Demographic ageing through alternative indicators in the NUTS 2 regions of Czechia between 2003 and 2023

Filip Čábela, Luděk Šídlo*

Charles University, Faculty of Science, Department of Demography and Geodemography, Czechia
* Corresponding author: ludek.sidlo@natur.cuni.cz

ABSTRACT
The main objective of this article is to compare standard and alternative methodologies in measuring demographic ageing at the regional level in Czechia. We apply different indicators, such as the proportion of elderly people, the ageing index, the old-age dependency ratio, the pensioners to workers ratio, and real elderly dependency ratio, at the NUTS 2 regions of Czechia between 2003 and 2023. The concept of prospective age and linear interpolation method were also used in this article. The analysis revealed a continuing increase in the regional heterogeneity of Czechia in demographic ageing, as well as significant differences in the level of ageing between standard and alternative methodological approaches. When using alternative indicators, the North-west region can be considered the oldest, while the Prague region appears to be the youngest. It should also be noted that alternative indicators exhibit higher sensitivity to external mortality influences.

KEYWORDS
demographic ageing; NUTS 2 regions; Czechia; alternative indicators; prospective age

Received: 30 April 2025
Accepted: 13 August 2025
Published online: 9 September 2025

Čábela, F., Šídlo, L. (2025): Demographic ageing through alternative indicators in the NUTS 2 regions of Czechia between 2003 and 2023. AUC Geographica 60(2), 155–170
https://doi.org/10.14712/23361980.2025.13

1. Introduction

The number of older people has increased in recent years in almost every society in the world, (e.g. Gregory and Patuelli 2013; Sanderson and Scherbov 2013; Spijker and MacInnes 2013). This complex and multidimensional phenomenon is known as demographic ageing, a topic that has become one of the most intensely discussed issues of the 21st century. Although this phenomenon is unprecedented in human history, it should be perceived as a natural aspect of human development, which is closely linked to changes in the age and sex-age structures of the population. But why is the professional community so concerned with the study of demographic ageing and population structures? The study of the sex-age structure has the potential to assist experts in approximating the historical development of the population and to create a basis for estimating future developments. The early identification of potential social and economic challenges based on expected changes in the sex-age structure of the population plays an important role in terms of the design of policy measures, especially with concern to the social, health and economic systems of regions and the labour market (e.g. labour shortages, the participation of seniors etc.) (Siegel 2002).

The development of the population and demographic ageing are affected primarily by three basic factors, the first of which is the birth rate, i.e. fertility, and primarily unrealised fertility. The long-term decline in realised fertility, which has resulted in the stabilisation of the level of fertility at low values, has been attributed primarily to changes in family life and delayed parenthood. The concept of the second demographic transition (van de Kaa 1997; Lesthaeghe 2010) attempts to explain the declining fertility issue. However, the number of live births is related not only to the level of fertility but is also influenced by the number of women of reproductive age. The above-mentioned processes together influence demographic ageing from the bottom of the age pyramid upwards.

The second factor is referred to as the mortality component. Demographic ageing is influenced by increasing life expectancy both at birth and in old age. According to Omran (1971), the improvement in mortality rates is the result of a reduction in, or the disappearance of, mortality associated with certain causes of death, which is closely related to his theory of epidemiological transition. In contrast to this claim, the theory of morbidity expansion (Gruenberg 1977) claims that improving the health status of the population and increasing the quality of human life is not always associated with improving mortality rates. However, the increase in life expectancy leads in many ways to the deepening of the demographic ageing process, in which case we consider ageing from the top of the age pyramid downwards.

The last, and least stable, factor that impacts population ageing comprises migration, one of the important specific features of which concerns variations in its impact on the composition of the population in proportion to the size of the population of the monitored area. According to Eurostat (2025), immigrants have an average median age that is lower than the native population, which results in the “rejuvenation” of target regions, or in other words cohort turnover effect (the ability to compensate for the deficit of the working-age population) (Ghio et al. 2022). On the other hand, a corresponding decrease in the representation of, especially, working age persons can be expected in regions that experience emigration, which inevitably impacts the population ageing process. We can name it ageing (or rejuvenation) from the middle of the age pyramid. Today, migration is becoming, or has already become, an integral part of the reproduction dynamics of many European regions (Šídlo et al. 2020a) and it can be assumed that its importance in terms of human reproduction and population growth will continue to increase.

The initial age structure undeniably influences the trajectory of demographic ageing. Its imbalances, stemming from the historical development of the observed population, may either accelerate or slow down the process of demographic ageing (through the shifting of various cohorts into older ages). This process is referred to, as previously mentioned, as the cohort turnover effect (Ghio et al. 2022).

Most of the methods currently applied to analyse demographic ageing continue to be based on a set of multiple standard indicators (the ageing index, old-age dependency ratio, average age, etc.), which, however useful, provide only a limited and partially distorted view of the ageing issue. The amount of research on demographic ageing increased significantly in the first decade of the 21st century; however, despite the increasing interest in the topic, no significant changes have been applied to the approaches and analytical tools employed to measure the level of demographic ageing (Sanderson and Scherbov 2007).

Most of the analyses at the time (as well as mostly today) were based on the afore-mentioned set of indicators with the consideration of the number of years lived. The authors of standard (retrospective/classic) studies apply a fixed value of old age as determined according to the time of the lived (chronological) age (e.g. 65 years), which results in a partially limited and distorted view of the ageing issue. A further disadvantage of the use of these indicators concerns the fact that they remain unchanged in time and space, which results in non-objective comparisons of populations with different mortality rates and, potentially, in distorted conclusions (Sanderson and Scherbov 2007, 2013). Several authors have attempted to contribute to solving this problem, mainly over the last twenty years, by applying the so-called prospective age concept, according to which the age limit of old age is based on the same remaining life expectancy (see the following chapter). In summary, we can consider two basic approaches to the analysis of demographic ageing: standard (retrospective), which expresses the number of years that a given person has already lived, and alternative (including prospective indicators), which is understood as the number of years that a given person probably has left to live (Sanderson and Scherbov 2007).

This article outlines and applies both main approaches to demographic ageing and, further, seeks to complement them with potential alternative indicators (e.g. Spijker 2015), thus providing an interesting and unique approach to the development of population ageing with particular reference to the NUTS 2 regional level in Czechia between 2003 and 2023. The first aim of this article is to highlight the regional differences in the level of demographic ageing between the NUTS 2 regions of Czechia. The second aim is to analyse and compare progress in the level of demographic ageing by selected indicators (e.g. the proportion of elderly people, the ageing index, the old-age dependency ratio, the pensioners to workers ratio and the real elderly dependency ratio) of standard and alternative (including prospective indicators) methodologies during the studied period and simultaneously focusing on the effect of Covid-19 pandemic.

1.1 The concept of prospective age

Demographic ageing can be described as a complex phenomenon that affects almost every aspect of human life. The biggest "problem" in the analysis of demographic ageing concerns the determination of the boundary, threshold or limit of old age, which is related primarily to the continuous increase in life expectancy. In most cases (e.g. Lutz et al. 2008a, 2008b; Šídlo et al. 2020a), the age limit (following the standard/chronological approach associated with standard indicators) is set at 65 years. However, determining a fixed age limit based on the chronological age has a number of disadvantages. Differences in life expectancy at age 65 vary considerably over time and between populations; thus, the comparison of persons of the same chronological age across time and space is both problematic and even confusing (Sanderson and Scherbov 2008; Šídlo et al. 2019; Šprocha and Ďurček 2019), as confirmed by our views of the world around us. For example, it is becoming increasingly common to see people aged 65 and older living independent and active lifestyles, and a significant number of them prefer to remain active in the labour market.

The potential for adopting an alternative approach to the analysis and calculation of demographic ageing indicators was first mentioned by Norman B. Ryder in the 1970s in his paper on stable populations (1975). He suggested replacing the set age limit (65 years) with a tabular age (i.e. using life tables) at which a given population has 10 years left to live based on his view of chronological age, which loses its meaning for adults (in his opinion, it is valid only from birth to adulthood). Although it was a relatively revolutionary idea, his proposal came at a time when demographic ageing was not particularly relevant and was, therefore, of no real interest to either the professional or the lay public. Nevertheless, Ryder's ideas were gradually adopted by several other authors (e.g. Siegel and Davidson 1984; Seigel 1993), who proposed a further modification, i.e. changing the age limit to the age at which the tabular population has 15 years left to live.

However, Warren Sanderson and Sergei Scherbov (2005, 2007, 2008, 2010, 2013, 2016) made the most significant contribution to following up on Ryder's suggestions via the determination of new approaches to the analysis of demographic ageing via the concept of prospective age. The authors' consideration and subsequent modification of the afore-mentioned standard (retrospective) indicators led to the creation of a completely new approach applying prospective indicators, which consider information on changes in life expectancy over time. Bloom, Canning and Fink (2010) provided support for this approach, arguing that, due to increasing life expectancy, people are spending more time in retirement than before. Sanderson and Scherbov (2005) stated that it is important to take into account changes in life expectancy values over time, especially with concern to the older part of the population. Today's older populations differ from past older populations in terms of almost all the applied key characteristics. Put simply, this means that a person aged 65 today has different options and perspectives (e.g. concerning healthcare, disease prevention, the environment, education) than had a person of the same age in 1921, 1963 or 1998, or will have in 2050. According to Klapková et al. (2016), people live their last years of life at increasingly older ages, which acts to significantly affect their quality of life during these years. This appears to indicate that societies today should focus more on the number of years people have left to live than on the number of years they have already lived. Standard indicators based on the number of years lived do not take into account significant regional, national or gender-based differences (Šídlo et al. 2020b), whereas the concept of prospective age can be applied both to the analysis of changes over time and the analysis of differences between individual regions (Šprocha et al. 2018; Šprocha and Ďurček 2019; Gietel-Basten et al. 2020).

