Demographic ageing in Romania and the EU countries: a quantitative approach using a composite index

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Abstract

This study presents a comprehensive methodological approach to construct a composite index of demographic ageing, with a particular focus on Romania in comparison to the other 26 Member States of the European Union (EU). Drawing on data from 2000 to 2022, the research integrates multiple demographic indicators, such as birth and death rates, ageing and dependency ratios, migration flows and population structure into a single index. Using Principal Component Analysis (PCA) for weighting and aggregation, the index captures both the magnitude and dynamics of the ageing phenomenon across countries. The findings reveal significant heterogeneity in ageing patterns across the EU, with Romania positioned in an intermediate but upward trajectory. The study contributes to the literature by offering a replicable, multidimensional tool for comparative demographic analysis and underscores the urgent need for data-informed policy responses to address the socioeconomic impacts of population ageing.

Keywords: demographic ageing, composite index, European Union, Romania, dependency ratio

Introduction

The demographic transformations of recent decades represent a major challenge for all European Union Member States, including Romania. Phenomena such as declining birth rates, increasing life expectancy, population ageing and large-scale external migration have led to significant changes in population structure, with visible effects on both economic and social balances, carrying profound implications for labour markets, public health systems, social protection scheme and economic sustainability.

Demographic ageing constitutes one of the most serious challenges currently facing Romania, as well as both developed and less developed countries. These demographic changes have far-reaching consequences for the labour market, as well as for healthcare and pension systems.

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From a statistical perspective, demographic ageing is a multidimensional process that cannot be fully captured by a single indicator. Therefore, composite indices provide a valuable methodological alternative by integrating multiple indicators into a single, standardized measure, allowing for a more comprehensive and comparable evaluation across countries and time periods. This study adopts a quantitative methodology, constructing a composite index to measure and compare the degree of demographic ageing across Romania and other EU countries over the period 2000–2022.

This paper aims to conduct an analysis of a composite index built using a couple of demographic variables that are relevant for the demographic ageing phenomenon. The methodological approach involves the selection of key demographic indicators, such as total population, birth rate, mortality rate, demographic ageing rate and dependency rate, active population replacement rate and net migration. From the methodology, PCA is used for dimensionality reduction and to identify the latent factors that explain most of the variance in the dataset. The extracted components are then interpreted and used to construct the composite index.

The resulting composite index synthesizes the initial set of variables into a unidimensional score, which serves as the basis for comparing countries in terms of the intensity and evolution of demographic ageing.

The objective is to highlight the extent to which Romania's demographic trajectory aligns with or diverges from the European average, the focus being on the demographic ageing pattern. Based on the findings and the values obtained by the composite index, this study outlines the distinctive features of individual countries.

Romania, like many countries in Central and Eastern Europe, has undergone a dramatic demographic transformation in recent decades. The primary driver of demographic ageing is the sustained decline in birth rates. Romania has experienced several critical historical moments that have significantly shaped its demographic trends, including agrarian reforms, legislation concerning the organization of the healthcare system and laws regulating marriage, divorce and abortion (Trebici, 1978 and 1981).

Understanding the magnitude and pace of ageing within Romania's population, particularly in comparison with other EU states, can inform strategic planning, resource allocation and long-term socio-economic resilience. This article develops a composite index to measure demographic ageing, enabling robust cross-country comparison while identifying national specificities and broader regional patter.

The purpose of this study is to present a statistically grounded methodological approach to constructing a composite index of demographic ageing and to empirically evaluate Romania's demographic profile in the context of the European Union, based on data spanning from 2000 to 2022.

1. Literature Review

Understanding the level of demographic ageing is of critical importance, as this phenomenon is essential for identifying trends and informing the adoption of appropriate policy measures. Demographic ageing represents one of the most profound structural changes affecting modern populations, resulting from a combination of factors such as declining fertility and birth rates, increased life expectancy and reduced mortality, all of which are further amplified by migration. This process has significant implications for social protection systems, labour markets and economic dynamics and is regarded as an advanced stage of the demographic transition (Lee & Mason, 2010).

Demographic changes profoundly affect the economic, social and political structure of a country. Among all ongoing transformation, whether declining birth rates, migration or increased life expectancy, the most significant and impactful is the phenomenon of demographic ageing, which places considerable pressure on the sustainability of modern societies.

One of the primary challenges posed by demographic ageing concerns the economy, particularly its effects on the active labour force and economic productivity. As the number of economically active adults declines and the number of retirees rises, economic systems face a dual strain: decreasing contributions to pension schemes and increasing public expenditures for elderly care. The growing old-age dependency ratio, especially relative to the working-age population, threatens the sustainability of social protection systems. In the absence of timely reforms in pension policies and labour markets, these pressures risk evolving into severe economic crises.

Population ageing directly impacts labour market equilibrium by reducing the number of working age individuals and increasing the proportion of retirees within the total population. This trend leads to labour shortages, economic stagnation and mounting pressure on social protection systems.

During the communist period, Central and Eastern European countries exhibited high fertility rates. However, following the collapse of these regimes, fertility declined sharply due to economic instability, high unemployment, changes in family behaviours (such as delayed marriage and postponement of the first child) and increased access to contraception and individual reproductive choices. Since the early 2000s, fertility patterns have shown signs of recovery, largely attributed to economic stabilization and the implementation of family-friendly policies (Sobotka, 2011). This evolution suggests a direct relationship between fertility trends and socio-economic conditions.

The main drivers of economic growth - labour supply, productivity, consumption and savings, are all significantly influenced by the age structure of the population. Economies with a higher proportion of the working age population—those fit for employment—tend to have a greater potential for economic expansion. Conversely, countries with a disproportionately high share of young or elderly populations often face more limited growth prospects.

Research by Maestas, Mullen and Powell (2016) identifies a clear relationship between population ageing and productivity growth. This relationship is mediated through three core elements: output levels, labour productivity and workforce participation. Their findings suggest that a 10% increase in the share of the population aged 60 and over is associated with a 5.5% decline in per capita GDP growth. Two-thirds of this reduction stems from slower productivity growth across all age groups, while one-third is due to a deceleration in labour force expansion.

Similarly, a study by Iftimi and Panaite (2021) concludes that the pace of demographic ageing may hinder economic growth—both in terms of GDP per capita and labour productivity. As the population ages, the demand for social services, healthcare and pension benefits is expected to rise, placing additional strain on the working-age population.

While earlier research (Preston, 1975, cited in Bloom et al., 2011) found that increased life expectancy is strongly correlated with higher per capita income, more recent studies (Iftimi and Panaite, 2021) confirm that demographic ageing can dampen GDP and productivity growth. These findings underscore the need for proactive economic measures to mitigate the potential adverse effects of ageing on economic performance.

Demographic ageing has significant implications for healthcare systems, influencing both the demand for medical services and their structural organization. As the population ages, the prevalence of chronic illnesses and comorbidities increases significantly, prompting a reorientation of priorities within the healthcare sector.

As individuals age, the likelihood of developing chronic diseases increases substantially. According to Prince et al. (2015) in their study "The Burden of Disease in Older People and Implications for Health Policy and Practice", over 70% of older adults suffer from at least one chronic condition, with more than 50% experiencing comorbidities. This clinical complexity necessitates an integrated and multidisciplinary approach to healthcare, placing additional pressure on medical infrastructure and service delivery systems.

The construction and use of composite indices have gained prominence in recent years as a means of capturing complex, multidimensional phenomena. In the context of demographic analysis, such indices enable the synthesis of various indicators, such as birth and death rates, ageing ratios, dependency levels and migration into a single, interpretable measure (OECD, European Commission and Joint Research Centre, 2008).

Despite the wealth of research, relatively few studies focus on the creation of a composite index specifically aimed at quantifying the intensity of demographic ageing across EU countries. This study addresses that gap by offering a detailed methodology and applying it to current European data, with a particular focus on Romania. Therefore, a composite index integrates demographic indicators, enabling nuanced cross-national comparison and contextualizing Romania's ageing pathway in the broader EU demographic landscape.

2. Methodological approach to construct a composite index

The construction of a composite index requires a rigorous and transparent methodological framework to ensure its validity, reliability and interpretability. Composite indices are widely used in empirical research to synthesize multidimensional phenomena into a single metric, facilitating comparative analysis and informed decision-making. This section outlines the key methodological steps involved in building the composite index, including indicator selection, data normalization, weighting and aggregation.

