. In contrast,

 

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the eastern part has a lower population density and an older demographic. The spatial differences are the result of historical and economic factors, with economic growth and development being more pronounced in the western part (Ďurček & Šuvada 2015).

The purpose of this study is to examine the temporal and spatial modifications in the age structure of 79 districts in Slovakia between 2001, 2010, and 2020. Specifically, this research focuses on pre-productive (0–14 years), productive (15–64 years), and post-productive (65 years and older) age groups in terms of economic activity in order to identify regional disparities and changes at the district level.

The ageing population impacts Slovakia's economy, influencing labor markets, productivity, and economic growth. An older population demands more from the healthcare system. The social fabric of Slovakia is changing as families adapt to a diffrent demographic regime. This includes shifts in living arrangements, caregiving roles, and intergenerational relationships.

In regards to spatiotemporal transformations and their effects, we pose the following questions: Which regions have the lowest and highest growth rates for the post-working age group? Which regions show a more moderate or dynamic aging trend? How do these changes impact society?

## 2 Regional context: age structure, demographic changes and regional differences

The enduring development of the population structure in Slovakia demonstrates a prolonged narrative of migration and demographic transformations. Before World War II, Slovakia was part of Czechoslovakia and had a mostly rural population. Subsequent to the War, however, the country underwent rapid industrialisation and urbanisation, facilitating significant transformations in the population's structure. During the post-war years, Slovakia's population experienced significant growth, with a notable increase in the proportion of urban residents. In the aftermath of World War II, Slovakia boasted one of the youngest populations in Europe. This increase was a result of various factors such as economic progress, better healthcare, and reduced mortality rates. The proportion of residents in post-productive age for every 100 residents in the pre-productive stage was 17 in 1945. This number rose to 65 in 2009 (Bucher 2010) and further to 92 in 2021 (data sourced from SOE 2022). During the same period, the proportion of individuals in the pre-productive stage (0-14 years) declined from 31.5% in 1961 to 15.9% in 2021, while the post-productive age component increased from 7.0% to 17.1% (Table 1). From 1961 to 1991, this component accounted for a quarter or more of the entire population.

**Table 1** Population structure in Slovakia by age group (%).

| year | 0–14 | 15–64 | 65+ |
|---|---|---|---|
| 1961 | 31.5 | 61.5 | 7.0 |
| 1970 | 27.2 | 63.6 | 9.2 |
| 1980 | 26.1 | 63.5 | 10.4 |
| 1991 | 24.9 | 64.8 | 10.3 |
| 2001 | 19.0 | 69.5 | 11.5 |
| 2011 | 15.3 | 72.0 | 12.7 |
| 2021 | 15.9 | 67.0 | 17.1 |

(Statistical office of the Slovak Republic 2022)

The decline in fertility and birth rates constitutes a substantial influence on the structure of Slovakia's population. The aggregate fertility rate in Slovakia fell from 1.44 in 2000 to 1.30 in 2020, which falls significantly below the simple replacement rate of 2.10. Recent data from Šprocha et al. (2019) and Zeman et al. (2018) demonstrate a trend of stabilizing fertility rates between 2011 and 2021. Declining fertility rates have contributed to an ageing population, which in turn has significant implications for the country's workforce and future economic growth. Upon examining the post-productive demographic (65 years and over), a 10 percentage point increase in this group's proportion of the total population has been observed between 1961 and 2021.

The country is highly internally diverse, with the regions of northern and eastern Slovakia having the youngest age structure. Vaňo (2015) identifies significant regional differences, pointing out the changes caused by the second demographic transition during the 1980s and 1990s. This event resulted in drastic transformations in family and reproductive trends. These changes are strongly associated with variations in marriage, divorce, fertility, total fertility, mortality, abortion, and both natal and migratory expansion. Furthermore, Šprocha et al. (2019) explored district-level variations in demographic characteristics such as average age and made predictions up to 2040. The authors highlight that regional disparities not only result from but also contribute to socioeconomic disparities within a country. The findings reveal an unfavourable trend in Slovakia's age structure that will impact all districts of the nation in the com-

 

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ing years. This is partly attributable to the fact that the robust cohorts of women born in the 1970s have reached the end of their reproductive lifespan while the smaller cohorts of women born in the 1990s are starting to reach their reproductive years. Following analysis of age structure and reproductive behavior characteristics outlined in previous studies, several precise regions in Slovakia can be identified. One region that stands out is the capital, Bratislava, and its surrounding districts. Bratislava exhibits the highest mean age, yet boasts a comparatively favourable old age index and above-average life expectancy. It also presents significant recuperation of fertility and is rich in migratory income, similarly to neighbouring districts affected by the suburbanisation trend. The second homogeneous area comprises a large part of western and central Slovakia, with a higher average age and age index, and stable low migration flows. The third homogenous region comprises the eastern part of the country, which exhibits the highest total fertility rate and, conversely, the lowest average age and old age index. Additionally, the region experiences a predominantly negative migration balance, except for Košice. The last fourth region consists of southern Slovakia and the peripheral part of the northern and eastern parts of the country with the highest mortality and emigration intensity and with a rather younger age structure (Bucher 2010; Šprocha et al. 2019).

## 3 Data and methods

We utilized data from the publicly available database of the Slovak Statistical Office, known as DATAcube. The data consistently refers to December 31 of each calendar year. The analysis of changes in the age structure was conducted over a twenty-year period, spanning from 2001 to 2020. This specific timeframe was selected to evaluate alterations that occurred after the transformative changes of the 1990s had subsided. The standard method of categorizing the population by economic groups was adopted, with age ranges of 0–14 years categorized as pre-productive, 15–64 years as productive, and 65 and over as post-productive. These definitions align with guidelines from Eurostat and the UN, with ages 15 and 65 established as the boundaries of the working-age population (Kashnitsky et al. 2017). Using the Ossan triangle method, we assessed the proportion of individuals in each of the primary age (economic) groups residing in the districts (Local Administrative Units; LAU1) of the country for the years 2001, 2010, and 2020. This approach utilizes an equilateral triangle for observing the population structure, and alterations in this structure are represented by three coordinates (Mládek et al. 2018). Each side of the triangle serves as an axis in the coordinate system, defining an element of the structure. This technique proves advantageous in assessing the primary age groups (Voženílek & Kaňok 2011). Each side of the triangle represents a percentage from 0 to 100, indicating the proportion of the respective age group in the overall population. Changes in the proportions of age groups are evaluated using indices: the ageing index (the ratio of age groups 0–14 years to 65 and over), the green dependency ratio (the ratio of age groups 0–14 years to 15–64 years), and the grey dependency ratio (the ratio of age groups 65 and over to 15–64 years). For these indices, changes during the period 2001-2020 are assessed using the average rate of increase, and regional changes at the LAU1 level are visualized in cartograms.