Just as the boundaries of entry into the final stage of life are changing, on the opposite side of the age spectrum the age of entry to work is also changing; today, the age of 15 no longer corresponds to reality in most cases due to the lengthening of the period of education. Participation in the labour market for people between the ages of 15 and 19 is relatively rare; therefore, the age of 20 is increasingly being considered and applied as the age of the commencement of economic activity, although this is still a not generalised approach.

A 2007 study by Sanderson and Scherbov assigned each person two ages (retrospective/chronological and prospective/remaining), which represented different aspects of old age, while complementing each other. The application of the dual age principle was not new and, indeed, had been applied in practice for some time for example in the healthcare sector, where concerning selected procedures related to the musculoskeletal system (total endoprostheses), doctors take into account whether a replacement will significantly increase the number of years of mobility of the patient (Klapková et al. 2016).

In recent decades, demographic ageing has increasingly been studied from the economic perspective, with the focus on its impacts on national economic systems (e.g. income growth or fiscal sustainability and stability) (Cuaresma et al. 2014; Bloom et al. 2010). Holzmann (2013), who examined the economic determinants of demographic ageing in depth, called for the reshaping of existing indicators and identified the key factors involved in the reform of pension systems.

The importance of the study of demographic ageing is confirmed by increasingly frequent concerns about the sustainability and stability of national social and pension systems, which are clearly justified. However, the majority of concerns are based on chronological (standard) indicators based on a fixed old age value (Klapková et al. 2016). Seniors are living longer today, and studies indicate that life expectancy will continue to increase in the future. Moreover, the health of older people is improving due to increasing numbers of seniors adopting an active ageing approach in both their leisure and work activities (Šídlo et al. 2020b).

The above examples highlight the importance of determining an alternative approach to the analysis of demographic ageing. In addition to Sanderson and Scherbov, the issue is addressed by Spijker (2023, 2022, 2015); Skirbekk et al. (2019); Riffe (2015); Spijker et al. (2014) and Spijker and MacInnes (2013). Their publications approach demographic ageing applying previously established standard, as well as alternative (including prospective) indicators, related to, for example, employment, the health status of the population and time-to-death (TTD). The main idea behind these new alternative indicators is to improve the added value of the indicators that are entered into the calculation process (related not only to the age structure, but for example, to those in paid employment [regardless of age], to all those who receive a pension, to the number of years spent in health or with a disability, or to economic indicators [e.g. GDP], etc.). One of the most important directions in terms of alternative indicators of demographic ageing concerns their connection with the influence of healthcare on the lives of individuals. The analysis of demographic ageing through alternative indicators (e.g. a constant prospective age) has the potential to provide a higher informative value (Čábela and Šídlo 2024); moreover, it also has the potential for use in other, previously unconsidered, areas.

2. Data and methods

This paper bases the analysis of demographic ageing on both standard (chronological/retrospective) indicators and their alternative equivalent (including prospective) indicators, which adapt to changes in life expectancy values. The basic and most important foundation stone for calculating most of the alternative indicators concerns the determination of the prospective age, which is understood as "*the age that is assigned to a given population in a given year based on the same remaining life expectancy in the reference year (and population)*" (Klapková et al. 2016, p. 131). According to Sanderson and Scherbov (2005), the prospective age can be defined as the number of years that a given person/population still has ahead of them according to the relevant mortality rates (i.e. the number of years of life remaining until the probable age of death). Spijker (2015, p. 6) describes prospective age as "*the age of a person in the standard life table who has the same remaining life expectancy as the person of interest*". The exact prospective age needed for the calculations can be estimated applying the linear interpolation method according to the following formula (see e.g. Ježek 2016, p. 20):

$$x = x_0 + (z - z_0)\frac{x_1 - x_0}{z_1 - z_0}$$

where the quantity x refers to the age and the quantity z denotes the remaining average life expectancy at age x. The designation x_0 subsequently denotes the age at which the remaining life expectancy is higher than the value that we wish to determine, while x_1 refers to the age (higher than x_0), when the remaining life expectancy is already lower than the specified value. Concerning the quantity z (the remaining life expectancy at the prospective age we wish to determine), the designation z_0 denotes the life expectancy at age x_0 and z_1 the remaining life expectancy at age x_1.

The so-called **Constant Prospective Age** was chosen for the analytical needs of the paper in accordance with similar studies, i.e. a remaining life expectancy (RLE) of 15 years **($CPA\ RLE$ 15–)**. This age is based on the fact that for each population in each year we are attempting to determine the age with a remaining life expectancy equal to 15 years (Sanderson and Scherbov 2013), for which the linear interpolation method can also be applied. The constant prospective age can be employed, for example, when calculating the proportion of elderly people in the selected population. One of the specific indicators concerns the **Proportion of the Population at Ages with Remaining Life Expectancy of 15 Years or Less ($Prop.RLE$ 15–)**, for which the criterion 15 years of life remaining is equivalent to the standard indicator the **Proportion of the Population at Ages 65 Years or Above (*Prop*.65+)**; moreover, according to Sanderson and Scherbov (2008, 2010); or Lutz et al. (2008a, 2008b), the indicator sets an alternative age threshold of 65 years. The calculation formulae are as follows:

$$Prop.RLE\ 15- = \frac{P_{x_{RLE15-}}}{P} * 100$$

$$Prop.65+ = \frac{P_{65+}}{P} * 100$$

Further indicators considered in this paper comprise the **Prospective Ageing Index (*PAI*)** and its standard counterpart the **Ageing Index (*AI*)**. Both are calculated as the ratio of the number of people at older ages (specifically ages with a remaining life expectancy of 15 years or less – $P_{xRLE15-}$ or the number of people aged 65 and over – P_{65+}) to the number of people from birth to the completed age of 19 years (P_{0-19}). The corresponding formulae are as follows:

$$PAI = \frac{P_{x_{RLE15-}}}{P_{0-19}} * 100$$

$$AI = \frac{P_{65+}}{P_{0-19}} * 100$$

A further indicator used in the analysis of demographic ageing concerns the **Prospective Old-Age Dependency Ratio (*POADR*)**; this very specific indicator is calculated by combining the prospective and retrospective ages. It can be expressed as the relation between the number of people with a remaining life expectancy of 15 years or less to the number of people between the age of 20 and the considered prospective age limit (constant prospective age) (Sanderson and Scherbov 2008). The retrospective analogy of the *POADR* indicator comprises the standard **Old-Age Dependency Ratio (*OADR*)**. The calculation of the indicators can be illustrated as follows:

$$POADR = \frac{P_{x_{RLE15-}}}{P_{20-x_{RLE>15}}} * 100$$

$$OADR = \frac{P_{65+}}{P_{20-64}} * 100$$

where $P_{20-xRLE>15}$ defines the number of persons from 20 years of age to the constant prospective age.

Changes in the age structure significantly (e.g. the demographic dividend) affect economic growth (Bloom et al. 2010), where investment in the development of human capital and technological progress serve to increase the economic productivity of societies and regions (Spijker 2015). The "economic miracle" in East Asia from the mid-1960s to the early 1990s provides a typical example of the use of changes in the age structure (Bloom et al. 2010). The main impact of demographic ageing on the economy concerns the increasing number of older economically inactive (dependent) citizens compared to the economically active population. However, it is important to consider that the size of the economically active population does not depend only on age (Spijker and MacInnes 2013). Historically, it was influenced by, for example, lower female employment rates, which have increased dramatically over the last 50 years (the elimination of gender discrimination and the weakening of the "male breadwinner" paradigm) (Spijker 2015).

In addition, a significant part of the working-age population cannot be considered to be part of the labour force since they are not active in the labour market (students etc.), whereas conversely, in some countries persons over 65 years of age are considered to be economically active (Spijker 2015), which is related to personal preferences, the inability to live solely on the amount of pension received or, simply, the absence of a national old-age pension system. On the other end of the scale, certain high-income countries have statutory retirement ages of lower than 65 years (e.g. France and Japan), in which case the number of people receiving a pension is likely to exceed the number of people aged 65 and over (Bongaarts 2004).

Based on the above-mentioned factors, efforts have been made since the turn of the millennium to determine alternative demographic ageing indicators, e.g. Bongaarts (2004) considered the **Pensioners to Workers Ratio (*PWR*)** to be a more accurate indicator of the burden on the economically active population:

$$PWR = \frac{P^{PENS}}{P^{PE}} * 100$$

According to Spijker (2015), this ratio attains much higher values than the conventional *OADR*, especially in certain high-income countries (especially France and Italy). Interesting proposals include, for example, that only those in paid employment (P^{PE}) should pay for the health and well-being of older (P^{PENS}) people (not all people of working age) (Spijker and MacInnes 2013). Subsequently, an indicator known as the **Real Elderly Dependency Ratio (*REDR*)** was proposed whereby Spijker (2023) and Spijker and MacInnes (2013) applied their ideas in combination with the methodology considered by Sanderson and Scherbov (2007) that applied the constant prospective age method to determine the older part of the population. The calculation formula is as follows:

$$REDR = \frac{P_{x_{RLE15-}}}{P^{PE}} * 100$$

where the numerator ($P_{xRLE15-}$) refers to the number of men and women with a remaining life expectancy of 15 years or less and the denominator (P^{PE}) indicates the number of men and women in paid employment. One of the disadvantages of the *REDR* proposal concerns the fact that it considers all people in paid employment to be equally productive despite probable differences (e.g. in the hours worked) (Spijker 2015).