The construction of a composite index involves the following steps: an analysis of the theoretical framework, followed by the selection of data and variables, imputation of missing data, data normalization, weighting and aggregation and finishes by the uncertainty and sensitivity analysis.

a. Theoretical framework analysis

This step involves examining the theoretical foundation that underpins the construction of the composite index.

b. Data and variable selection

This step entails selecting relevant data and analytical variables.

c. Missing data imputation

Imputing missing data helps to standardize the database, minimize errors and correct for information that is difficult or costly to collect (OECD, European Commission and Joint Research Centre, 2008).

In the case of a dataset containing missing values, one of the following methods may be applied (OECD, European Commission and Joint Research Centre, 2008):

- Simple imputation (e.g., replacing missing data with the mean, median, or using regression methods, hot and cold deck imputation, or the Expectation Maximisation (EM) method).
- Multiple Imputation (e.g., using methods such as Markov Chain or Monte Carlo algorithms).

Regardless of the method used, a complete dataset is essential for the accurate calculation and use of a composite index.

d. Data normalization

According to OECD guidelines (2008), data normalization is recommended prior to applying any data aggregation method to form a composite index. This is necessary due to the differing ranges of variation often found among quantitative variables (Pintilescu, 2022).

Some of the most used statistical variable normalization methods include:

- Ranking Method – a simple method where scores are assigned to each value of a variable based on its relative importance (Încalțărău, 2023).
- Min-Max normalization – transforms original variables into new variables with values in the range [0, 1], aiming to reduce the influence of outliers. The normalization formula is:

$$\frac{x_i - x_{min}}{x_{max} - x_{min}}$$

where x_{max} and x_{min} are the maximum and minimum values of the given variable.

- Standardization (Z-score calculation) – transforms variables into new ones with a mean of zero and a variance of one (Pintilescu, 2022). The transformation from a normal distribution to a standard normal distribution is done following the relationship (Jaba, 2002):

$$x_i' = \frac{x_i - \bar{x}}{s}$$

Standardization is particularly appropriate when comparing variables expressed in different units of measurement and it is recommended when using methods aiming to maximize the variance, such as Principal Component Analysis (Pintilescu, 2022).

Regardless of the normalization method applied, it is essential to consider the direction of influence of each variable. If a variable has a negative influence on the phenomenon being studied, it should be normalized in reverse. This adjustment ensures interpretative consistency and contributes to the development of a meaningful and comparable synthetic indicator (Încalțărău, 2023).

e. Weighting and aggregation

The primary statistical methods used to determine the weights of variables in constructing a composite index are multivariate data analysis techniques, particularly Principal Component Analysis and Factor Analysis.

Principal Component Analysis (PCA) is a descriptive method of multidimensional data analysis applied to the study of relationships among quantitative variables, using Euclidean distance to measure the distance between points. PCA is used to reduce the dimensionality of statistical variables and to assess whether the phenomenon's dimensions are statistically balanced in the composite index calculation (OECD, European Commission and Joint Research Centre, 2008).

Starting with a number of p variables, PCA reveals p ranked lines, known as factorial axes or principal components, onto which individuals and variables are projected based on their degree of differentiation (Pintilescu, 2022). These axes are ordered according to their discriminatory power (i.e., the variance or inertia explained), in descending order. The sum of the eigenvalues equals the number of original variables.

In PCA, correlated statistical variables are grouped into a new set of uncorrelated variables, based on the covariance matrix or correlation table. Factor Analysis (FA) is similar to PCA, but is based on a specific statistical model (OECD, European Commission and Joint Research Centre, 2008). It is particularly useful when analysing a large number of highly correlated variables (Stevens, 2002). FA aims to identify the underlying structure of the relationships among variables, revealing latent factors not directly measured in the analysis (Pintilescu, 2022).

The authors of the OECD, European Commission and Joint Research Centre (2008) recommend the usage of multivariate analysis methods only when the number of statistical units exceeds the number of variables. Otherwise, the statistical robustness of the results may be compromised.

Weight calculation (w_i) is based on the correlation coefficients between variables and the factorial axes (factor loadings). The squared correlations are calculated and divided by the sum of variances for each factor. The highest value for each variable across all axes is then selected and multiplied by the proportion of variance explained by that axis. Finally, the weight for each variable is computed by dividing this product by the sum of all such values.

Once the weights for all variables are obtained, a linear combination is formed by multiplying each weight with the corresponding variable value (V_i, $i=1, p$):

$$composite\ index = w_1 * V_1 + w_2 * V_2 + \cdots + w_p * V_p$$

f. Uncertainty and sensitivity analysis

The construction of a composite index involves numerous decisions regarding the selection of indicators, data normalization methods, weight calculation and so forth. Therefore, it is strongly recommended to perform sensitivity analysis and robustness checks on the resulting composite indicator.

3. Building the composite index

In order to calculate the composite index, this study considered the period 2000 – 2022 for all 27 member states of the European Union. The variables considered are presented in Table 1 below:

Table 1. Definition of the variables of interest used in the calculation of the composite index

Indicator	Definition	Measurement unit
Total population (pop_t)	Population recorded on January 1st, with a certain citizenship, residing in a given territory	Number of inhabitants
Birth rate (birth_rate);	Number of live births recorded in a year, relative to the population recorded at mid-year	Births per 100 inhabitants (%)
Crude death rate (death_rate)	Number of deaths recorded in a year, relative to the population recorded at mid-year	Deaths per 1,000 inhabitants (‰)
Demographic ageing rate (ageing)	Number of elderly persons (aged 65 and over) relative to the number of young persons (under 15 years old)	Elderly per 1,000 young persons (‰)
Demographic dependency rate (dependency)	Number of elderly (65+ years old) and young (under 15 years old) persons relative to the number of working-age adults (15–64 years old)	Young and elderly per 1,000 adults (‰)
Active population replacement rate (replacement)	Estimates the number of adults who will be active in the labour market over the next 15 years; calculated by multiplying the number of young people (under 15 years old) by three times and dividing the total by the adult population (15–64 years old)	Young per 1,000 adults (‰)
Net migration (net_migr)	Difference between the number of immigrants and emigrants during a given reference period	Number of persons

Source: Eurostat

In order to calculate the composite index, the analysis period selected was between 2000 and 2022, as the statistical information available from international organizations for this timeframe is valid and complete compared to the years prior to 2000. This period includes key stages of social and economic transformation in Romania as well as in the EU countries, capturing a new phase of transition experienced by Romania—its accession to the European Union and the opening of international borders for the labour force.

Additionally, this timeframe includes major global events such as the economic crisis of 2007–2008 and the COVID-19 pandemic that began in 2019. All these events had a significant impact on economic development and produced measurable demographic effects relevant to the present study. Moreover, data availability for the 2000–2022 period is accurate, providing valid and relevant statistical information for all EU countries.

3.1. Missing data imputation

In order to use only complete time series, a simple imputation method was applied —the Expectation-Maximization (EM) algorithm. This approach estimates a regression model based on all available observed values and then replaces the missing data with the values predicted by the regression model. This is an iterative process, repeated until the estimated values converge and stabilize.

The EM method relies on the principle of maximum likelihood estimation and is performed in two main steps (Dellaert, 2002): during the first step, E-step (Expectation), a local lower bound of the posterior distribution is constructed and the missing values are estimated based on the conditional distribution of the observed data and the current model parameters. During the second step, M-step (Maximization), the lower bound found in the E-step is optimized, thereby improving the estimation of the missing values. In other words, the parameters are re-estimated to maximize the likelihood function for both the observed and the estimated data.

3.2. Calculation of variable weights in the construction of the composite index

Principal Component Analysis (PCA) is a descriptive method of multidimensional data analysis that, starting from a large set of variables, identifies a system of factorial axes that concentrate the information for better visualization. In other words, it is a dimensionality reduction technique that transforms a large number of variables into linear combinations in the form of principal components (factorial axes). The method also involves data standardization, where the variables are centered and scaled (Pintilescu, 2022).