Subsequently, cluster analysis was employed to identify LAU1 with the highest degree of similarity, which were then grouped into clusters. Cluster analysis is a statistical method that operates on multiple variables. We utilized cluster analysis to examine spatial disparities and changes in age structure over the period 2001 to 2020, based on the calculated average growth coefficients of the pre-productive, productive, and post-productive age groups. We implemented the agglomerative clustering method to subdivide the data into several groups containing elements with similar variable values. Within clusters, the values of objects for each variable should be as homogeneous as possible, while the differences between clusters should be as large as possible (Hendl 2012). The goal is to balance inter-cluster and intra-cluster variability. Every object must belong to a single cluster with certainty. We implemented hierarchical clustering, whereby clusters are formed gradually through individual steps. The total number of clusters equals n=1 (Hebák 2013). Distance measurements were performed using the square of Euclidean distance to evaluate the similarities among the groups:

$$\sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \tag{1}$$

A distance matrix is generated between objects, enabling the closest elements to cluster together. The clustering process continues until the formation of a complete cluster is achieved, using a distance matrix between individual object pairs as the primary basis. Clustering was carried out using the Ward method, which employs variance calculation for each pair of elements at every step. Clus-

 

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ters are formed by merging pairs with the lowest variance sum until all objects merge into one cluster (Hendl 2012). The optimal number of clusters was determined based on the distance matrix and graph of individual object connections (Hebák 2013).

## 4 Results

### 4.1 Spatio-temporal shifts in age structure across Slovak districts

In this section, we examine alterations in Slovakia's age distribution and offer a more comprehensive exploration of the shifts at the district level (Fig. 1). Objective analysis reveals significant changes in the population's age structure, as demonstrated by the graph. We will further elaborate on these changes in subsequent paragraphs. In 2001, Slovakia's population consisted of 18.9% pre-productive individuals aged 0–14 years, 69.5% productive individuals aged 15–64 years, and 11.6% post-productive individuals aged 65 years and above. The proportion of individuals within the age bracket of 0–14 years (pre-productive) in the districts of Slovakia during the same year varied between 16% and 22%, while it ranged from 65% to 72% for the age range of 15–64 years (productive), and 8% to 17% for individuals aged 65 and over (post-productive).

In 2010, there was a partial alteration at the national and district levels. The share of pre-productive segment of the populace at the national level was 15.4% in 2010, which saw a decrease of almost four percentage points compared to 2001. In contrast, the productive cohort accounted for 72.1%, showing an increase of three percentage points, while the post-productive category increased by one percentage point to 12.5%. The district-level values underwent a change in their ranges across age groups. For the 0–14 age group, the population percentage was between 11% and 24%; for the 15–64 age group, it ranged from 67% to 82%; and for the 65 and over age group, it fell within 5% to 18%. In 2020, a significant shift occurred within the post-productive category, where the proportion of the population aged 65 and over was 17.2%, exhibiting an almost 6-percentage point surge in contrast to figures recorded in 2001. Conversely, the pre-productive group, compared to figures from 2010, remained stagnant at 15%. The sole decrease observed between 2010 and 2020 is within the productive demographic, with the proportion of individuals falling to 67.1%, a figure inferior to that documented in both 2001 (69.5%) and 2010 (72.1%).

In 2001, the age structure of Slovak districts displayed significant inconsistency, as depicted in Fig. 1. There is a notably higher proportion of the post-productive division in Bratislava I and Bratislava III suburbs, which simultaneously report a below-average ratio of individuals aged 0–14. Stará Ľubovňa constituted another distinct cluster, showcasing below-average representation of post-productive individuals and an above-average proportion of the pre-productive group. In contrast, the Bratislava V and Košice III districts had a significantly lower share of individuals aged 65 and over, accompanied by a low share of the pre-productive group.

Comparing data from 2010 and 2001, it becomes clear that the ageing trend in Slovakia is intensifying with a rise in the percentage of residents aged 65 and older in most districts. At the same time, it is evident that the age structure of most districts in Slovakia has merged as they have formed a relatively homogeneous cluster. The only outlier is the Bratislava I district with a consistent share of the post-productive age group higher than average and a share of the pre-productive age group lower than average. In addition, there were other districts with a habitually low proportion of the post-productive component, including Námestovo, Sabinov, and Kežmarok. Námestovo, Sabinov and Kežmarok still had a high percentage of the pre-productive group, whereas Bratislava V and Košice III had a low percentage.

In 2020, the distributions of the main age groups underwent further changes, resulting in a slightly more diverse age structure compared to 2010. There was a further decline in the pre-productive and productive age categories, offset by an increment in the proportion of the post-productive cohort. The regions of Bratislava I and Košice IV, which have a higher proportion of the post-productive age group than average, held a unique position. Conversely, the Čadca and Snina districts displayed a lesser proportion of individuals aged 65 and above, alongside a reduced percentage of the pre-productive cohort. By contrast, the Námestovo, Kežmarok, Sabinov, Senec, and Gelnica districts showed a lower proportion of post-productive individuals, but a higher-than-average share of the 0–14 age group (Fig. 1).

Trends in age structure can be summarised as follows:

The most significant change over time has been the increase in the post-productive age group by approximately 6 percentage points (p.p.) between

 