The authors of this article selected the NUTS 2 regions of Czechia for their relatively detailed analysis of the development of the chronological and alternative indicators of demographic ageing aimed at both determining and clarifying the development of regional differences over the period 2003–2023. NUTS regions were created so as to allow for the comparability of statistical data within the EU. Given the differences in the spatial characteristics of the NUTS 3 regions of Czechia, it was considered that more reliable outcomes would be determined via the comparison of the statistical data for the higher order NUTS 2 regions. It is evident that although demographic ageing is, in most cases, studied at the national level, populations do not age uniformly at the regional level. Since the aim of this article is to determine in which parts of Czechia the level of demographic decline is most advanced and in which, conversely, the population is ageing more slowly, it was deemed most appropriate to study the NUTS 2 regions.

The time period was chosen aimed at both capturing developments and changes essentially from the beginning of the new millennium to the present day and taking into account the impact of the Covid-19 pandemic on the considered indicators at the regional scale. The Public Database of the Czech Statistical Office (CZSO) and the Product Catalogue (Statistical Yearbooks of the Czech Republic 2004–2024) (CZSO 2024a; CZSO 2024b) served as the data bases. Specifically, detailed mortality tables for each year were employed (life expectancy at specific ages) together with the sex-age structure according to age units for the given years (number of persons at a specific age). The basic characteristics of the economic status of the population aged 15 and over were taken from a labour force sample survey (the number of persons in paid employment) together with selected indicators for the NUTS 2 and NUTS 3 regions for each given year (the number of pensioners).

Within the research, two main hypotheses were formulated. The first hypothesis posits the absence of homogenisation in the level of demographic ageing across the NUTS 2 regions of Czechia over time. The second hypothesis states that the values of alternative (including prospective) indicators – based on life table measures – are more sensitive to external mortality influences, such as various epidemics (e.g. Covid-19), thereby resulting in greater differentiation of these indicators over time.

3. Results

The study of the development of demographic ageing at the regional level in Czechia, specifically NUTS 2 regions, in the period 2003 and 2023 revealed significant inter-regional differences. In terms of the constant prospective age (*CPA RLE* 15–), differences were evident both between the genders and the NUTS 2 regions (Fig. 1). The constant prospective age values for men were significantly lower than for women within the individual regions, which is not surprising given the higher excess mortality of men at middle and older ages due to their more at-risk behaviour (Rochelle et al. 2015) and higher consumption of addictive substances (Clark and Peck 2012). Women, on the other hand, devote more attention to their health and more often undergo preventive health check-ups (Clark and Peck 2012). A further reason concerns genetic predisposition, e.g. women have higher levels of oestrogen in their blood, a hormone that protects against cardiovascular diseases (Rochelle et al. 2015). In addition, the research revealed greater interregional differences for the male part of the population than for the female part.

The lowest values of the indicator were recorded for both sexes in the North-west and Moravian-Silesian regions (Fig. 1), both of which exhibit lower than average life expectancy at birth and in older ages, higher unemployment rates and the highest levels of air pollution in Czechia due to the historically high presence of heavy industry. Conversely, the highest values were observed in the Prague region. These three regions recorded the lowest and highest life expectancy values throughout the studied period both at birth and at age 65, as well as at the constant prospective age. Moreover, it was observed that the age for determining the expected last 15 years of life was higher than the limit of 65 years for women in all the monitored regions throughout the period, and since 2007 it did not fall below 68 years in any of the regions. The constant prospective age for men did not reach values above 65 years throughout the period in any of the regions studied, with the exception of the Prague region in the first of the monitored years, i.e. 2003. During the first 10 monitored years, all the regions reached the value of 65 years for men, except for the afore-mentioned North-west region where this value was exceeded only 5 years later, in 2016.

The highest gender differences between the regions were observed for 2021, which was most likely linked to the Covid-19 pandemic, concerning which a paper by Dzúrová and Hulíková (2021) noted a higher level of excess mortality in the male part of the population from Covid-19 than in the female population. This was further confirmed by the higher decline in life expectancy values for men in Czechia during the Covid-19 pandemic than for women (Appendix 1).

One possible explanation for the regional differences relates to the higher quality of life in cities (the Prague region comprises only the city of Prague). Large cities and their hinterlands (the Central Bohemia region can be considered the Prague hinterland) have higher levels of employment in the tertiary sector than other parts of the country and lower levels of physically demanding professions. This is supported

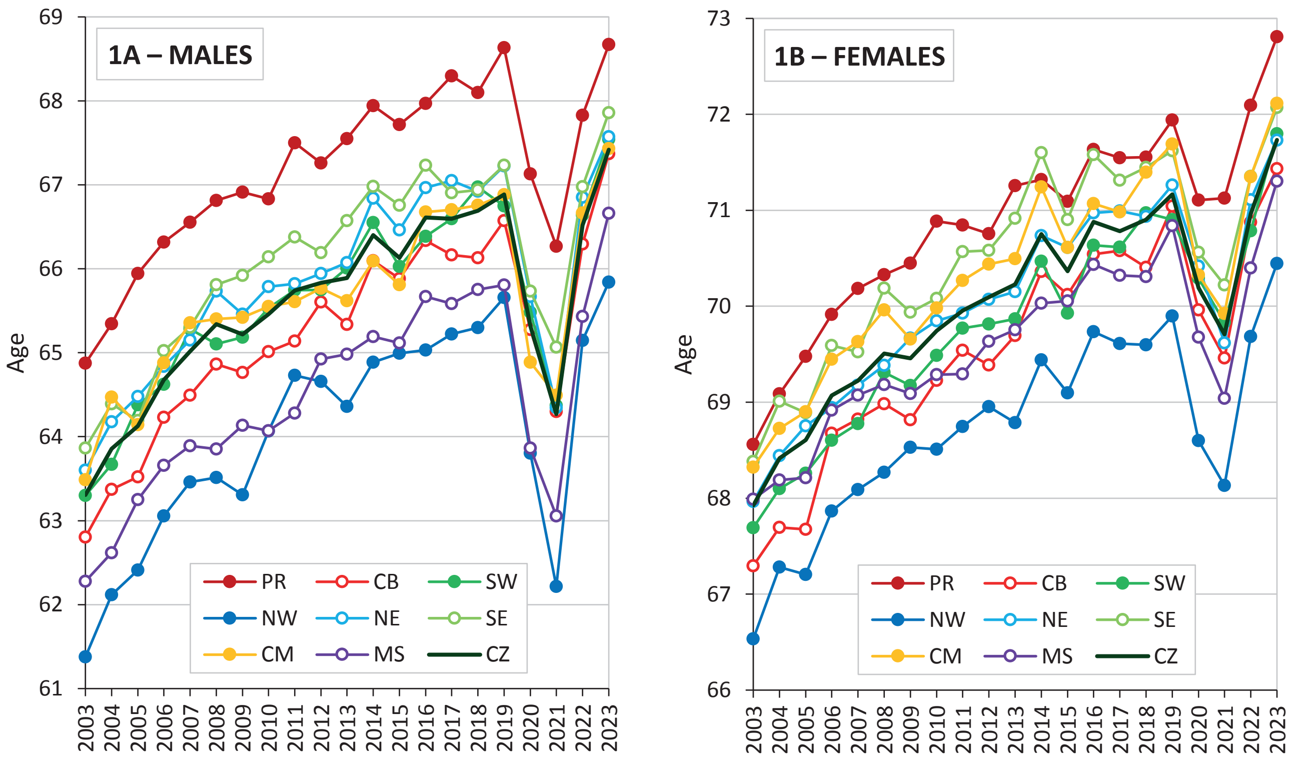

Fig. 1 Constant Prospective Age (*CPA RLE* 15–), Males (1A) and Females (1B), NUTS 2 Regions of Czechia, 2003–2023.
Note: PR = Prague region (CZ01), CB = Central Bohemia region (CZ02), SW = South-west region (CZ03), NW = North-west region (CZ04), NE = North-east region (CZ05), SE = South-east region (CZ06), CM = Central Moravia region (CZ07), MS = Moravian-Silesian region (CZ08), CZ = Czechia. Source: CZSO; authors' calculations.

by the fact that more people with higher levels of education who, according to Murtin et al. (2017) have higher average life expectancy rates, live in larger cities. In addition, Czechia routinely reports relatively higher differences in life expectancy values based on the level of education achieved than other European countries (Murtin et al. 2017).

The proportions of people in older age categories (the proportion of the population aged 65 and over – *Prop.*65+, and the proportion at ages with a remaining life expectancy of 15 years and less – *Prop.RLE* 15–) is one of the characteristics that is often used to quantify and analyse the population ageing process. Moreover, the values applied in the two approaches differ significantly (Appendix 2). The *Prop.RLE* 15– in the individual regions evinced lower values than the *Prop. 65+* throughout the monitored period. Values obtained for 2021 revealed the significant influence of the Covid-19 pandemic via the convergence of the values of the two approaches, which resulted in a decrease in the life expectancy values of older age groups in society and, thus, a decrease in the constant prospective age values.

The differences between the two approaches evinced a mainly increasing trend. The Prague region exhibited the greatest differences between the two approaches throughout the monitored period (with the exception of 2019 and 2023), while the North-west region evinced the lowest differences – even in 2003 the values of the standard proportion were lower than the prospective share in this region. The authors assume that the main reason for the North-west region achieving the lowest differencies concern the low values of the life expectancy (thus also low values of constant prospective age) in this region. The North-west region is also characterized by the relatively high unemployment rate (CZSO 2025), which is reflected in the emigration of younger, more educated people from this region.