In this study, PCA was applied to the statistical variables defined above and the results are presented in Table 2, which shows the eigenvalues of the correlation matrix and the variance explained by the factorial axes. The first principal component has an eigenvalue (variance) of 2.83, explaining 40.46% of the total variance of the data. The second principal component has a variance of 1.63, accounting for 23.26% of the total variance. Together, the first two components explain a cumulative variance of 63.73%. The third principal component has a variance of 1.23, explaining 17.56% of the total variance. Altogether, the first three principal components explain 81.29% of the total variance in the dataset.

Table 2. Eigenvalues of the correlation matrix and the variance explained by the principal components

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.832	40.461	40.461	2.832	40.461	40.461
2	1.629	23.264	63.725	1.629	23.264	63.725
3	1.229	17.560	81.285	1.229	17.560	81.285
4	0.502	7.178	88.464			
5	0.477	6.820	95.283			
6	0.323	4.613	99.896			
7	0.007	0.104	100.000			

Source: own calculations based on Eurostat data

Based on Kaiser's criterion, the principal components selected for analysis are those with eigenvalues greater than 1. Therefore, according to Kaiser’s criteria, the first three principal components are retained for further analysis. Thus, Table 3 presents the loading values (coordinates) of the variables on each principal component. For interpretation purposes, this study considered loadings with an absolute value greater than or equal to 0.5 as statistically and interpretatively significant.

Accordingly, the demographic ageing rate, mortality rate, active population replacement rate and birth rate are correlated with the first principal component—the first two positively and the latter two negatively. The demographic dependency rate is associated with the second principal component, while total population and net migration are correlated with the third principal component.

Table 3. Principal component matrix

Factor Method: Principal Factors
Covariance Analysis: Ordinary Correlation
Sample: 2000 2022
Included observations: 621
Number of factors: Minimum eigenvalue = 1
Prior communalities: Squared multiple correlation

	Unrotated Loadings			**Communality**	**Uniqueness**
Variables	**F1**	**F2**	**F3**		
dependency	0.27199	**0.90468**	-0.2847	0.973489	0.026511
ageing	**0.96757**	0.20299	-0.0604	0.981041	0.018959
replacement	**-0.8244**	0.53451	-0.1322	0.982804	0.017196
pop_t	0.29078	0.29247	**0.50878**	0.428952	0.571048
death_rate	**0.50326**	-0.0742	-0.3681	0.39425	0.60575
birth_rate	**-0.7189**	0.15487	0.09817	0.550479	0.449521
net_migr	0.23637	0.26156	**0.57028**	0.449495	0.550505

Source: own calculations based on Eurostat data

Based on factor analysis, three key components were identified: The first factor (F1), *the ageing and demographic transition factor* is represented by the variables related to the demographic ageing rate (0.968), mortality rate (0.503), active population replacement rate (-0.824) and birth rate (-0.719). This factor captures the opposition between the intensification of demographic ageing and the decline in birth rates, as well as the difficulty of replacing the retiring labour force with younger cohorts entering the labour market.

The 2nd factor (F2): *the demographic pressure factor*, is primarily associated with the demographic dependency ratio of the young and elderly on the working-age population (0.905). Additionally, the active population replacement rate (0.535) exceeds the 0.5 threshold, although it has a stronger association with the first factor. This factor reflects the demographic pressure exerted by the inactive population on the active population.

Finally, the 3rd factor (F3): *the migration and population dynamics factor* is defined by the net migration (0.570) and total population (0.509), capturing population dynamics and migratory flows.

Table 4 presents only the variance explained by these three factors. This step is crucial for evaluating the explanatory power of the factor analysis and the degree of dimensionality reduction achieved. The total variance accounted for by the three retained factors is 4.76. The first principal component explains over half of the total variance (54.62%), identifying it as the most influential factor. This highlights the predominance of the demographic ageing and transition dimension in the dataset. The second principal component accounts for 27.91% of the common variance, while the third principal component explains the remaining 17.46%. Together, these three components capture the majority of the shared variance, indicating a substantial dimensionality reduction and effective summarization of the original variables.

Table 4. Total variance and the proportion of common variance explained by the three factors

Factor	Variance	Cumulative	Difference	Proportion	Cumulative
F1	2.60036	2.60036	1.27158	0.546236	0.546236
F2	1.32879	3.92915	0.49743	0.279127	0.825364
F3	0.83136	4.76051	---	0.174636	1
Total	**4.76051**	**4.76051**		1	

Source: own calculations based on Eurostat data

3.3. Composite index calculation

In order to calculate the composite index, the next step involved squaring the loading values of each factor (Table 5). Subsequently, each squared loading was divided by the variance of the corresponding factor (as shown in Table 6).

Table 5. Steps in the calculation of the composite index

Variables	Unrotated loadings			Squared factor loadings for each variable		
	F1	F2	F3	$F1^2$	$F2^2$	$F3^2$
dependency	0.27199	**0.90468**	-0.2847	0.07398	0.81844	0.08107
ageing	**0.96757**	0.20299	-0.0604	0.93619	0.04120	0.00365
replacement	**-0.8244**	0.53451	-0.1322	0.67964	0.28570	0.01746
pop_t	0.29078	0.29247	**0.50878**	0.08455	0.08554	0.25886
death_rate	**0.50326**	-0.0742	-0.3681	0.25327	0.00551	0.13547
birth_rate	**-0.7189**	0.15487	0.09817	0.51686	0.02398	0.00964
net_migr	0.23637	0.26156	**0.57028**	0.05587	0.06841	0.32521
Variance	2.60036	1.32879	0.83136			

Source: own calculations based on Eurostat data

Table 6. Steps in the calculation of the composite index

Variables	Ratio of squared factor loadings to the variance explained by each principal component			Relative weight of the factors	Product between maximum value and factor weight
	F1	F2	F3		
dependency	0.02845	**0.61593**	0.09751	0.27913	0.17192
ageing	**0.36002**	0.03101	0.00439	0.54624	0.19666
replacement	**0.26136**	0.21501	0.02101	0.54624	0.14277
pop_t	0.03252	0.06437	**0.31137**	0.17464	0.05438
death_rate	0.09740	0.00414	**0.16295**	0.17464	0.02846
birth_rate	**0.19876**	0.01805	0.01159	0.54624	0.10857
net_migr	0.02149	0.05148	**0.39118**	0.17464	0.06831
Total					0.77107

Source: own calculations based on Eurostat data

Based on Table 6, for each variable, only the factor on which it registers its maximum value is considered further (for example, the highest value for demographic dependency appears on Factor 2, meaning that only this value is retained). This maximum value is then multiplied by the proportion of variance explained by the corresponding factor (from Table 4, "Proportion" column). Next, to compute the final weight of each variable (presented in Table 7), the resulting values were normalized once more by dividing each of them by the sum of all previously computed values.

Table 7. Computed weight assigned to each variable

Variables	Assigned factor	Proportion of each variable
dependency	F2	0.22297
ageing	F1	0.25504
replacement	F1	0.18515
pop_t	F3	0.07052
death_rate	F3	0.03691
birth_rate	F1	0.14081
net_migr	F3	0.08860
TOTAL		**1.00000**

Source: own calculations based on Eurostat data

In order to calculate the composite index, the seven statistical variables were normalized using the standard min-max normalization method. As a result, for each variable considered, values ranging between 0 and 1 were obtained for each year. Then, weights were applied to the normalized values of the selected statistical variables and the values of the indices were aggregated.

3.4. Results

The composite index was calculated for each European Union country for every year during the period 2000–2022. The higher the index value, the more aged the population of the country; on the other hand, the lower the index value, the younger the population.