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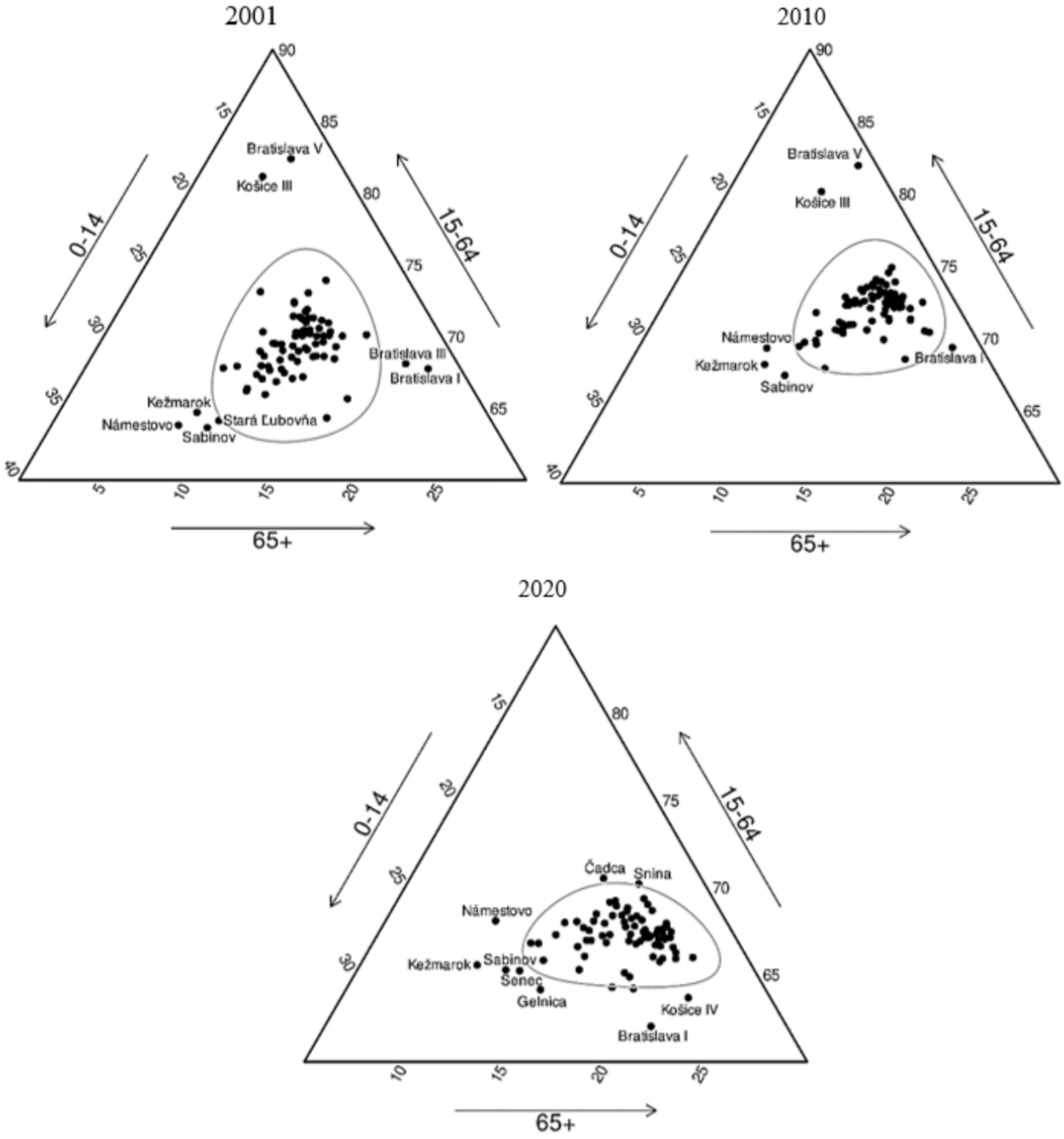


**Fig. 1** Distribution of pre-productive, productive, and post-productive age groups in Slovakia's LAU1 regions in 2001, 2010, and 2020 (%); (Statistical office of the Slovak Republic (DATAcube) 2022; own work)

2001 and 2020. However, the change between 2001 and 2010 was not as substantial as the acceleration in growth rates between 2010 and 2020. This is also evident in the values of the average rate of increase grey dependency ratio in the period 2001 2020 (Fig. 2).

The percentage of individuals in the pre-productive age group has declined by approximately 3 points over time, with a more significant drop occurring between 2001 and 2010. The value has since remained stagnant between 2010 and 2020. The change in the green dependency ratio is visualized by the values of the average rate of increase in the period 2001–2020 (Fig. 3) and the change in the aging index for the same period (Fig. 4)

In contrast, the share of the productive group has exhibited the least change and primarily saw the unification of regional disparities in 2020.

 

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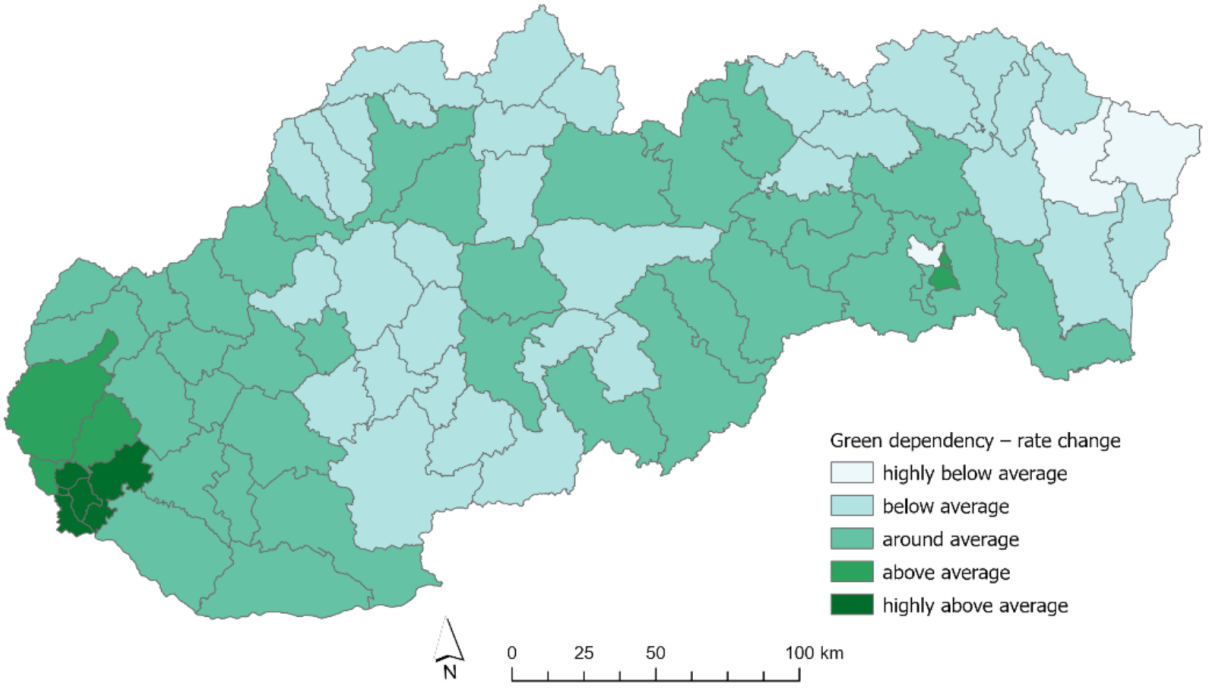