Fig. 2 illustrates the shares of people with a remaining life expectancy of 15 years or less. The NUTS 2 regions did not experience particularly sharp increases in the values during the monitored period. This was due to the application of a variable age limit, which is the basis of the prospective age concept.

While the share of people aged 65 and over evinced almost linear growth in most Czech NUTS 2 regions between 2003 and 2023 (Fig. 2), the share of people with a remaining life expectancy of 15 years or less exhibited a sharp increase in values in 2020 and 2021. Moreover, the values of the two indicators converged significantly in these two years. This factor was attributed to the Covid-19 pandemic, which reduced life expectancy values at older ages (Dzúrová and Hulíková 2021).

Other indicators employed to analyse demographic ageing include the prospective ageing index and the prospective old-age dependency ratio, and its

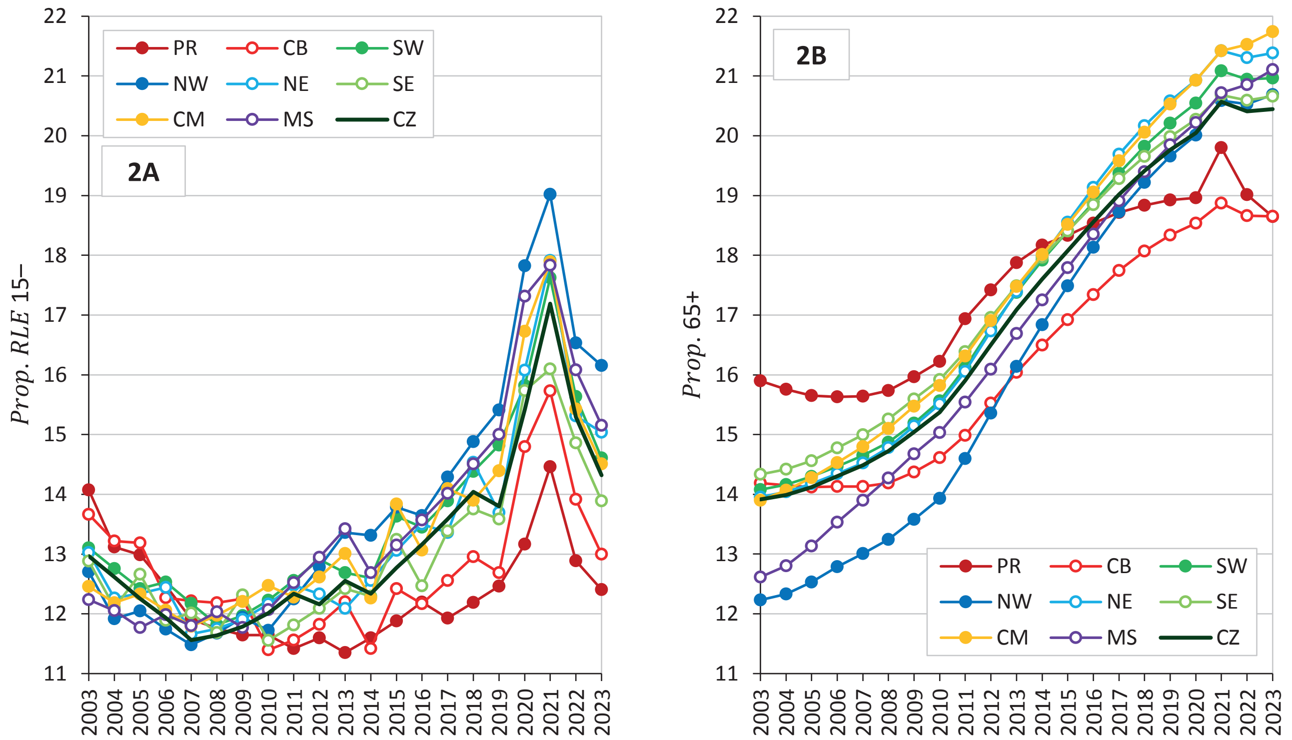

Fig. 2 Proportions of the Population at Ages with Remaining Life Expectancy of 15 years or less (*Prop.RLE* 15–) (2A), Proportions of the population aged 65 and over (*Prop.*65+) (2B), NUTS 2 regions of Czechia, 2003–2023.
Note: see Fig. 1. Source: CZSO; authors' calculations.

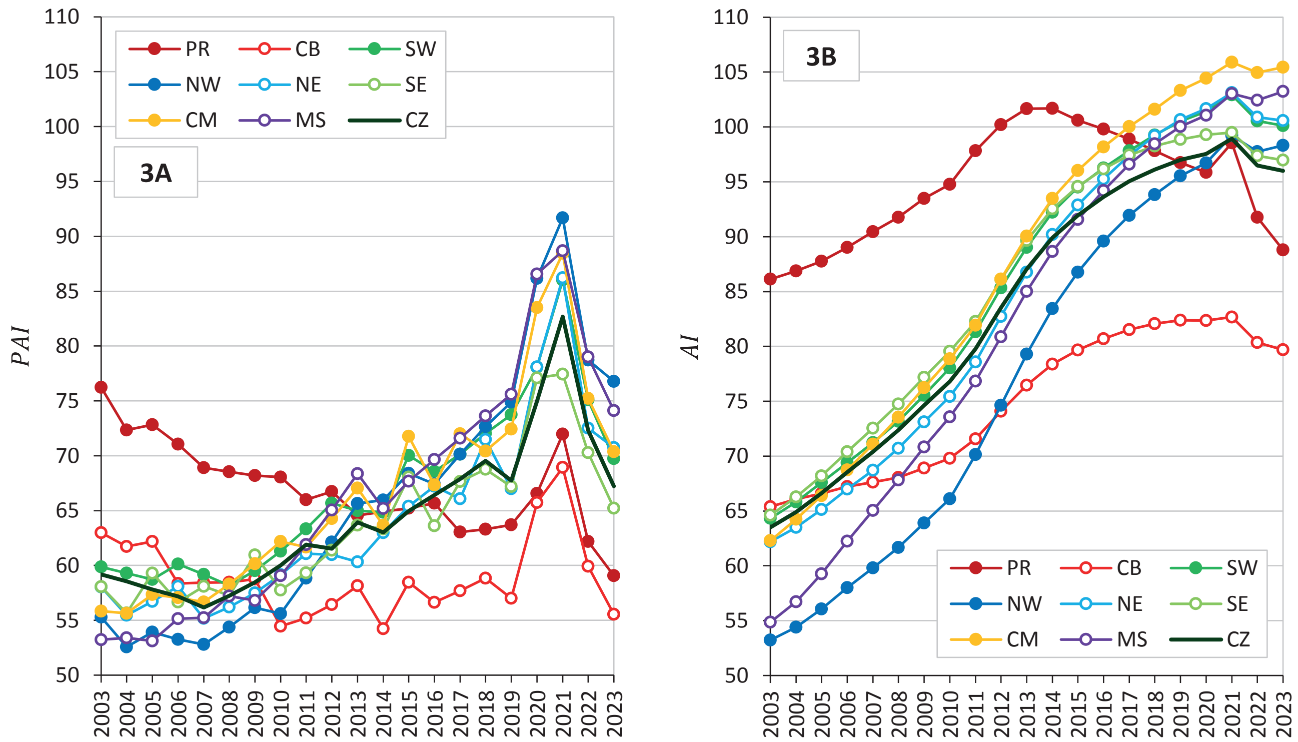

Fig. 3 Prospective Ageing Index (*PAI*) (3A) and the Ageing Index (*AI*) (3B), NUTS 2 regions of Czechia, 2003–2023.
Note: see Fig. 1.Source: CZSO; authors' calculations.

standard counterparts, i.e. the ageing index and the old-age dependency ratio.

Both pairs of indicators are closely related both to mortality at older ages and the fertility levels of people in the productive age group. Based on the time development of the prospective ageing index (Fig. 3), the NUTS 2 regions could be divided into two groups. The first group comprised the Prague and Central Bohemia regions, for which a decreasing trend in the development of values was observed. The second group consisted of the remaining six regions, for which the development trend was mainly of an increasing character. The standard ageing index values exhibited an increasing trend.

Once again, the highest differences were recorded in the NUTS 2 region of Prague, and in the last two years of the monitored period also in the Central Moravia region (Appendix 3). The lowest differences were observed in the North-west and Central Bohemia regions, as well as in the Moravian-Silesian region at the beginning of the monitored period. Although both the Prague and Central Bohemia regions were amongst the oldest regions in Czechia at the beginning of the monitored period (Fig. 3), they were amongst the youngest regions at the end of the period. The Central Bohemia region was a stagnant region with a decreasing population in the early 1990s; however, by 2010 it had become the most populous and in 2011 the youngest region in Czechia (CZSO 2023). One possible explanation for the downward trend in both regions concerns their mutual demographic, social and economic interconnection. For example, the Central Bohemia region is today considered a suburban area of the Prague region and according to Kashnitsky et al. (2020), mainly younger people of productive age move to the hinterlands of large cities, where they start a family, thus increasing the number of those in the pre-productive age category (0–19 years).

This change was confirmed by the CZSO (2023), which reported that the spread of suburbanisation from Prague to Central Bohemia is associated with intensive housing construction, especially in the immediate vicinity of Prague and in areas with good transport accessibility. According to Čábela (2023), the LAU 1 regions of Prague-West and Prague-East (the immediate hinterland of Prague) evince the lowest prospective ageing index values in Czechia. In addition, a lower proportion of people with a remaining life expectancy of 15 years and less has been recorded in both NUTS 2 regions since 2010. The decrease in the prospective ageing index in the Prague region can be attributed to both the highest life expectancy in Czechia and the permanently negative migration of people aged 60 and older from this region (CZSO 2012), as well as the immigration of younger people for study or career purposes.