The composite index values obtained for each EU countries during the 2000–2022 period are presented in the Annex 1. The results obtained were analysed from three perspectives:

- A comparative analysis between the European Union countries across intervals (low, medium and high rates of demographic ageing);
- A spatial analysis of the evolution of the composite index within the EU countries:
- A temporal analysis of the composite index in the year 2022 and the average annual change over the period 2000–2022.
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Comparative analysis of countries based on the intensity of the demographic ageing phenomenon

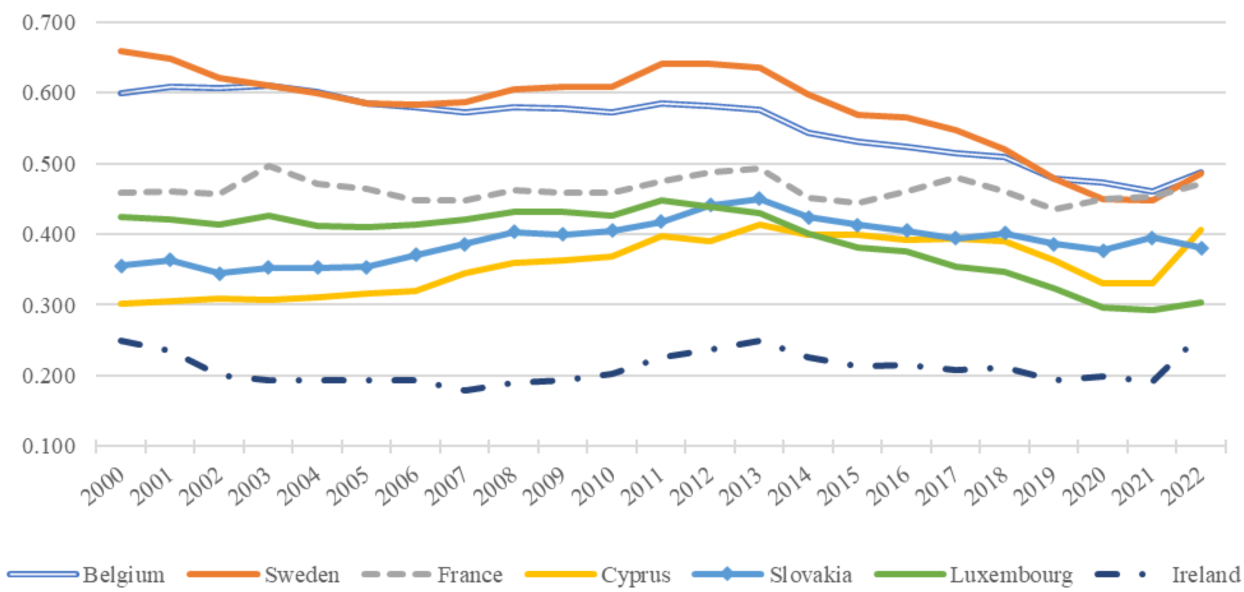
For a more detailed analysis, the European Union member states were categorized into three groups based on their composite index values for the year 2022:

- countries with index values below 0.5;
- countries with index values ranging from 0.5 to 0.65;
- countries with index values above 0.65.

A comparative analysis was then carried out for each of these groups.

Among European Union countries, seven states fall into the category of *low rates of demographic ageing,* according to the results obtained from the composite index calculation: Ireland, Luxembourg, Slovakia, Cyprus, France, Sweden and Belgium. The evolution of the demographic ageing index for these countries over the period 2000–2022 is presented in Figure 1.

Figure 1. The evolution of the composite index values (during the period 2000–2022) for countries with low rates of demographic ageing



Source: own calculations and representation based on Eurostat data

Based on Figure 1 of this research, some particular characteristics of the countries were observed. First, among the European Union countries, Ireland registered the lowest composite index value, indicating the youngest population throughout the analysed period. The index exhibited a continuous decline until 2007, reaching a minimum value of 0.180. Subsequently, it experienced an upward trend until 2013, peaking at 0.248, followed by a slight decline, culminating at 0.258 in 2022. This pattern suggests a relatively stable demographic structure with limited pressure from ageing phenomena.

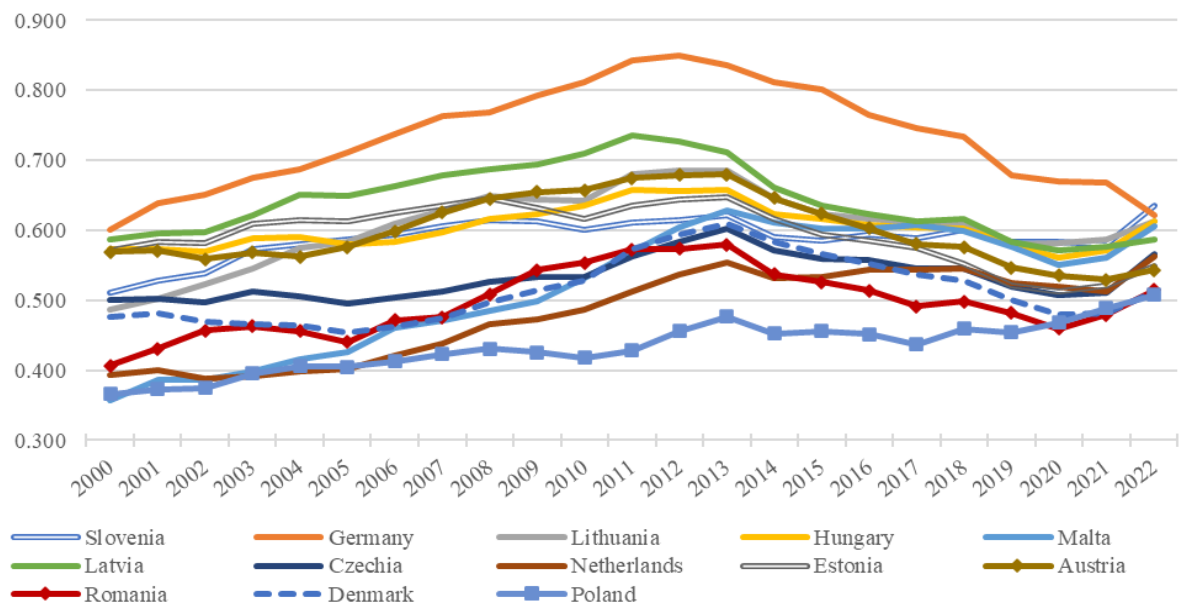
France also demonstrated a relatively stable demographic ageing index over time; its index remained comparatively constant throughout the analysed period, oscillating between a minimum of 0.435 in 2019 and a maximum of 0.497 in 2003, indicating a stable demographic ageing profile.

Belgium and Sweden, while starting the period with higher index values above 0.6, experienced a gradual decline over time; since 2019, both countries have consistently recorded values below 0.5, reflecting a reduction in the intensity of demographic ageing.

Luxembourg, Slovakia and Cyprus followed similar trajectories, marked by relatively stable index values near the 0.4 threshold, showing minor fluctuations over the analysed period. Their composite index values increased until the period 2011–2013, but shown a significant decrease afterwards, mostly notable in Luxembourg.

Thirteen EU countries fall into the category of *moderate demographic ageing*, with composite index values ranging between 0.5 and 0.65 in 2022. Although these countries exhibited considerable variation in their demographic ageing index throughout the 2000–2022 period—fluctuating between 0.357 and 0.850, Figure 2 shows that by the end of the reference period, the variation range of the demographic ageing index had narrowed considerably, lying between 0.508 and 0.635. This indicates the presence of a similar pattern in demographic ageing among these countries.

Figure 2. The evolution of the composite index values (during the period 2000–2022) for countries with moderate rates of demographic ageing



Source: own calculations and representation based on Eurostat data

From the countries in the moderate demographic ageing category, Poland recorded the lowest value of the composite index in 2022, of 0.508. Notably, this value also represents the highest level reached by Poland over the entire analysis period (2000–2022). This indicates a gradual and steady increase in demographic ageing, though still moderate compared to other states.

Several countries, including the Netherlands, Malta, Denmark, Romania and the Czech Republic, followed similar evolutionary trends with cyclical behaviour. These countries share a comparable trajectory: initially low index values (below 0.5), followed by a gradual increase until approximately 2013, then a slight decline leading up to the COVID-19 pandemic. In the case of Romania, the index ranged from 0.407 in 2000 to 0.580 in 2013, with an average annual growth rate of 1.17%, reflecting a progressive intensification of the demographic ageing process.

Six countries, Slovenia, Lithuania, Austria, Hungary, Estonia and Latvia saw an evolution of the composite index in two-phases. These countries began the reference period with index values around 0.5, experiencing a marked increase until 2013, surpassing the 0.7 threshold. Subsequently, the period between 2014 and 2020 saw slight declines, followed by renewed increases from 2021 onwards, suggesting a resurgence in demographic ageing pressures.