**Fig. 2** Green dependency ratio (the ratio of age groups 0–14 years to 15–64 years) in Slovak LAUs1 average rate of change during the period 2001 2020 (absolutely); (Statistical office of the Slovak Republic (DATAcube) 2022; own work)

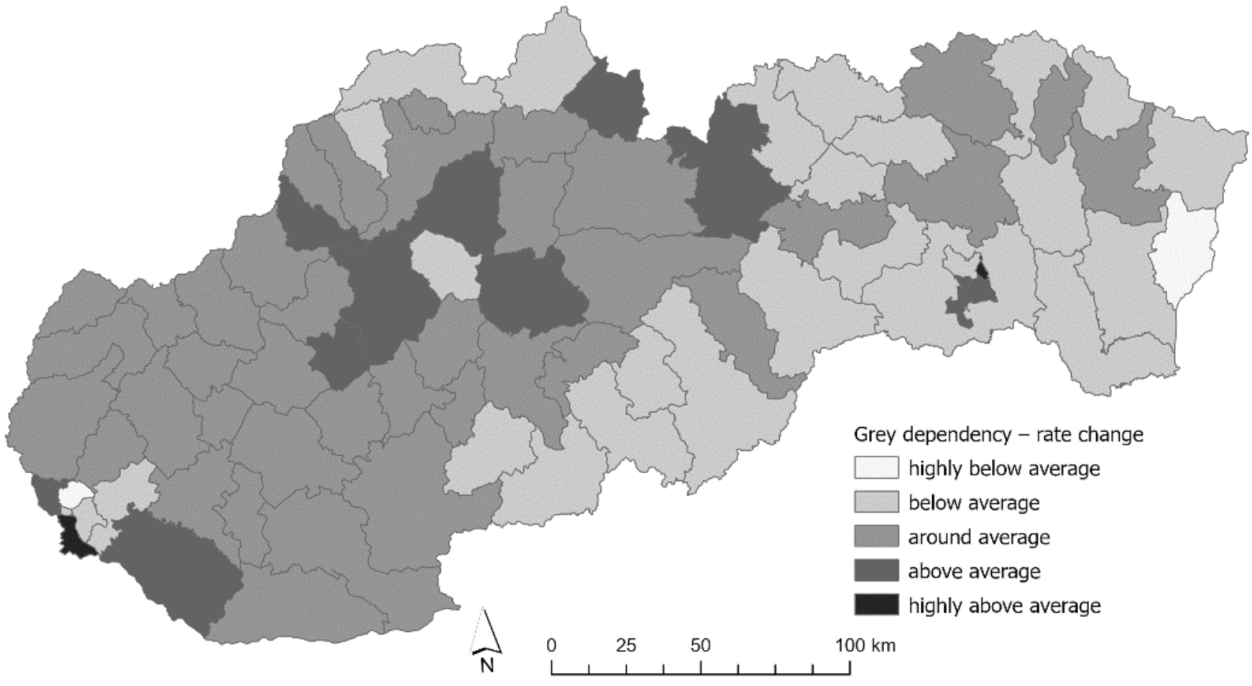


**Fig. 3** Grey dependency ratio (the ratio of age groups 65 and over to 15–64 years) in Slovak LAUs1 average rate of change during the period 2001 2020 (absolutely); (Statistical office of the Slovak Republic (DATAcube) 2022; own work)

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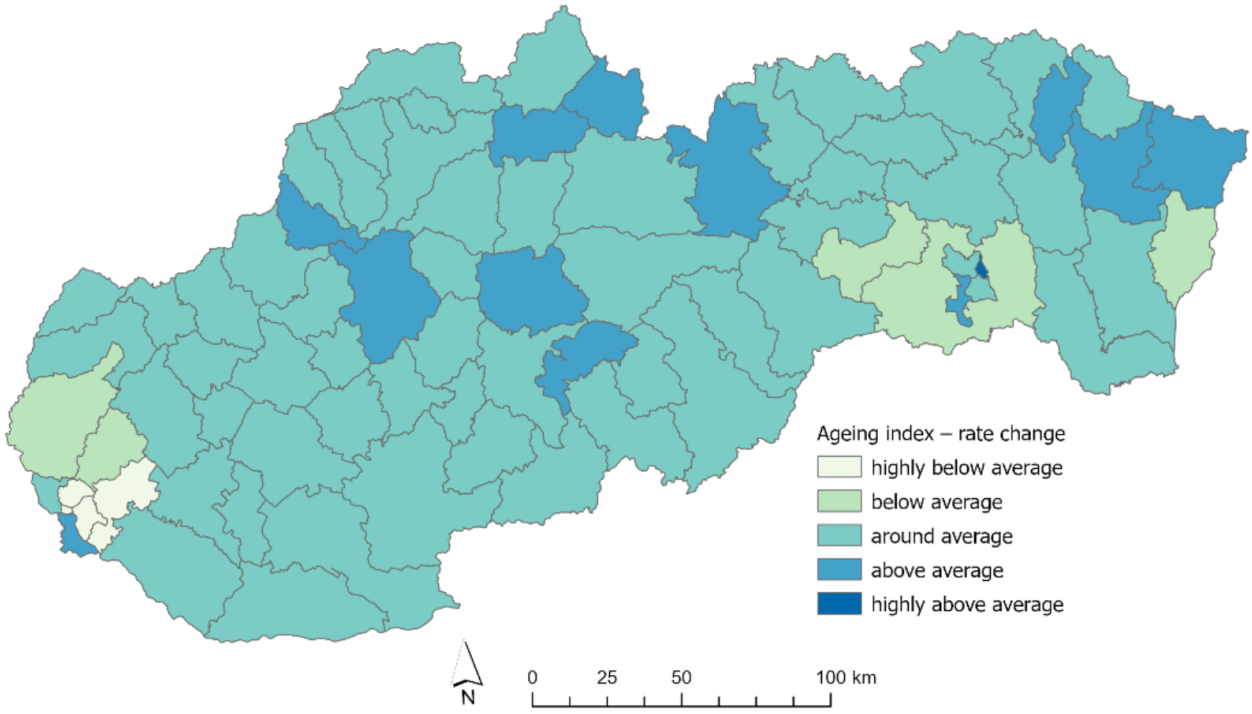


**Fig. 4** Ageing index (the ratio of age groups 0–14 years to 65 and over) in Slovak LAUs1 average rate of change during the period 2001 2020 (absolutely); (Statistical office of the Slovak Republic (DATAcube) 2022; own work)

### 4.2 Diversity in age structure across Slovak districts

In assessing trends in age structure changes, it is important to consider the significant regional and inter-district differences that manifest through various phenomena.