Very similar trends can be observed in the development of both the prospective and standard old-age dependency ratios (Fig. 4). Again, significant increases are evident in the values of the standard indicator, while the increase in the prospective index is gradual with slight fluctuations at around 2015 caused by an increase in the intensity of mortality in Czechia (Kurkin et al. 2016) and at around 2020 and 2021 due to the Covid-19 pandemic (Dzúrová and Hulíková 2021). The differences between the values of the measurement approaches again increased throughout the period (Appendix 4), apart from the pandemic years 2020 and 2021. Concerning the prospective ageing index and the prospective old-age dependency ratio, a decrease in values can be observed in all the regions, which was most probably due to the end of the Covid-19 pandemic. A further explanation is provided by the wave of immigration since the outbreak of the war in Ukraine, when approximately 300 thousand people, mainly young mothers with small children, immigrated to Czechia; this served to increase the number of people in both the productive and pre-productive age categories (Štyglerová and Němečková 2023).

The pensioners to workers ratio comprises one of the more recent alternative indicators considered in the article. This indicator includes all pensioners regardless of whether they receive an old-age or other pension and all economically active residents regardless of age (from 15 years old). This indicator potentially provides a more accurate insight into the real situation in terms of dependency; moreover, it serves for the comparison of all dependent residents (= pensioners) in Czechia (except for the pre-productive age category) with those who contribute to the pension system (= workers). Fig. 5 illustrates the significant regional differences in the *PWR* values. The differences in the values between 2003, 2013 and 2023 are shown in Appendix 5.

The value of the indicator decreased between 2003 and 2023 in the Prague region due most likely to an increase in the number of workers by more than 70 thousand, while the number of pensioners remained essentially the same (CZSO 2024b). A further possible explanation is that many people rather than spending their pension years in the hustle of a large city, prefer to live in more peaceful rural areas. A decrease in this indicator was also evident for the Central Bohemia region, where, although the number of pensioners increased slightly, the number of workers increased by more than 120 thousand people in the studied period (CZSO 2024b). The *PWR* indicator values increased in all the other NUTS 2 regions between 2003 and 2023. However, it was interesting to note that between 2013 and 2023, all the regions evinced decreases in this indicator value (Appendix 5). Thus, overall increases in the *PWR* values of the NUTS 2 regions in the first half of the monitored period were followed by decreasing values in the second half of the period. The highest values achieved during the monitored period related to the NUTS 2 region Moravian-Silesian, which was most probably due to this region having the highest numbers of pensioners of all the regions and, conversely, one of the lowest proportions of workers. The high number of pensioners could be attributed to the historical predominance of the mining industry and the associated earlier retirement age of miners (Štefko 2018).

The real elderly dependency ratio indicator serves for the comparison of the number of people with a remaining life expectancy of 15 years or less to

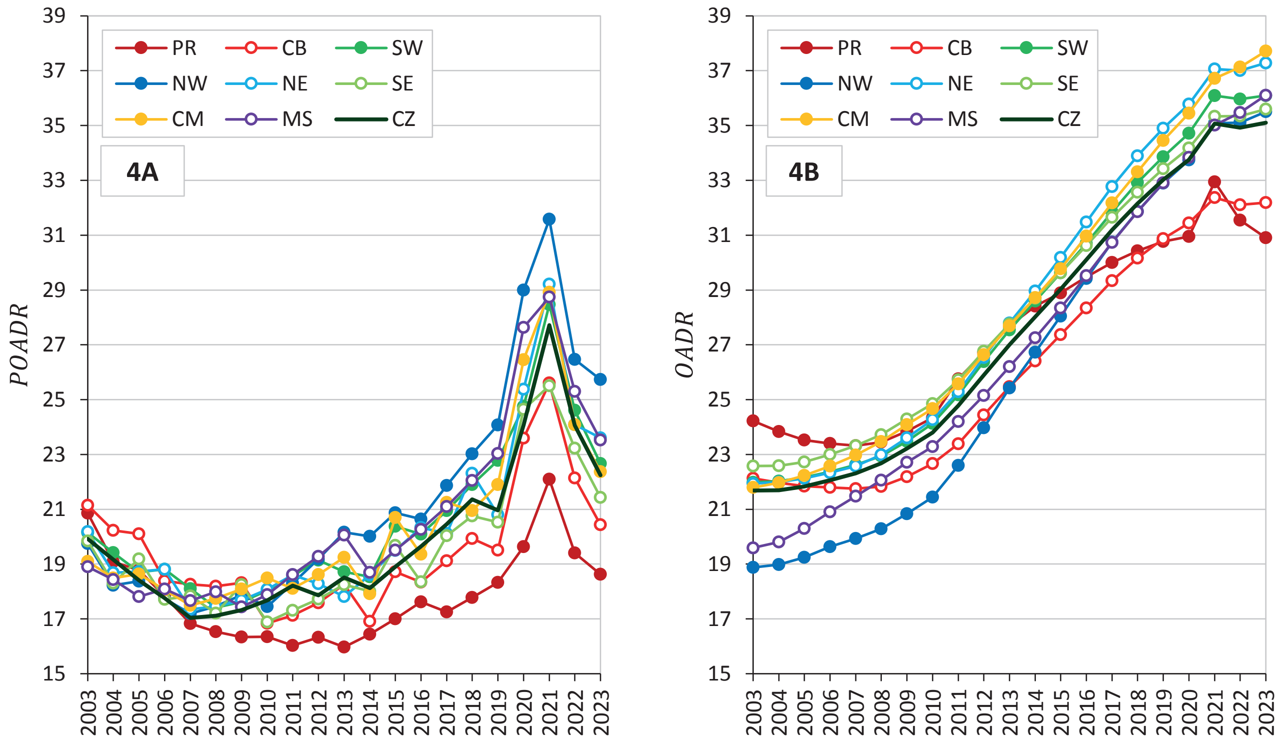

Fig. 4 Prospective Old-Age Dependency Ratio (*POADR*) (4A) and the Old-Age Dependency Ratio (*OADR*) (4B), NUTS 2 regions of Czechia, 2003–2023.
Note: see Fig. 1. Source: CZSO; authors' calculations.

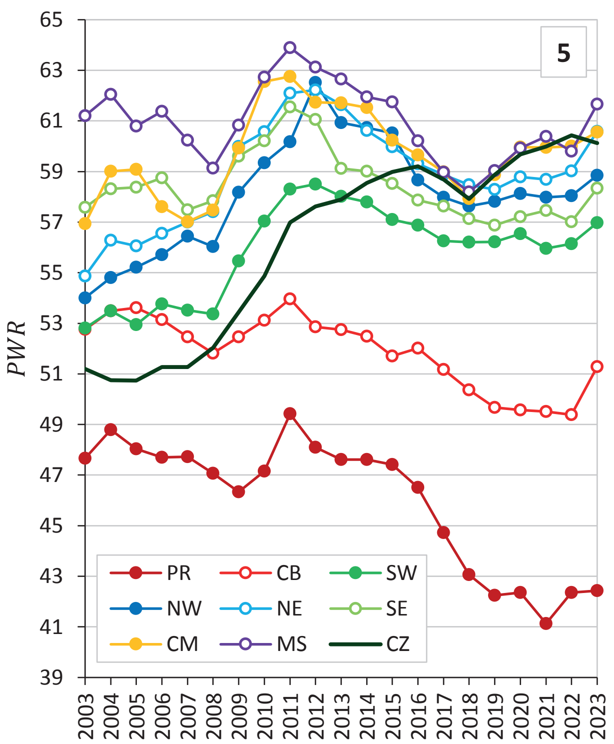

Fig. 5 Pensioners to Workers Ratio (*PWR*), NUTS 2 regions of Czechia, 2003–2023.
Note: see Fig. 1. Source: CZSO; authors' calculations.

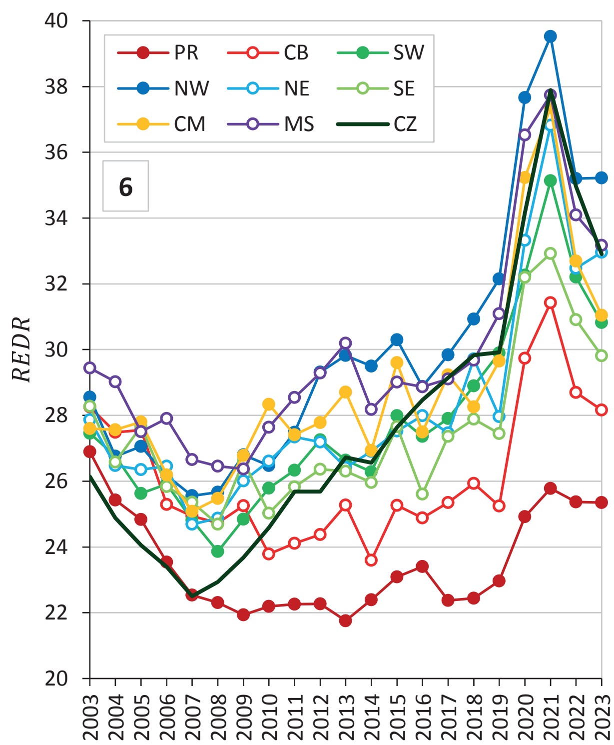

Fig. 6 Real Elderly Dependency Ratio (*REDR*), NUTS 2 regions of Czechia, 2003–2023.
Note: see Fig. 1. Source: CZSO; authors' calculations.

the number of people in paid employment. Spijker and MacInnes (2013) introduced this indicator on the grounds that only those who are employed and receive a salary should be considered as the population that finances the health and wellbeing of older people rather than all working-age people.