Germany stands out for its fluctuating and irregular trend, with index values around 0.6 at both the beginning and end of the period, and a notable peak at 0.850 in 2012, marking it as an outlier in terms of demographic ageing dynamics.

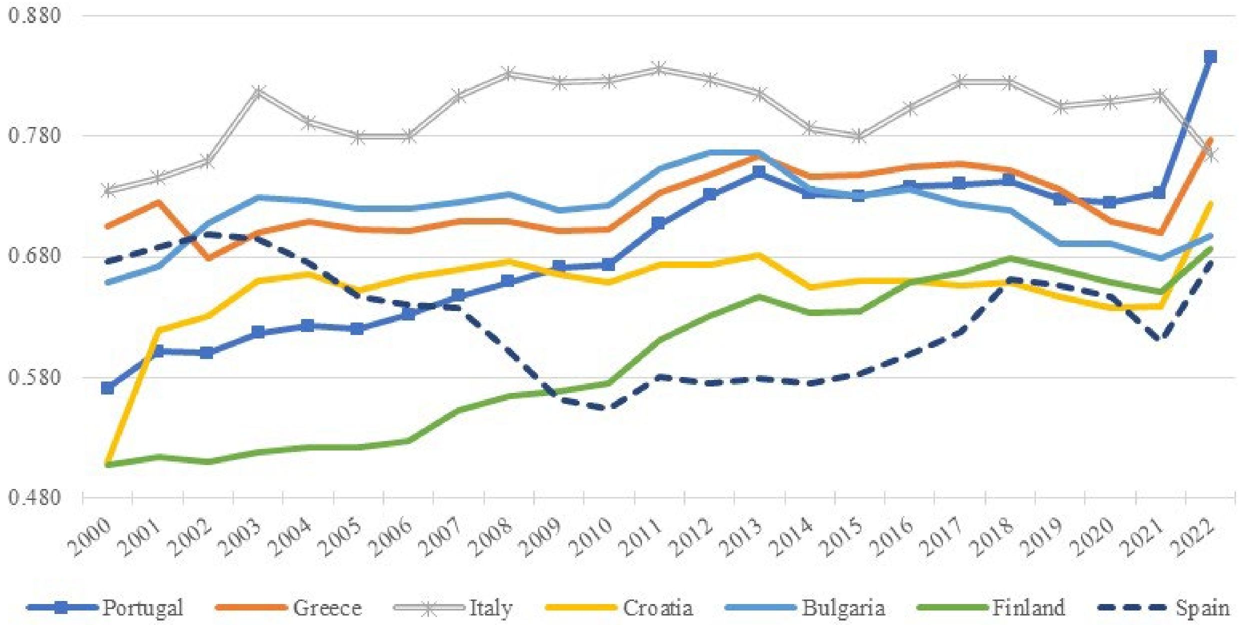
While the countries in this category display intermediate levels of demographic ageing, a more detailed analysis reveals distinct evolutionary patterns that tend to converge in the later years of the period under review. This suggests a relative homogenization of the demographic ageing process across the EU countries falling within this medium category.

The third category comprises countries experiencing *high rates of demographic ageing* with composite index values ranging from 0.675 to 0.846 in 2022. These countries reflect the most advanced stages of demographic transition within the EU, characterized by a significant ageing population. The data are graphically represented in Figure 3.

Among the countries facing high rates of demographic ageing, several distinct trends emerge. Finland experienced a steady increase in its composite index, rising from 0.507 in 2000 to 0.687 in 2022, with an average annual growth rate of 1.42%.

Portugal followed a similar upward trajectory but with more pronounced increases, starting at 0.571 in 2000 and reaching the highest value among all analysed countries—0.846—in 2022. Notably, Portugal also registered the highest year-on-year growth rate between 2021 and 2022, at +15%.

Figure 3. The evolution of the composite index values (during the period 2000–2022) for countries with high rates of demographic ageing



Source: own calculations and representation based on Eurostat data

Spain, by contrast, showed significant fluctuations, while the index remained roughly the same at both ends of the period (around 0.68). However, the country experienced an average annual decline of 2% between 2000 and 2010, reaching a minimum of 0.554. Subsequently, the index began to rise again at a similar average annual rate.

Greece and Bulgaria displayed relatively stable patterns, with index values generally around 0.7. Both countries recorded increases up to 2013, followed by slight declines until 2021. In 2022, Greece experienced a notable increase of 11% compared to the previous year. Croatia followed a similar but more moderate path than the other two, with its index rising from 0.510 in 2000 to 0.724 in 2022.

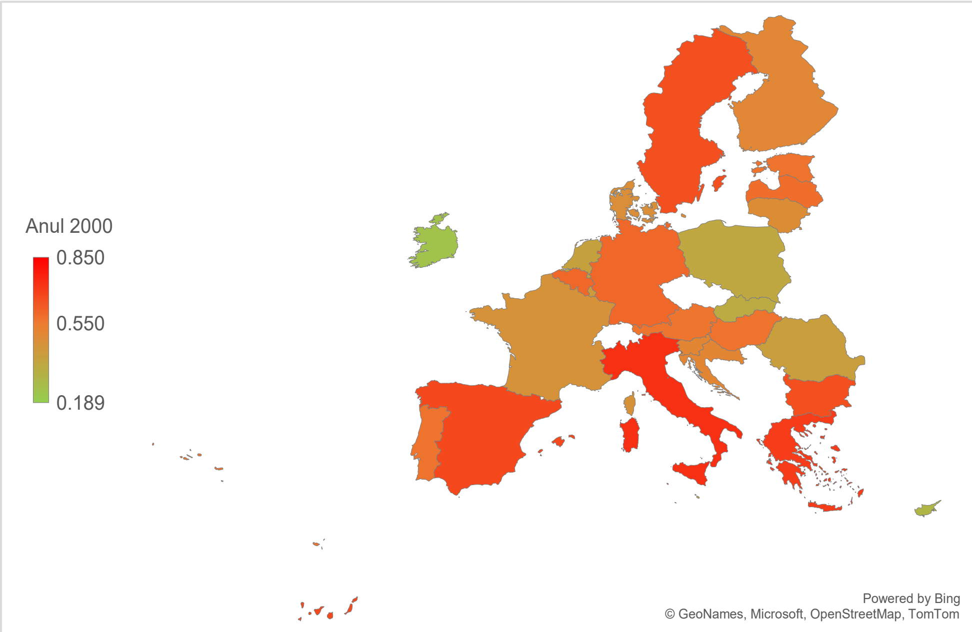
Italy recorded the highest values of the composite demographic ageing index throughout the 2000–2021 period. Although overtaken by Portugal in 2022, Italy maintained consistently high index values, ranging from 0.735 at the beginning of the reference period to a peak of 0.836 in 2011.

Spatial analysis of the evolution of the composite index in European Union countries

The maps presented in Figures 4, 5, 6 and 7 illustrate the spatial distribution of the composite index values across the 27 European Union Member States for four reference years: 2000, 2008, 2019 and 2022 (the calculated differences are provided in Annex 2).

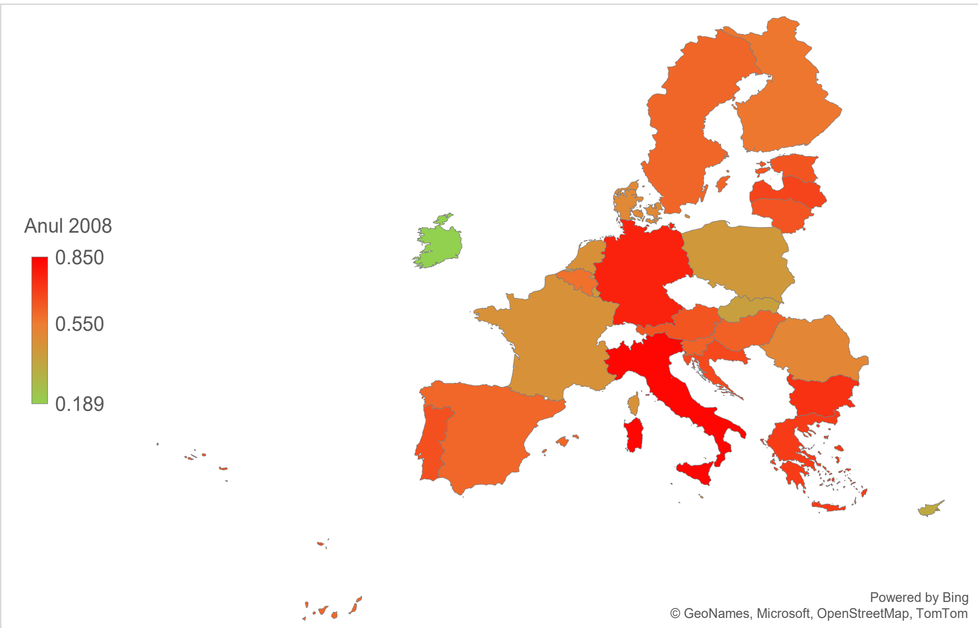
The colour symbolism used in the maps follows a gradient fr indicating low index values), through orange (moderate values), to bright red (high index values). The more intense the red hue, the higher the value of the composite index; on the other side, the closer the colour is to green, the lower the index value for the respective country. The orange shade denotes an intermediate level, situated between the minimum and maximum values.