The age structure in the districts of the capital city in western Slovakia, specifically Bratislava I to V, underwent the most significant change. Although the age structure was different in 2001, the proportions of the primary age groups were similar in 2020. With Malacky, Senec and Pezinok included, there has been a rise in the pre- and post-productive aspects and a decline in the productive component. In other districts in western Slovakia, the group of individuals in the pre-productive and productive age range has decreased, while the post-productive group has increased.

Values in the districts of central Slovakia were close to the national average, and all districts recorded a decrease in the pre-productive component and an increase in the post-productive component.

In the eastern part of the country, there have been notable alterations in the age distribution, yet internal disparities persist. There has been a significant increase in the post-productive group in Košice districts, especially in Košice III district, as the representation of this group has grown from 3.8% in 2001 to 19.9% in 2020. By contrast, districts situated in the north-eastern part of Slovakia, namely Sabinov, Levoča, Kežmarok, and Stará Ľubovňa , consistently sustained lower proportions of the post-productive demographic throughout the specified duration. Only the districts of Stará Ľubovňa , Spišská Nová Ves, and Gelnica were able to maintain a pre-productive group share of over 20% throughout the period.

We conducted a cluster analysis, using average growth coefficients of the main age groups in the period from 2001 to 2020, in order to investigate the regional variability of age structure development. The outcomes of the analysis showed that there are 8 distinct clusters of Slovak districts. Clusters 1 and 3 comprise the majority, accounting for over two-thirds of all districts within the country. Conversely, only one district constitutes clusters 7 and 8 (Fig. 5). Each of the clusters links districts possessing comparable age structure variation features (Table 2). Population ageing is occurring in the districts of Slovakia, although variations in the pace of this phenomenon have been observed in different regions. The typical characteristic consists of a minor decrease in the pre-productive factor, a stagnation, or slight decrease, in the productive element, and a more rapid rise in the post-productive component.

 

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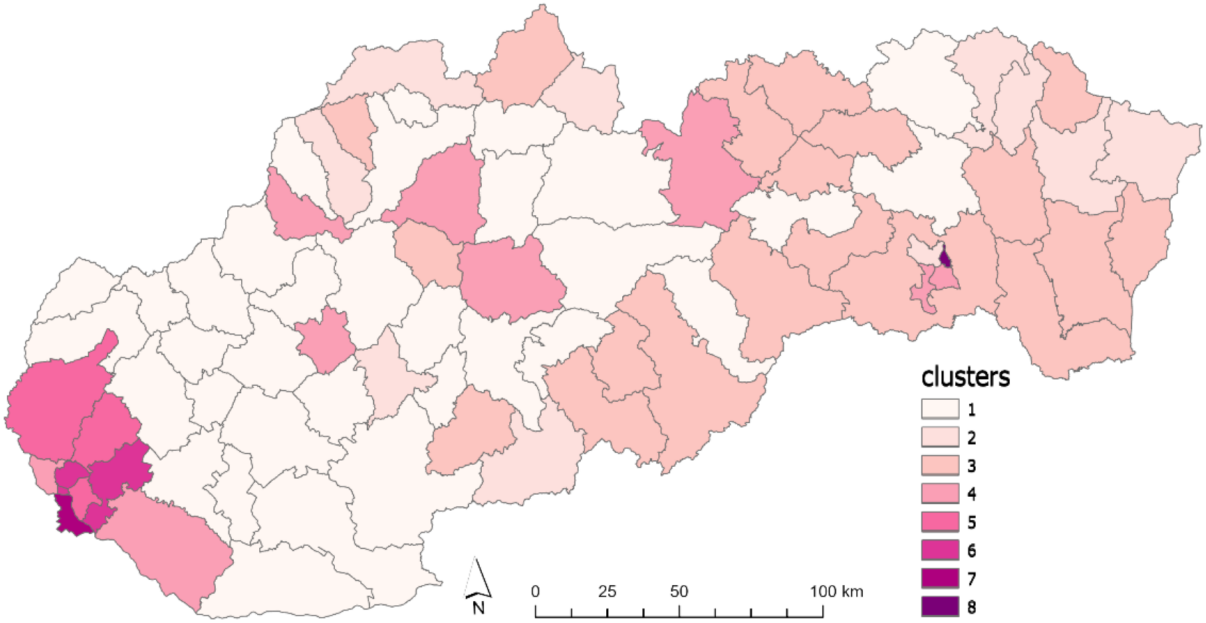


**Fig. 5** Slovak LAUs1 divided based on cluster analysis of the average coefficient of growth of the pre-productive, productive, and post-productive population components during the period 2001 2020 (Statistical office of the Slovak Republic (DATAcube) 2022; own work)

**Table 2** Cluster Analysis Based on Average Growth Rates of Primary Age Groups in Slovakia's LAU1 Regions During 2001–2020

| Cluster | Districts | Description of changes in age structure |
|---|---|---|
| 1 | Trenčín, Nitra, Žilina, Prešov, Nové Mesto n.V., Revúca, Trnava, Spišská Nová Ves, Kysucké Nové Mesto, Bardejov, Púchov, Brezno, Ružomberok, Levice, Zlaté Moravce, Nové Zámky, Banská Štiavnica, Galanta, Žiar nad Hronom, Detva, Dolný Kubín, Zvolen, Piešťany, Myjava, Komárno, Liptovský Mikuláš, Senica, Bánovce nad Bebravou, Topoľčany, Hlohovec, Šaľa Skalica a Prievidza | A slight decline in the pre-productive and productive age groups with an increase in the post-productive age group |
| 2 | Tvrdošín, Humenné, Považská Bystrica, Snina, Košice I, Čadca, Svidník, Veľký Krtíš, Žarnovica a Stropkov | The highest rate of decline is observed in the pre-productive age group, while the increase in the post-productive age group is low |
| 3 | Rimavská Sobota, Kežmarok, Lučenec, Rožňava, Sabinov, Trebišov, Gelnica, Košice-Surroundings, Turčianske Teplice, Poltár, Vranov nad Topľou, Michalovce, Stará Ľubovňa, Levoča, Námestovo, Bytča, Krupina, Medzilaborce, Sobrance | A slight decline in the pre-productive age group and a moderate increase in the productive and post-productive age groups |
| 4 | Bratislava IV, Banská Bystrica, Ilava, Poprad, Partizánske, Martin, Dunajská Streda, Košice II a Košice IV | High growth dynamics in the post-productive age group |
| 5 | Malacky, Pezinok a Bratislava II | An increase in the pre-productive age group |
| 6 | Bratislava I, Bratislava III a Senec | The highest rate of growth is observed in the pre-productive age group |
| 7 | Bratislava V | High dynamics of decline in the pre-productive and productive age groups, and high dynamics of growth in the post-productive age group |
| 8 | Košice III | The highest rate of growth is observed in the post-productive age group |

 

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Between 2001 and 2020, certain districts in the eastern and northern parts of the UK, as well as some districts in the south, had a more advantageous age composition of their population when compared to other regions.