The development of the real elderly dependency ratio demographic ageing indicator during the monitored period was very similar to that of the prospective old-age dependency ratio indicator. This was not a coincidence since both indicators are very similar in terms of the calculation approach. The comparison of the *REDR* (Fig. 6) with the *POADR* (Fig. 4) revealed more significant differences between the individual regions for the *REDR* indicator. The highest *REDR* values were observed at the beginning of the monitored period for the Moravian-Silesian region and the lowest for the Prague region, whereas at the end of the period the highest values were observed for the North-west region and, again, the lowest for the Prague region. The North-west region has one of the highest unemployment rates in Czechia (CZSO 2025) and a relatively low quality of life. Appendix 6 shows that between 2003 and 2023, the value decreased only in the Prague and Central Bohemia regions, while the values increased in all the other regions.

Significantly high relative increases were recorded in all the regions in the period 2013–2023, which was probably at least partly due to the sharp increase in values during the Covid-19 pandemic; the indicator values had not returned to pre-Covid values at the end of the monitored period. The development of the *REDR* for the Prague region in 2020 and 2021 is interesting; all the other regions recorded a sharp increase in this indicator value, whereas the increase for the Prague region was notably less intense (as was the subsequent decrease). The decrease in the values after 2021 in all the regions was, again, due mainly to the end of the Covid-19 pandemic.

4. Discussion

Changes in the age structure of the population, as associated with the process of demographic ageing, exert a wide range of socioeconomic consequences. For example, they lead to an increased burden on the pension system, higher healthcare costs, greater demands in terms of caring for the elderly and labour shortages. Simply put, many countries are witnessing a situation in which in today's media age, the term demographic ageing is perceived negatively by the majority of society, a situation that is compounded by the fact that the extension of life expectancy at older ages does not automatically mean an extension of life expectancy in good health (e.g. Straka et al. 2024). This has resulted in an interesting paradox, i.e. one of the greatest achievements of the modern human era – increasing life expectancy – is generally perceived as an existential problem for the population (Spijker and MacInnes 2013). Although the potential impacts of ageing populations are significant in many areas, this phenomenon should not be viewed solely from the negative perspective. It should also be seen as a challenge for society, one that opens up new opportunities in the context of active ageing (e.g. Forster and Walker 2015), the participation of seniors in the labour market (e.g. Posthuma and Campion 2009) and research and development and innovation targeted at the specific needs of seniors.

The application of standard demographic ageing indicators based on chronological age is limited by the ability to compare these indicators across time and space. Alternative (including prospective) indicators, however, benefit from the fact that rather than employing fixed age limits, they consider changes in life expectancy values, i.e. variable age limits that better capture the real picture of the demographic ageing of society. For example, in many countries, the alternative principle for the measurement of ageing is used to set the retirement age (e.g. the Netherlands, Denmark and Greece, as well as Czechia – at the end of 2024, a pension reform was approved concerning the application of the alternative approach in the calculation of this age). However, the two approaches are interconnected and should not be applied in isolation. Together, they allow for the analysis of both the age dimension and the assessment of the ageing process of the population as a whole, which is also confirmed in the article by Šprocha and Ďurček (2018).

The comparison of development trends is better able to clarify ongoing changes and potential impacts on the age structure of the population. The increasing differences in the values of the indicators between the two approaches are the consequence of increasing life expectancy, which acts to increase the value of the constant prospective age (and, at the same time, diverges from the fixed age limit of 65 years). On the other hand, the convergence of the values of the indicators of the two approaches (e.g. as during the Covid-19 pandemic) reflects a decrease in life expectancy as a cross-sectional indicator in a given calendar year even though this impact is not particularly noticeable in the resulting representation of the number of people of senior age.

One of the disadvantages of applying alternative (including prospective) indicators of demographic ageing concerns their higher variability than more traditional indicators and susceptibility to minor fluctuations during the monitored period. Moreover, since their calculation is tied to cross-sectional mortality tables, these indicators fully reflect those changes that cause temporary fluctuations to current mortality rates. Despite these minor disadvantages, it is reasonable to assume that the application of a concept based on the number of years of life remaining to social, economic and healthcare systems has the potential to reduce state expenditure. Moreover, the authors recommend that these approaches be used to provide support primarily for those who really need it. At the same time, however, it is important to note that population ageing is associated solely with age. A certain degree of dependency in society is associated purely with pensioners or with the real number of people in paid employment (*PWR* and *REDR*). These alternative indicators provide proof that the demographic ageing of the population can be viewed in various ways, which influence the perception of population ageing.

However, since this article aimed to describe changes at the regional level, it is important to consider why the analysis of regional differences is crucial in terms of demographic ageing. National averages often mask significant heterogeneities between regions. However, analysis at the regional level allows for the more detailed understanding of the dynamics of ageing in different parts of a country, which often exhibit different fertility, migration and mortality trends. These differences may be due to historical, economic, sociocultural and geographical factors. For example, regions with a traditionally strong industrial sector may face specific challenges associated with the outflow of young labour, while rural areas may face more rapid population ageing due to the migration of young people to large cities. The distinctiveness of individual regions thus indicates the need for a specific, targeted approach to local policy intervention, e.g. regions with more progressive demographic ageing rates must adopt more active approaches to addressing, for instance, the construction of residential facilities for seniors or the support of other forms of social services for this group. It is important that, in cooperation with health insurance companies, such regions should optimise the network of healthcare providers so as to be able to meet the increasing demand for healthcare associated with advancing age and adapt local infrastructures, including public transport, and services to better meet the needs of an ageing population.

5. Conclusions

In today's world of easily accessible information, society is being influenced from all sides by opinions regarding the development and necessity of solving the issue of demographic ageing. Negative attitudes often prevail in the media, which is due largely to the standard (retrospective) approach to measuring the level of demographic ageing. Unfortunately, emphasis is often placed only on increasing numbers over time, without the explanation of their values, in terms of either the causes of, or connections between, rapid increases in standard indicator values.

The aims of this article were to both draw attention to this issue and compare standard and alternative approaches to measuring ageing, and to provide new insights into regional differences in terms of the development and pace of demographic ageing at the Czech NUTS 2 regional level. Although it may seem at first glance that these regions are relatively stable and mutually comparable, the results of the analysis indicate the opposite. Persistent differences were revealed between more economically developed regions and regions that are struggling with socioeconomic problems, which often have their roots in the transformation of the industrial base and related structural changes. A number of indicators even pointed to an increase in heterogeneity, thus supporting the first selected hypothesis. Accordingly, it is essential that society responds adequately to these changes via the introduction of policy measures at both the national and local government levels. The second hypothesis, suggesting that alternative indicators of demographic ageing are more sensitive to external mortality influences, was likewise confirmed (e.g. Covid-19 pandemic). Following a constructive approach to demographic ageing has the potential to uncover more positive responses to the various social challenges associated with this major 21st century phenomenon aimed at combating the negative perceptions that are currently prevalent in society.

Acknowledgments

The article was written with the financial support of institutional supports of research and creative activities at Charles University: Cooperatio Geography (COOP) research programme and the Specific Academic Research (SVV).

References

Bloom, D. E., Canning, D., Fink, G. (2010): Implications of Population Ageing for Economic Growth. Oxford Review of Economic Policy 26(4), 583–612, https://doi.org/10.1093/oxrep/grq038.

Bongaarts, J. (2004): Population aging and the rising cost of public pensions. Population and Development Review 30(1), 1–23, https://doi.org/10.1111/j.1728-4457.2004.00001.x.

Burcin, B., Šprocha, B., Šídlo, L. (2023): Vybrané aspekty úmrtnosti v Česku a na Slovensku v pandemickém roce 2020. Epidemiologie, mikrobiologie, imunologie 72(2), 99–110 (in Czech).

Clark, R., Peck, M. (2012): Examining the Gender Gap in Life Expectancy: A Cross-National Analysis, 1980–2005. Social Science Quarterly 93(3), 820–837, https://doi.org/10.1111/j.1540-6237.2012.00881.x.

Czaja, S. J., Boot, W. R., Charness, N., Fisk, A. D., Hertzog, C., Nair, S. N., Rogers, W. A., Sharit, J. (2006): Improving technology for older adults. Human Factors: The Journal of the Human Factors and Ergonomics Society 48(3), 625–663.

Cuaresma, J. C., Lábaj, M., Pružinský, P. (2014): Prospective Ageing and Economic Growth in Europe. The Journal of the Economics of Ageing 3, 50–57, https://doi.org/10.1016/j.jeoa.2014.05.003.