Figure 4. Map of the composite index of demographic ageing in European Union countries, in 2000



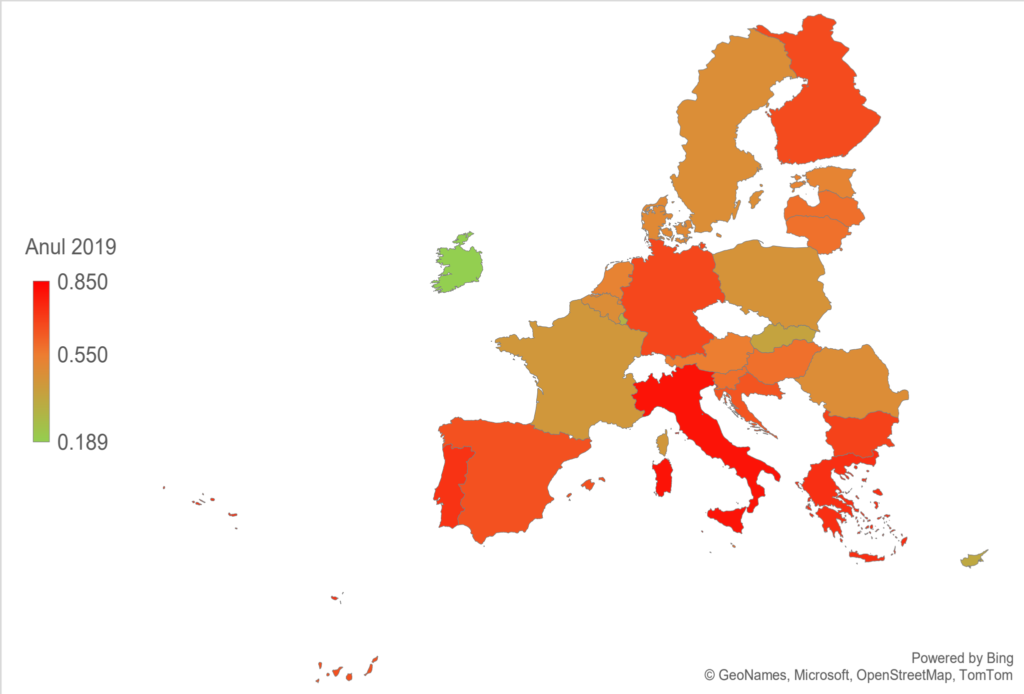
Source: own calculations and representation based on Eurostat data

Figure 5. Map of the composite index of demographic ageing in European Union countries, in 2008



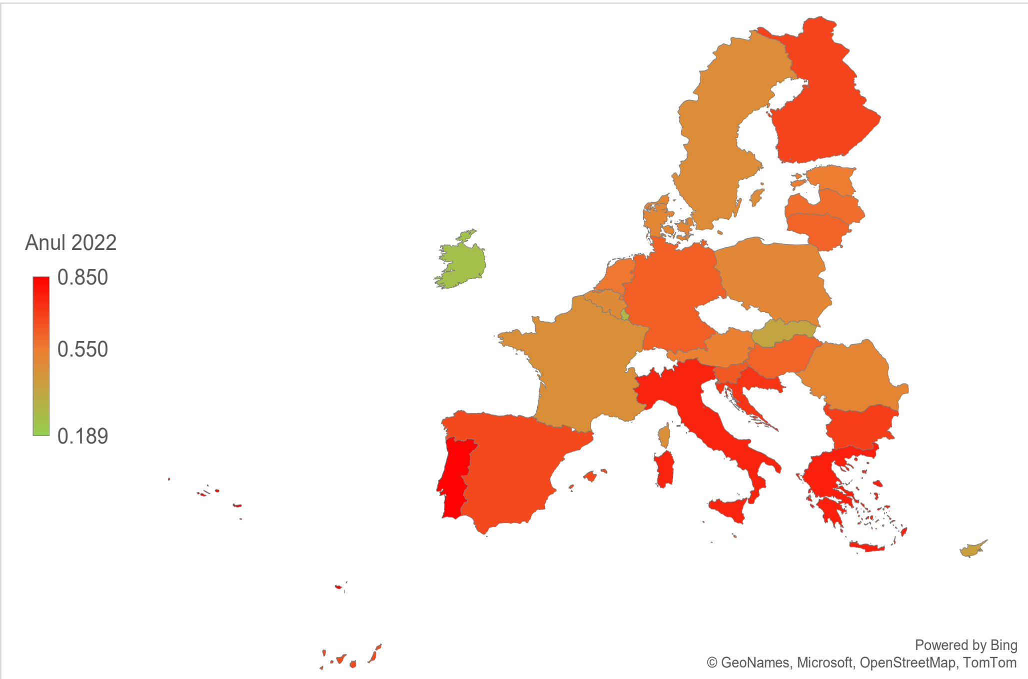
Source: own calculations and representation based on Eurostat data

Figure 6. Map of the composite index of demographic ageing in European Union countries, in 2019



Source: own calculations and representation based on Eurostat data

Figure 7. Map of the composite index of demographic ageing in European Union countries, in 2022



Source: own calculations and representation based on

In 2008, compared to 2000, a generalized increase in the composite index can be observed across most EU countries, as evidenced by the progressively redder tones in the map shown in Figure 5. This trend reflects a marked intensification of the demographic ageing process. Exceptions to this pattern include Belgium (-0.021), Ireland (-0.061), Spain (-0.075) and Sweden (-0.053), where the index either remained stable or experienced a slight decline.

On the other hand, by 2019, a declining trend in the composite index was observed in more than half of the European Union Member States compared to 2008. Specifically, reductions in the composite index were recorded in 17 countries: Belgium, Bulgaria, the Czech Republic, Germany, Estonia, France, Croatia, Italy, Latvia, Lithuania, Luxembourg, Hungary, Austria, Romania, Slovenia, Slovakia and Sweden.

Although these decreases were relatively modest—ranging between 0.007 and 0.127—the phenomenon is still noteworthy in the context of demographic ageing. This is visually represented by the paler or more orange tones in the map shown in Figure 6 (specific for year 2019), compared to the deeper red tones in Figure 5 (specific for year 2008). In contrast, countries such as Finland, Malta, Portugal, the Netherlands, Spain, Greece, Poland, Ireland, Cyprus and Denmark exhibit more intense red hues in Figure 6 relative to Figure 5, indicating an increase in the composite index values between 2008 and 2019. This reflects a continued intensification of demographic ageing in these countries during this period.

In contrast to the previous period, the year 2022 (Figure 7) shows a renewed intensification of the population ageing phenomenon compared to 2019, as indicated by the increase in the composite index values across all European Union Member States. The most significant increases were recorded in Portugal (+0.118), Croatia (+0.077), Ireland (+0.065), Poland (+0.053) and Slovenia (+0.051), each exceeding 0.05 units. Only five countries exhibited a reverse trend, with the composite index values in 2022 being lower than those in 2019: Germany (-0.058), Italy (-0.040), Luxembourg (-0.019), Slovakia (-0.005) and Austria (-0.003).