### 4.3 Assessment of changes in the age structure of society

Changes in the age structure of the population, specifically the aging process and declining birth rates, can considerably affect Slovakian society. This effect is especially evident in regions with the highest growth rates in the 65+ age bracket and a corresponding decline in the 0–14 age bracket.

Which regions exhibit a dynamic trend in aging? These districts primarily belong to western and central Slovakia (for example, Bratislava IV, Dunajská Streda, or Banská Bystrica) as well as districts located in the eastern regions of the country (Poprad, Košice II, III, and IV). These regions have an above-average growth rate of individuals aged 65 and over, with the exception of Bratislava V, which displays a positive growth rate in the 0–14 age group.

Which regions experience the smallest growth rates for the 65+ age group? The Bratislava I and III districts in the west, as well as the Medzilaborce district in the east, display the lowest growth rates.

Which regions exhibit a less pronounced trend towards ageing? These are the districts of western Slovakia, including the capital city, with the districts of Bratislava I and II and its suburban hinterland, as well as the district of Pezinok. The Pezinok, Malacky, Kežmarok, and surrounding districts of Košice exhibit a favorable growth rate among the pre-productive age segment. However, the growth rate of the post-productive age group slightly surpasses this rate.

Excluding the aforementioned districts that deviate from the mean, the remaining districts form a fairly uniform cluster (Fig. 3).

## 5 Discussion

The findings indicate that consistent with other nations, Slovakia is undergoing the ageing process. In the 1990s, Slovakia experienced a relative bottom-up ageing process, which gained in intensity. On the contrary, the process of top-down ageing of the population was low-intensity. The main cause of this phenomenon was a significant decline in fertility coupled with a slight improvement in mortality. The large number of people born after the Second World War contributed to a shift in the age structure of the Slovak population towards the age of over 45, which captures the aging process itself from the middle (Káčerová et al. 2022).

The intensification of the ageing process in Slovakia occurred during the turn of the 20$^{th}$ and 21$^{st}$ centuries when there was a marked decline in fertility while the regional differences mentioned above were maintained (Šprocha et al. 2019). The decade from 2011 to 2021 shows a gradual but temporary reversal in the age structure of the Slovak population. This period was characterized by a rejuvenation of the population in the lower age groups and an intensification of the aging process from top to bottom, with the process of population rejuvenation occurring mainly around the Slovak capital (Káčerová et al. 2022). It remains unconfirmed that the covid-19 pandemic will affect fertility rates (Harper 2021). Lower fertility and reduced fertility rates result in a decrease in the proportion of the pre-productive age group, leading to the so-called aging from below. This demographic phenomenon is also accompanied by the aging of individuals in the middle (Káčerová & Ondačková 2015) and upper age groups due to the rise in life expectancy (Káčerová & Bleha 2007).

The phenomenon of population aging in Slovakia is apparent, but it shows regional variations. The western regions of the country, along with some central Slovak regions, display a higher proportion of older people, whereas northern and eastern regions have a comparatively younger age structure. The presented results are also supported by the **?**, which uses a prospective approach to regional analysis of ageing in Slovakia. The Western and Central regions of Slovakia were historically the oldest, while the Northern and Eastern areas tended to be the younger ones. However, a prospective analysis has led to significant shifts in how we perceive population aging across different regions. Districts with significant urban centers in Western and Central Slovakia, traditionally seen as relatively older based on standard indicators, now exhibit populations that are average or even younger when viewed through a prospective lens. Conversely, in the southern parts of Western and Central Slovakia, districts previously considered average or below average in terms of aging are now revealed to be among the oldest in Slovakia when using the prospective approach (Šprocha & Ďurček 2018). These differentiations arise from both the development of reproductive processes and a range of social, societal, political, economic, and geographical factors (Cséfalvaiová 2012).

 

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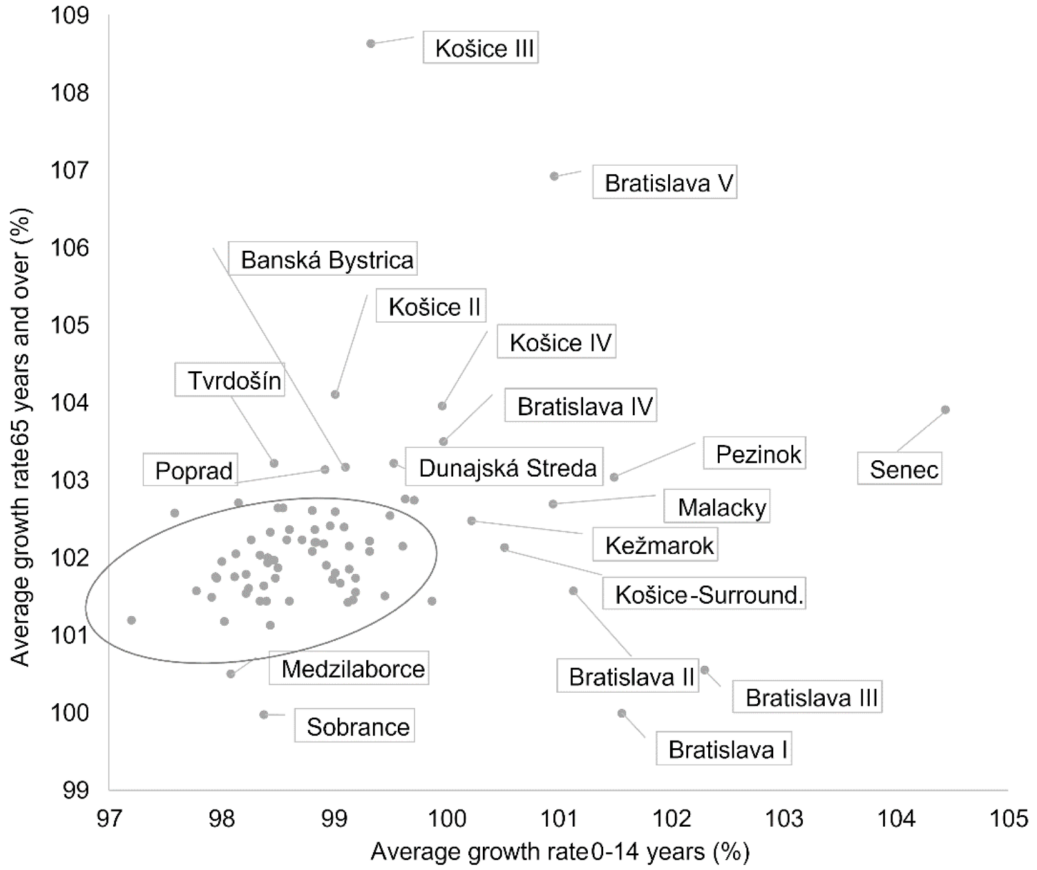