CZSO (Czech Statistical Office) (2012): Migrace v hl. m. Praze v letech 2001 až 2011 – Saldo migrace v Praze. Available online: https://csu.gov.cz/docs/107508/32905400-cb55-f8d5-3e3e-2e4ecc2d0a97/104035

-12k05.pdf?version=1.0 (accessed on 20 March 2025, in Czech).
CZSO (Czech Statistical Office) (2022a): Vloni zemřelo v Česku nejvíce lidí od konce války. Available online: https://csu.gov.cz/produkty/vloni-zemrelo-v-cesku-nejvice-lidi-od-konce-valky (accessed on 10 March 2025, in Czech).
CZSO (Czech Statistical Office) (2023): Základní tendence demografického, sociálního a ekonomického vývoje Středočeského kraje. Available online: https://csu.gov.cz/docs/107508/cd06ac63-add5-d884-7cdb-55bf7ad72b47/3301262401.pdf?version=1.7 (accessed on 19 March 2025, in Czech).
CZSO (Czech Statistical Office) (2024a): Veřejná databáze. Available online: https://vdb.czso.cz/vdbvo2/faces/cs/index.jsf?page=statistiky (accessed on 1 February 2025, in Czech).
CZSO (Czech Statistical Office) (2024b): Katalog produktů. Available online: https://csu.gov.cz/katalog-produktu?pocet=10&start=0&pouzeVydane=true&pouzePosledni=false&razeni=-datumVydani (accessed on 20 February 2025, in Czech).
CZSO (Czech Statistical Office) (2025): Nezaměstnanost v Ústeckém kraji k 31. 3. 2025 (podle MPSV). Available online: https://csu.gov.cz/ulk/nezamestnanost-v-usteckem-kraji-k-31-3-2025-podle-mpsv (accessed on 30 April 2025, in Czech).
Čábela, F. (2023): Aplikace prospektivních ukazatelů demografického stárnutí na okresní úrovni v Česku. Diploma Thesis. Charles University, Faculty of Science, Department of Deography and Geodemography. Supervizor: Luděk Šídlo. Available online: https://dspace.cuni.cz/handle/20.500.11956/181078 (accessed on 12 March 2025, in Czech).
Čábela, F., Šídlo, L. (2024): Demografické stárnutí v Česku mezi lety 2012–2022 prostřednictvím vybraných retrospektivních a prospektivních ukazatelů. Demografie 66(2), 154–165, https://doi.org/10.54694/dem.0341 (in Czech).
Dzúrová, D., Hulíková, K. (2021): Pandemie Covid-19 a její dopad na úmrtnost v Česku. 50th Conference of Czech Demographic Society, Ostrava, 15.–17. September 2021. Available online: https://www.czechdemography.cz/res/archive/008/000963.pdf (accessed on 11 March 2025, in Czech).
Eurostat (2025): EU population diversity by citizenship and country of birth. Statistics Explained, Lucemburk. Available online: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=EU_population_diversity_by_citizenship_and_country_of_birth (accessed on 1 March 2025).
Gietel-Basten, S., Saucedo, S. E. G., Scherbov, S. (2020): Prospective measures of aging for Central and South America. PLoS One 15(7), https://doi.org/10.1371/journal.pone.0236280.
Foster, L., Walker, A. (2015): Active and successful aging: a European policy perspective. Gerontologist 55(1), 83–90, https://doi.org/10.1093/geront/gnu028.
Ghio, D., Goujon, A., Natale, F. (2022): Assessing the demographic impact of migration on the working-age population across European territories. Demographic Research 46(9), 261–272, https://doi.org/10.4054/DemRes.2022.46.9.
Gregory, T., Patuelli, R. (2013): Regional Age Structure, Human Capital and Innovation – Is Demographic Ageing Increasing Regional Disparities? Discussion Paper 13-057, 1–31, http://dx.doi.org/10.2139/ssrn.2316259.
Gruenberg, E. M. (1977): The Failures of Success. Milbank Q 2005 83(4), 779–800, https://doi.org/10.1111/j.1468-0009.2005.00400.x.
Holzmann, R. (2013): A Provocative Perspective on Population Aging and Old-Age Financial Protection. IZA Discussion Paper Series, 7571. Available online: https://ssrn.com/abstract=2318752 (accessed on 5 March 2025).
Ježek, J. (2016): Geostatistika a prostorová interpolace. Praha: Nakladatelství Karolinum (in Czech).
Kashnitsky, I., De Beer, J., van Wissen, L. (2020): Unequally ageing regions of Europe: Exploring the role of urbanization. Population Studies 75(2), 221–237, https://doi.org/10.1080/00324728.2020.1788130.
Klapková, M., Šídlo, L., Šprocha, B. (2016): Koncept prospektivního věku a jeho aplikace na vybrané ukazatele demografického stárnutí. Demografie 58(2), 129–141 (in Czech).
Koukalová, J. (2023): Population development in the Czech Republic in 2022. Demografie 65(4), 221–239, https://doi.org/10.54694/dem.0336.
Kurkin, R., Němečková, M., Štyglerová, T. (2016): Population Development in the Czech Republic in 2015. Demografie 58(4), s. 299–319.
Lesthaeghe, R. (2010): The unfolding story of the second demographic transition. Population and Development Review 36(2), 211–251, https://doi.org/10.1111/j.1728-4457.2010.00328.x.
Lutz, W., Sanderson, W. C., Scherbov, S. (2008a): Global and regional population ageing: how certain are we of its dimensions? Population Ageing 1, 75–97, https://doi.org/10.1007/s12062-009-9005-5.
Lutz, W., Sanderson, W. C., Scherbov, S. (2008b): The Comming Acceleration of Global Population Ageing. Nature 451, 716–719, https://doi.org/10.1038/nature06516.
Murtin, F., Mackenbach, J., Jasilionis, D., d'Ercole, M. M. (2017): Inequalities in longetivity education in OECD countries: Insights from new OECD estimates. OECD, https://dx.doi.org/10.1787/6b64d9cf-en.
Omran, A. R. (1971): The epidemiological transition: a theory of epidemiology of population change. Milbank Memorial Fund Quarterly 49(4), 509–538, https://doi.org/10.1111/j.1468-0009.2005.00398.x.
Posthuma, R. A., Campion, M. A. (2009): Age Stereotypes in The Workplace: Common Stereotypes, Moderators, and Future Research Directions. Journal of Management 35, 158–188, https://doi.org/10.1177/0149206308318617.
Riffe, T. (2015): The force of mortality by life lived is the force of increment by life left in stationary populations. Demographic Research 32, 827–834, https://doi.org/10.4054/DemRes.2015.32.29.
Rochelle, T., Yeung, D. K. Y., Bond, M. H., Li, L. M. W. (2015): Predictors of the gender gap in life expectancy across 54 nations. Psychology, Health & Medicine 20(2), 129–138, https://doi.org/10.1080/13548506.2014.936884.
Ryder, N. B. (1975): Noteson Stationary Populations. Population Index 41(1), 3–28, https://doi.org/10.2307/2734140.

Sanderson, W. C., Scherbov, S. (2005): Average remaining lifetimes can increase as human populations age. Nature 435(7043), 811–813, https://doi.org/10.1038/nature03593.

Sanderson, W. C., Scherbov, S. (2007): A new perspective on population aging. Demographic Research 16, 27–58, https://doi.org/10.4054/DemRes.2007.16.2.

Sanderson, W. C., Scherbov, S. (2008): Rethinking Age and Aging. Population Bulletin 63(4), 3–16. Available online: https://www.prb.org/wp-content/uploads/2021/01/Population-Bulletin-2008-63.4-aging.pdf (accessed on 3 March 2025).

Sanderson,W. C., Scherbov, S. (2010): Remeasuring Aging. Science 329(5 997), 1287–1288, https://doi.org/10.1126/science.1193647.

Sanderson, W. C., Scherbov, S. (2013): The Characteristics Approach to the Measurement of Population Aging. Population and Development Review 39(4), 673–685, https://doi.org/10.1111/j.1728-4457.2013.00633.x.

Sanderson, W. C., Scherbov, A. (2016): A Unifying Framework for the Study of Population Aging. Vienna Yearbook of Population Research 14, 7–39, https://doi.org/10.1553/populationyearbook2016s007.

Siegel, J. S., Davidson, M. (1984): Demographic and Socioeconomic Aspects of Aging in the United States. Current population reports. Available online: https://www2.census.gov/library/publications/1984/demographics/p23-138.pdf (accessed on 14 March 2025).

Siegel, J. S. (1993): A Generation of Change: a Profile of America's Older Population. New York: Russell Sage Foundation, 1993, xxxvi, 647 p.

Siegel, J. S. (2002): Applied demography. Applications to Business, Government, Law, and Public Policy, San Diego: Academic Press.

Skirbekk, V. F., Staudinger, U. M., Cohen, J. E. (2019): How to Measure Population Aging? The Answer Is Less than Obvious: A Review. Gerontology 65(2), 136–144, https://doi.org/10.1159/000494025.

Spijker, J., MacInnes, J. (2013): Population Ageing: the Time Bomb that Isn't? British Medical Journal 347: 6598, https://doi.org/10.1136/bmj.f6598.

Spijker, J., Riffe, T., MacInnes, J. (2014): Incorporating Time-To-Death (TTD) in health-based population ageing measurements. Available online: https://www.oeaw.ac.at/fileadmin/subsites/Institute/VID/PDF/Conferences/2014/p1-Spijker.pdf (accessed on 9 March 2025).

Spijker, J. (2015): Alternative indicators of population ageing: an inventory. Working papers, Vienna Institute of Demography, Vienna, https://doi.org/10.13140/RG.2.1.2115.8884.

Spijker, J. (2022): The future of ageing in Latin America and the Caribbean from different methodological perspectives. Papeles de Poblacion 28(114), 15–36, http://dx.doi.org/10.22185/24487147.2022.114.20.

Spijker, J. (2023): Combining remaining life expectancy and time to death as a measure of old-age dependency related to health care needs. International Journal of Health Economics and Management 23(2), 173–187, https://doi.org/10.1007/s10754-022-09328-7.

Straka, J., Šídlo, L., Kulhánová, I. (2024). Trends in healthy life years between 2005 and 2019 in 31 European countries: the compression or expansion of morbidity? International Journal of Public Health 69: 1607574, https://doi.org/10.3389/ijph.2024.1607574.