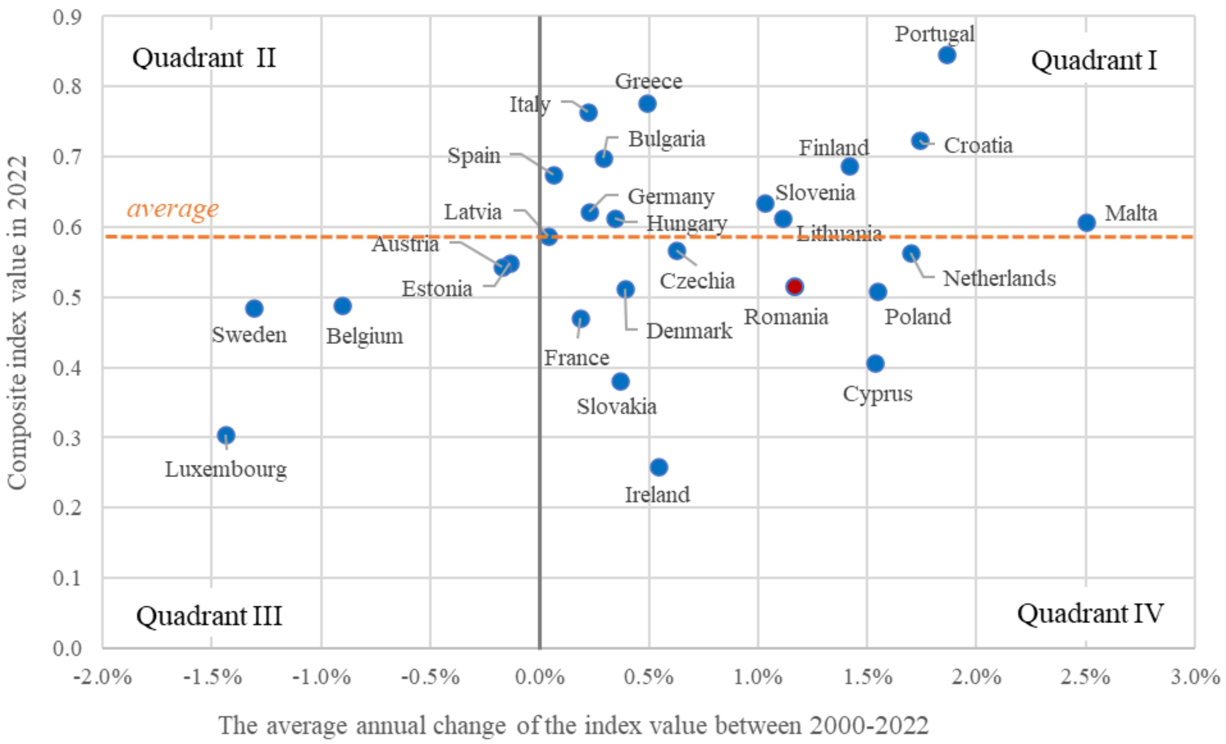
Temporal analysis of the composite index in 2022 and the average annual change over the period 2000–2022

The temporal analysis of the composite index highlights significant differences among European Union States, both in terms of the current level of demographic ageing and the trajectories observed over time.

Figure 8 provides an overview of the current state of demographic ageing in the 27 European Union Member States by comparing two key dimensions: the value of the composite index in 2022 and its average annual change over the period 2000–2022, based on the computed index values. A positive average annual change in the composite index indicates an intensification of the ageing process, whereas a negative value reflects a reduction in demographic ageing.

This two-dimensional representation illustrates the relationship between these two variables, enabling the classification of EU countries into four quadrants, each representing a specific profile based on the interplay between the level and progression of demographic ageing.

Figure 8. The value of the composite demographic ageing index in 2022 compared with the average annual change recorded during the period 2000–2022



Source: own calculations and representation based on Eurostat data

Countries located in the *third quadrant* exhibit the most favourable ageing profiles, characterized by both low composite index values in 2022 and negative average annual changes over the analysis period. This group includes Luxembourg, Sweden, Belgium, Austria and Estonia, all of which recorded index values below 0.6 units, indicating comparatively limited demographic ageing.

At the opposite end, the *first quadrant* highlights countries experiencing continuous demographic ageing, with positive average annual changes and composite index values exceeding 0.57 units. The most affected countries in this group are Portugal, Croatia, Malta, Finland, Slovenia, Lithuania, Hungary, Germany, Latvia, Spain, Bulgaria, Italy and Greece.

The countries from the *fourth quadrant* are characterized by having composite index values below 0.57, but they are showing a positive average in the annual increases. This profile includes the Netherlands, Poland, Cyprus, Denmark, the Czech Republic, France, Slovakia, Ireland and Romania.

According to the graph, no EU country falls into the *second quadrant*, which would correspond to countries with composite index values above the 2022 EU average, but exhibiting negative average annual changes between 2000 and 2022.

Therefore, based on the temporal analysis, Romania, along with several Central and Eastern European countries, occupies an intermediate position, but follows an upward trajectory regarding demographic ageing. In contrast, countries such as Italy, Portugal and Germany are already facing the direct effects of an advanced ageing process, while a limited number of countries manage to maintain a sustainable demographic balance.

Conclusions

The findings of this study underscore the growing importance of demographic ageing as a policy challenge within the European Union. By constructing and applying a composite index based on robust statistical methodology, this research provides a clear and comprehensive picture of ageing trends across Member States.

The analysis of the composite index of demographic ageing across the 27 European Union Member States over the period 2000–2022 reveals significant spatial and temporal dynamics, reflecting both convergence and divergence in the ageing process at the national level.

Romania's position is particularly notable. While it remains in the intermediate tier in terms of ageing intensity, the upward trajectory of its composite index suggests accelerating demographic pressure in the near future. This trend aligns with the broader patterns observed in Central and Eastern Europe, where the combined effects of emigration, low fertility and increasing longevity are reshaping population structures.

But, there are still notable differences in pace and intensity of the ageing phenomenon across countries. Portugal, Finland and Italy showed the highest index values, with Portugal reaching the peak in 2022. While some countries like Spain experienced fluctuations, others such as Greece, Bulgaria and Croatia followed relatively stable trajectories. Italy led in ageing until 2022, when Portugal surpassed it. On the other hand, Ireland and Luxembourg are the European countries with the lowest levels of demographic ageing.

Spatial maps reveal a widespread increase in the index from 2000 to 2008, followed by slight declines in over half the Member States between 2008 and 2019. However, between 2019 and 2022, the ageing trend intensified again, with significant increases in Portugal, Croatia, Ireland, Poland and Slovenia. Only five countries recorded slight declines.

In summary, demographic ageing is accelerating across the EU, reinforcing the need for strategic policy responses. The empirical approach outlined in this study demonstrates the utility of composite indices in demographic research, particularly for cross-national comparisons. The multidimensional nature of the index ensures that it captures not only the magnitude but also the dynamics of ageing processes. The results highlight the need for proactive and tailored policy responses, including pension reform, labour market adaptation and targeted social services.

In conclusion, the demographic ageing process continues to be a pervasive and accelerating phenomenon across the European Union, with implications for social policy, healthcare, labour markets and intergenerational equity. While some countries exhibit more stable or fluctuating trajectories, the general trend points toward increasing demographic pressure associated with ageing populations, necessitating coordinated and forward-looking policy responses at both national and EU levels.

To sum up, this research contributes to the demographic literature by providing a replicable and adaptable tool for monitoring population ageing. It also offers a foundation for future studies aimed at linking demographic indicators with socio-economic outcomes and for designing evidence-based policy interventions that address the challenges of an ageing Europe.