**Fig. 6** Average Percentage Growth Rates for Age Groups 0–14 Years and 65+ Years in Slovakia's LAU1 Regions during 2001 2020 (Statistical office of the Slovak Republic (DATAcube) 2022; own work)

Population projections until 2060 indicate that the trend of population ageing in Slovakia is irreversible. The mean age is projected to reach 48 years this year, with distortions in the age structure expected to significantly impact the demographic situation (Káčerová & Ondačková 2015), owing to a strong cohort of individuals born before 1985 (Vaňo 2015). It is evident that the population of individuals aged 65 and above will consistently increase. However, such fact, singularly, does not signify anything about their living standards. The evaluation of social disparity and the standing of elderly individuals in society persists to be an imperative concern. Almost a quarter of young people aged 15 to 29 accept that the elderly live at the expense of the younger population and use up the financial resources that young people are supposed to have earned (Vidovičová & Rabušic 2005). The negative perception of ageing is exacerbated by the portrayal in the media and advertising that associates it with diseases, medical equipment, dependence on others, incapacity, declining mental and physical abilities, as well as vulnerability to financial exploitation (Mareková 2018).

Demographic characteristics of the ageing trends in Slovakia include a steadily declining fertility rate, stagnating mortality rates, increasing life expectancy, changes in the age structure and demographic indices, and a growing group of very old people (Bartosovic et al. 2017). In addition to social disparities, old age is also associated with gender and economic disparities. Due to higher male mortality rates, women constitute a larger proportion of the over-80 age group, referred to as the "oldest old", and this trend is expected to continue as life expectancy rises. There is also the so-called "double aging" (Hegyi 2012), which will have enormous social, economic and medical impact (Weber 2005). Higher male mortality rates in both the feminisation of old age and the feminisation of poverty (Mareková 2018). More boys are born than girls, and the ratio evens out around age 45, with a ratio of 3:1 in the over-90 group. The proportion of widows in the 80+ group is 81.5% (Hegyi 2012). Single elderly women are the most vulnerable group in terms of income poverty within society. Low retirement benefits have historically resulted from patriarchal influences in the domains

 

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of domestic, childcare, and parenting duties, which have led to lesser participation of women in the labour market particularly among older women (Kameníček 2012). It seems that contemporary social norms hold women responsible for caregiving duties, despite men's growing role in this field (Office of the Government of the Czech Republic 2021). Conversely, the education-related fluctuations of retirement pensions for elderly women vary significantly due to different historical standards and requirements imposed upon them at the time. The level of education achieved correlates with employment prospects and financial incentives during one's economic activity. As such, the previously mentioned statistics on income disparities experienced by women carry over into economic disparities in their later years.

Another aspect of demographic change in Slovakia concerning age is linked to ethnicity. Recent data from the 2019 Atlas of Romani Communities reveals that the growth rate of the Romani population in Slovakia is gradually dwindling. The larger Roma community primarily resides in the eastern region of Slovakia. Based on the latest figures from the 2021 Slovakian Census, around 89,000 individuals identified themselves as being of Roma descent, which is a decline from 106,000 individuals in 2011. The health status of the Romani community in Slovakia is poorer than that of other communities, and this is manifested in lower life expectancies and higher infant mortalities.

The assessment of changes in the age structure of the population in Slovakia, particularly the aging process and declining birth rates, highlights significant social impacts. The dynamics of these demographic changes vary across different regions, influencing socio-economic and healthcare aspects of Slovakian society. In terms of the social impact of ageing and population development changes, we can highlight the following aspects:

*a) Labour market effects:* As the population ages, especially in regions like Bratislava IV, Dunajská Streda, Banská Bystrica, and parts of Košice, there will be a decreasing proportion of the working-age population. Further on, this could lead to labour shortages that could affect economic development and growth (Bloom et al. 2015). Additionally, an aging population may require more, and varied health and social services, which could further strain the state budget (McKee et al. 2009; Mahon & Millar 2014). This demographic shift can lead to labour shortages, increasing the need for automation, immigration, or policy adjustments to extend working ages or increase workforce participation rates among women and older individuals. Given the political discourse and last election results, the immigration policies seem to be the least probable to be adopted in Slovakia. Moreover, the effect of immigration policies that would bring a reduction in dependency ratio and improvement in the labour market is limited or can have the opposite effect and increase unemployment (e.g. Newbold 2018; Herrmann 2012).

*b) Healthcare demand:* An increasing 65+ age population heightens the demand for healthcare services, particularly for chronic disease management and geriatric care. Regions with a higher proportion of elderly residents might face strained healthcare resources unless there is significant investment in healthcare infrastructure and personnel. This might be a problem for the health care system given the fact that spending on health in Slovakia remains well below the EU average and there is a shortage of personnel. The latest report on the state of health in Slovakia from 2023 (OECD/European Observatory on Health Systems & Policies 2023) points to a physician density slightly below the EU average, while the nurse density is even lower being one of the few EU countries where nurse-to-population ratios have continuously declined since 2000. This decline is reportedly due to workforce migration and reduced numbers of new nursing graduates. However, the situation is more complex and reflect issues related to a lack of attractiveness of nursing due to low wages compared to neighbouring countries (Austria or Czechia), high numbers of overtime hours and poor working conditions or low status of the profession.