Šídlo, L., Šprocha, B., Ďurček, P. (2020a): A retrospective and prospective view of current and future population ageing in the European Union 28 countries. Moravian Geographical Reports 28(3), 187–207, https://doi.org/10.2478/mgr-2020-0014.

Šídlo, L., Šprocha, B., Ďurček, P. (2020b): Prospective dimension of population ageing and potential use in pension security in V4 countries. Ekonomický časopis 68(6), 601–621. Available online: https://www.sav.sk/?lang=en&doc=journal-list&part=article_response_page&journal_article_no=18540 (accessed on 7 March 2025).

Šídlo, L., Šprocha, B., Klapková, M. (2019): Regional differences in population aging in Europe viewed through prospective indicators. Erkunde 73(3), 225–240, https://doi.org/10.3112/erdkunde.2019.03.06.

Šprocha, B., Ďurček, P. (2018): Prospektívny prístup pri regionálnej analýze procesu populačného starnutia na Slovensku. Geographica Cassoviensis XII., 2, 212–223 (in Slovak).

Šprocha, B., Ďurček, P. (2019): Starnutie populácie Slovenska v čase a priestore. Bratislava: Prognostický ústav, 96 s. Available online: https://www.prog.sav.sk/wp-content/uploads/Starnutie-populacie-SR.pdf. (accessed on 12 July 2025, in Slovak).

Šprocha, B., Šídlo, L., Klapková, M., Ďurček, P. (2018): Nové prístupy k hodnoteniu procesu populačného starnutia a ich aplikácia v prípade Slovenska a Európy. Geografický časopis 70(4), 351–371, https://doi.org/10.31577/geogrcas.2018.70.4.19 (in Slovak).

Štefko, M. (2018): Kauza hornické důchody v reformě z roku 2016, odůvodněnost zvláštního důchodového věku. Časopis pro právní vědu a praxi, 26(1), 87–100, https://doi.org/10.5817/CPVP2018-1-6 (in Czech).

Štyglerová, T., Němečková, M. (2023): Odraz války na Ukrajině v demografické statistice Česka. 52th conference of Czech Demographic Society, Hradec Králové, 24.–26. May 2023. Available online: https://www.czechdemography.cz/res/archive/011/001312.pdf (accessed on 11 March 2025, in Czech).

van de Kaa, D. J. (1997): Options and sequences: Europe's demographic patterns. Journal of the Australian Population Association 14(1), 1–29. Available online: https://www.jstor.org/stable/41110439 (accessed on 2 March 2025).

Appendix 1 Life Expectancy at Age 65 (e_{65}) and the Constant Prospective Age (*CPA RLE* 15–), Males and Females, Czechia, 2003–2023.

Year	Males (M)		Females (F)		Difference F vs. M	
	e_{65}	CPA RLE 15–	e_{65}	CPA RLE 15–	e_{65}	CPA RLE 15–
2003	13.90	63.31	17.29	67.92	3.40	4.62
2004	14.25	63.86	17.68	68.42	3.43	4.56
2005	14.43	64.13	17.83	68.61	3.41	4.48
2006	14.79	64.68	18.21	69.07	3.42	4.39
2007	15.01	65.02	18.34	69.22	3.33	4.21
2008	15.22	65.34	18.57	69.51	3.35	4.17
2009	15.14	65.22	18.53	69.46	3.39	4.24
2010	15.29	65.46	18.75	69.75	3.45	4.29
2011	15.48	65.74	18.91	69.95	3.43	4.21
2012	15.55	65.83	19.04	70.09	3.49	4.26
2013	15.59	65.89	19.12	70.23	3.53	4.34
2014	15.93	66.40	19.58	70.75	3.64	4.35
2015	15.76	66.13	19.26	70.37	3.51	4.23
2016	16.09	66.61	19.70	70.88	3.61	4.27
2017	16.09	66.60	19.62	70.78	3.53	4.19
2018	16.14	66.69	19.71	70.90	3.57	4.21
2019	16.29	66.89	19.94	71.17	3.65	4.28
2020	15.22	65.32	19.17	70.19	3.95	4.87
2021	14.51	64.27	18.65	69.71	4.14	5.44
2022	16.05	66.52	19.81	70.96	3.76	4.44
2023	16.70	67.42	20.43	71.73	3.73	4.32
2023–2003 abs.	+2.80	+4.11	+3.14	+3.81	+0.34	-0.30
2023–2013 abs.	+1.11	+1.53	+1.31	+1.51	+0.20	-0.02
2013–2003 abs.	+1.69	+2.59	+1.82	+2.30	+0.14	-0.28
2023–2003 rel.	+20.1%	+6.5%	+18.1%	+5.6%	+10.0%	-6.6%
2023–2013 rel.	+7.1%	+2.3%	+6.9%	+2.1%	+5.7%	-0.5%
2013–2003 rel.	+12.2%	+4.1%	+10.6%	+3.4%	+4.0%	-6.1%
Maximum	16.70	67.42	20.43	71.73	4.14	5.44
Minimum	13.90	63.31	17.29	67.92	3.33	4.17
Range	2.80	4.11	3.14	3.81	0.81	1.27

Source: CZSO; authors' calculations.

Appendix 2 Differences between the *Proportion 65+* and the *Proportion RLE 15–*, NUTS 2 regions of Czechia (in percentage points).

Region/Year	PR	CB	SW	NW	NE	SE	CM	MS
2003	1.82	0.52	0.98	−0.47	0.93	1.45	1.44	0.38
2008	3.98	2.00	3.05	1.57	3.03	3.57	3.13	2.24
2013	6.52	3.84	4.69	2.78	5.30	5.07	4.47	3.27
2018	6.65	5.11	5.44	4.34	5.64	5.90	6.15	4.89
2021	5.34	3.14	3.46	1.56	3.51	4.58	3.53	2.89
2023	6.24	5.66	6.36	4.53	6.35	6.77	7.23	5.95

Source: CZSO; authors' calculations.

Appendix 3 Differences between the Ageing Index (*AI*) and the Prospective Ageing Index (*PAI*), NUTS 2 regions of Czechia.

Region/Year	PR	CB	SW	NW	NE	SE	CM	MS
2003	9.88	2.42	4.46	−2.06	4.15	6.53	6.46	1.64
2008	23.23	9.60	15.02	7.30	14.51	17.49	15.24	10.62
2013	37.10	18.31	24.02	13.66	26.45	25.98	23.03	16.63
2018	34.52	23.22	27.24	21.17	27.73	29.49	31.18	24.82
2021	26.58	13.76	16.90	7.54	16.90	22.05	17.46	14.35
2023	29.73	24.17	30.37	21.53	29.85	31.77	35.06	29.12

Source: CZSO; authors' calculations.

Appendix 4 Differences between the Old-Age Dependency Ratio (*OADR*) and the Prospective Old-Age Dependency Ratio (*POADR*), NUTS 2 regions of Czechia.

Region/Year	PR	CB	SW	NW	NE	SE	CM	MS
2003	3.36	0.99	1.83	−0.87	1.76	2.73	2.69	0.70
2008	6.92	3.64	5.53	2.82	5.54	6.51	5.73	4.08
2013	11.72	7.21	8.82	5.26	9.98	9.51	8.44	6.16
2018	12.65	10.24	11.01	8.84	11.59	11.80	12.36	9.80
2021	10.85	6.76	7.61	3.51	7.85	9.83	7.81	6.28
2023	12.27	11.76	13.43	9.78	13.68	14.16	15.35	12.58

Source: CZSO; authors' calculations.

Appendix 5 Differences in the Pensioners to Workers Ratio (*PWR*), NUTS 2 regions of Czechia, 2023–2003, 2023–2013, 2013–2003.

Region/Year	PR	CB	SW	NW	NE	SE	CM	MS
2013–2003	−0.05	−0.02	5.21	6.92	6.77	1.54	4.77	1.45
2023–2013	−5.18	−1.46	−1.04	−2.09	−1.06	−0.78	−1.14	−0.99
2023–2003	−5.23	−1.48	4.17	4.84	5.71	0.75	3.62	0.45
2013–2003 rel. (%)	−0.10	−0.04	9.86	12.82	12.33	2.67	8.37	2.37
2023–2013 rel. (%)	−10.88	−2.77	−1.80	−3.43	−1.72	−1.32	−1.85	−1.59
2023–2003 rel. (%)	−10.97	−2.80	7.89	8.95	10.40	1.31	6.36	0.74

Source: CZSO; authors' calculations.

Appendix 6 Differences in the Real Elderly Dependency Ratio (*REDR*), NUTS 2 regions of Czechia, 2023–2003, 2023–2013, 2013–2003.

Region/Year	PR	CB	SW	NW	NE	SE	CM	MS
2013–2003	−5.14	−2.99	−0.82	1.27	−1.45	−1.98	1.11	0.75
2023–2013	3.59	2.89	4.18	5.39	6.55	3.51	2.33	2.97
2023–2003	−1.55	−0.10	3.36	6.66	5.10	1.54	3.45	3.72
2013–2003 rel. (%)	−19.10	−10.58	−3.00	4.45	−5.21	−6.99	4.03	2.56
2023–2013 rel. (%)	16.51	11.45	15.71	18.09	24.79	13.36	8.13	9.84
2023–2003 rel. (%)	−5.75	−0.34	12.24	23.34	18.29	5.44	12.49	12.65

Source: CZSO; authors' calculations.

Abbreviations

EU = European Union
PR = Prague region (CZ01)
CB = Central Bohemia region (CZ02)
SW = South-west region (CZ03)
NW = North-west region (CZ04)
NE = North-east region (CZ05)
SE = South-east region (CZ06)
CM = Central Moravia region (CZ07)
MS = Moravian-Silesian region (CZ08)