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Annexes

Annex 1. The values of the composite index calculated for the European Union countries, for the period 2000-2022

Table A1. The values of the composite index calculated for the European Union countries, for the period 2000-2022 (part I)

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Belgium	0.601	0.608	0.606	0.610	0.601	0.585	0.579	0.573	0.580	0.578	0.573	0.585
Bulgaria	0.659	0.673	0.708	0.729	0.727	0.721	0.720	0.725	0.732	0.718	0.722	0.753
Czechia	0.500	0.502	0.496	0.513	0.506	0.496	0.503	0.512	0.527	0.533	0.533	0.562
Denmark	0.477	0.481	0.470	0.467	0.464	0.453	0.462	0.475	0.497	0.514	0.528	0.574
Germany	0.600	0.639	0.651	0.676	0.687	0.712	0.737	0.764	0.769	0.793	0.811	0.843
Estonia	0.571	0.583	0.581	0.610	0.614	0.614	0.625	0.636	0.645	0.632	0.616	0.635
Ireland	0.250	0.234	0.201	0.193	0.194	0.193	0.192	0.180	0.189	0.194	0.202	0.225
Greece	0.706	0.725	0.678	0.701	0.709	0.703	0.701	0.710	0.710	0.702	0.702	0.733
Spain	0.677	0.689	0.699	0.695	0.674	0.647	0.640	0.638	0.602	0.562	0.554	0.581
France	0.459	0.461	0.457	0.497	0.472	0.465	0.448	0.448	0.462	0.460	0.460	0.475
Croatia	0.510	0.619	0.631	0.661	0.665	0.653	0.663	0.669	0.676	0.666	0.659	0.673
Italy	0.735	0.746	0.759	0.817	0.792	0.779	0.780	0.813	0.832	0.825	0.826	0.836
Cyprus	0.302	0.305	0.308	0.307	0.311	0.316	0.319	0.344	0.360	0.364	0.369	0.397
Latvia	0.587	0.596	0.598	0.622	0.650	0.649	0.663	0.678	0.687	0.694	0.710	0.736
Lithuania	0.486	0.502	0.524	0.546	0.574	0.584	0.610	0.629	0.649	0.644	0.641	0.680
Luxembourg	0.424	0.420	0.414	0.426	0.412	0.410	0.414	0.421	0.431	0.432	0.427	0.448
Hungary	0.573	0.574	0.569	0.589	0.591	0.581	0.583	0.598	0.617	0.622	0.636	0.658
Malta	0.357	0.386	0.386	0.398	0.415	0.427	0.460	0.471	0.484	0.499	0.532	0.570
Netherlands	0.393	0.401	0.388	0.392	0.399	0.401	0.420	0.438	0.466	0.473	0.486	0.513
Austria	0.569	0.571	0.559	0.568	0.562	0.576	0.599	0.625	0.646	0.655	0.658	0.675
Poland	0.366	0.373	0.374	0.395	0.406	0.405	0.413	0.423	0.431	0.426	0.418	0.429
Portugal	0.571	0.601	0.600	0.617	0.623	0.620	0.632	0.647	0.659	0.671	0.673	0.707
Romania	0.407	0.431	0.457	0.463	0.456	0.440	0.471	0.476	0.509	0.543	0.554	0.573
Slovenia	0.511	0.529	0.539	0.573	0.581	0.587	0.594	0.607	0.615	0.614	0.600	0.611
Slovakia	0.356	0.364	0.344	0.353	0.353	0.353	0.371	0.386	0.403	0.399	0.405	0.418
Finland	0.507	0.514	0.510	0.517	0.521	0.521	0.527	0.552	0.565	0.568	0.574	0.611
Sweden	0.658	0.648	0.621	0.610	0.600	0.586	0.583	0.587	0.605	0.609	0.608	0.641

Source: own calculations based on Eurostat data

Table A2. The values of the composite index calculated for the European Union countries, for the period 2000-2022 (part II)

Country	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Belgium	0.582	0,577	0,543	0,531	0,524	0,515	0,509	0,479	0,473	0,460	0,488
Bulgaria	0.766	0,766	0,736	0,731	0,736	0,724	0,719	0,691	0,690	0,678	0,698
Czechia	0.584	0,602	0,571	0,560	0,558	0,546	0,546	0,519	0,507	0,510	0,566
Denmark	0.594	0,610	0,583	0,566	0,552	0,538	0,528	0,500	0,479	0,482	0,512
Germany	0.850	0,837	0,812	0,801	0,766	0,745	0,734	0,679	0,671	0,669	0,622
Estonia	0.643	0,648	0,616	0,594	0,586	0,575	0,552	0,521	0,513	0,521	0,549
Ireland	0.237	0,248	0,225	0,213	0,215	0,207	0,211	0,193	0,199	0,192	0,258
Greece	0.748	0,764	0,746	0,748	0,755	0,757	0,752	0,736	0,709	0,700	0,777
Spain	0.575	0,579	0,575	0,584	0,599	0,618	0,661	0,656	0,647	0,610	0,675
France	0.488	0,492	0,452	0,445	0,460	0,480	0,461	0,435	0,450	0,454	0,471
Croatia	0.674	0,681	0,655	0,661	0,660	0,657	0,659	0,647	0,638	0,639	0,724
Italy	0.828	0,815	0,787	0,781	0,804	0,825	0,825	0,805	0,809	0,814	0,765
Cyprus	0.391	0,413	0,399	0,399	0,391	0,394	0,390	0,364	0,331	0,330	0,407
Latvia	0.728	0,712	0,662	0,636	0,624	0,614	0,617	0,584	0,572	0,576	0,587
Lithuania	0.685	0,686	0,645	0,622	0,617	0,612	0,610	0,580	0,581	0,587	0,613
Luxembourg	0.439	0,431	0,401	0,382	0,376	0,355	0,346	0,323	0,296	0,292	0,304
Hungary	0.656	0,658	0,623	0,616	0,608	0,604	0,603	0,580	0,562	0,571	0,613
Malta	0.604	0,629	0,612	0,603	0,602	0,608	0,599	0,576	0,551	0,561	0,606
Netherlands	0.537	0,554	0,532	0,533	0,543	0,544	0,546	0,525	0,519	0,512	0,563
Austria	0.679	0,680	0,646	0,624	0,603	0,581	0,576	0,547	0,536	0,529	0,543
Poland	0.456	0,477	0,453	0,456	0,452	0,437	0,460	0,455	0,468	0,489	0,508
Portugal	0.731	0,749	0,733	0,730	0,738	0,741	0,743	0,728	0,725	0,733	0,846
Romania	0.573	0,580	0,537	0,526	0,514	0,491	0,498	0,482	0,459	0,480	0,515
Slovenia	0.614	0,621	0,590	0,585	0,593	0,589	0,601	0,584	0,584	0,581	0,635
Slovakia	0.442	0,450	0,424	0,413	0,405	0,395	0,401	0,386	0,377	0,395	0,381
Finland	0.631	0,647	0,633	0,635	0,659	0,667	0,678	0,669	0,658	0,651	0,687
Sweden	0.642	0,635	0,598	0,570	0,565	0,546	0,520	0,478	0,450	0,448	0,486

Source: own calculations based on Eurostat data

Annex 2. Relative modification of the composite index values, in the UE27 countries, during the following years: 2008 compared with 2000, 2019 compared with 2008 and 2022 compared with 2019

Table A3. Relative modification of the composite index values, in the UE27 countries, during the following years: 2008 compared with 2000, 2019 compared with 2008 and 2022 compared with 2019

Country	2008-2000	2019-2008	2022-2019
Belgium	-3.4%	-17.4%	2.0%
Bulgaria	11.2%	-5.6%	1.0%
Czechia	5.3%	-1.4%	9.1%
Denmark	4.3%	0.5%	2.4%
Germany	28.2%	-11.6%	-8.5%
Estonia	13.1%	-19.3%	5.3%
Ireland	-24.3%	2.3%	33.4%
Greece	0.5%	3.8%	5.5%
Spain	-11.1%	9.1%	2.8%
France	0.5%	-5.8%	8.3%
Croatia	32.7%	-4.3%	11.9%
Italy	13.2%	-3.3%	-5.0%
Cyprus	19.0%	1.1%	11.9%
Latvia	17.0%	-14.9%	0.4%
Lithuania	33.4%	-10.6%	5.7%
Luxembourg	1.7%	-25.0%	-6.0%
Hungary	7.7%	-5.9%	5.6%
Malta	35.6%	19.0%	5.2%
Netherlands	18.5%	12.8%	7.1%
Austria	13.4%	-15.3%	-0.6%
Poland	17.9%	5.4%	11.7%
Portugal	15.5%	10.4%	16.2%
Romania	25.1%	-5.2%	6.7%
Slovenia	20.3%	-5.0%	8.7%
Slovakia	13.3%	-4.3%	-1.3%
Finland	11.5%	18.4%	2.6%
Belgium	-8.1%	-21.0%	1.5%

Source: own calculations based on Eurostat data