*c) Pension systems strain:* As the number of retirees increases, it may put pressure on the pension system, potentially resulting in alterations to the retirement age or benefit levels (Ediev 2013; Gruber & Wise 2000; Hammer & Prskawetz 2013). This is particularly pertinent in regions with pronounced aging trends where the growth of the elderly population outpaces that of the younger generation. The pension policies in many EU member countries including Slovakia have been trying to offer greater incentives towards longer working careers, improvements in the coverage of public pension schemes and implementation of private pension programs. All these measures have sought to reduce the strain for the state pension system and complement labour market policy (Zaidi 2012).

*d) Urban vs. rural divide:* Urban areas like Bratislava might experience different dynamics compared to rural districts. Urban districts such as Bratislava V, which show a positive growth rate in the 0–14 age group, may have better resilience

 

in maintaining a balanced age structure, thereby supporting a dynamic economy and sustainable social services. In contrast, rural areas with faster aging populations might face challenges such as depopulation, reduced economic vitality, and the erosion of community services.

e) Educational and social services: Regions with a growing number of young people will need to ensure adequate investment in educational and recreational services to support youth development. Conversely, regions with an aging population may need to shift resources toward adult education and lifelong learning programs to help older adults stay engaged, being active and not being a burden for the society. Zaidi and colleagues (UNECE/European Commission 2015:4) built an Active Ageing Index that aims to identify areas in which different policies and programmes can promote the contribution and potential of older people. Later research shows some differences in the Active Ageing Index between Slovakia and Czechia. Petrová Kafková (2022) points that the differences lay rather in the structural conditions in each country with poorer heath status or lower health care accessibility in Slovakia. Further on, the differences might be also explained by the situation in the labour market, where old age retired people are less active in the labour market in Slovakia than in Czechia.

*f) Housing and urban planning:* Changes in population age structure necessitate adjustments in housing and urban development. Regions with an aging population may need more age-friendly housing that is accessible and close to medical facilities.

*g) Social Cohesion and Integration:* Significant disparities in the age structure across regions can lead to social fragmentation. Younger regions may feel disconnected from the priorities of older regions, and vice versa, potentially leading to conflicts in policy priorities and resource allocation.

To mitigate the social impacts of these demographic changes, there is a need to consider a multifaceted approach that would deal with the following: 1) expanding in the geriatric and chronic disease care capacities, and adjusting social services to meet the needs of an aging population; 2) promoting flexible working conditions, re-skilling of older workers, and raise the retirement age to keep older individuals economically active (although increasing, the retirement age is still bellow other countries); 3) tailoring strategies to the specific demographic trends of each region, supporting those with aging populations through enhanced healthcare and those with younger populations through improved educational and employment opportunities.

## 6 Conclusion

The analysis of the changes in the age structure of the entire country reveals the following key points:

- From 2001 to 2010, although the age group shares changed, the changes became more significant after 2010.
- Since 2001, there has been a decrease in the percentage of the pre-productive age group
- The working age group showed a slight increase between 2001 and 2010, followed by a subsequent decrease between 2010 and 2020.
- Throughout the period, the share of the post-working age group continuously increased surpassing the 0–14 age group.

However, there are notable regional disparities in Slovakia between the western and some central districts and the northern and eastern regions where the age structure is younger. Some areas in the capital city, specifically Bratislava II and III, its nearby suburban areas, and the surrounding districts of Košice (clusters 5, 6, and 8 as shown in Table 2). After 2010, there was a notable surge in the pre-productive age category and other advantageous demographic shifts, which were primarily impacted by domestic migration. Additionally, these districts are exhibiting a gradual convergence in their age structure when compared to 2001, while the age structure discrepancies in the other districts of the country persist.

The effects of aging can be divided into the subsequent categories:

- Economic impacts: The aging of the population ”from below” the age structure could result in a decline of the working-age population, which may threaten economic support.
- Social and cultural consequences: An ageing population may result in social alienation and a decreased sense of community. Furthermore, it could potentially result in a reduced number of individuals within younger age brackets available to furnish support and care for older relatives. This, in turn, may culminate in greater demand for nursing homes, retirement residences, and similar long-term care establishments. The aging population may also lead to alterations in family structures, such as an increase in multigenerational households or a greater reliance

on social services.Impacts on the pension system: As the number of retirees increases, it may put pressure on the pension system, potentially resulting in alterations to the retirement age or benefit levels (Ediev 2013; Gruber & Wise 2000; Hammer & Prskawetz 2013). The Ministry of Labour, Social Affairs and Family established a catalogue of suggestions for assessing expenditure on social policy and labour market in 2017. The aim of this analysis was to identify opportunities to enhance spending efficiency by reallocating funds from less effective policies to more effective ones in the pension system. Over the period under examination, the retirement age for males and females in Slovakia increased.

- As the population of elderly individuals rises, a heightened need for housing specifically tailored to their needs, such as residential care homes and nursing homes, may arise. The heightened demand for smaller flats, particularly by single elderly women, may have reverberations in the real estate sector.
- Political impacts: If the population has fewer young individuals, politicians may prioritise concerns significant to older voters. Additionally, an aging populace's political conservatism may potentially affect the implementation of policies.

We recognize the limitations of this study, especially in light of the current economic restrictions for individuals aged 15 19. Nevertheless, to ensure comparability with previous research, we have opted to utilize the conventional classification of economic age groups. We evaluated temporal and spatial variations in the depiction of these economic age groups and their potential consequences. It's pertinent to mention that our article does not explore the dynamics of life extension. This area undoubtedly warrants comprehensive follow-up analyses.
Our research indicates that implementing effective measures to mitigate the consequences of demographic ageing across all areas of society is complex due to regional disparities in the intensity of ageing in Slovakia. Examining changes in the age structure provides valuable information for optimal planning, including ensuring access to education for the pre-productive age group and social and health services for the post-productive age group. Demographic ageing poses fundamental challenges and critical concerns in financing both social and healthcare systems. Vulnerable groups requiring support from the welfare state include those who encounter difficulties finding employment, lack family assistance, and experience economic hardship, such as elderly persons, single mothers, and Roma.
International relevance emerges as these challenges are not unique to Slovakia but are shared by many countries experiencing similar demographic transitions. By studying Slovakia's approach to these issues, we can derive insights applicable globally, enhancing our understanding of effective policy measures and planning strategies. Future research should focus on comparative studies between different regions and countries, identifying best practices and innovative solutions that can be adapted to diverse socio-economic contexts. This approach will contribute to a broader understanding of demographic ageing and its implications, fostering international collaboration and informed policy-making to address the global impact of ageing populations.

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