Efficiency Analysis of EU Member States in the Context of Population Aging[1]

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Abstract

The population aging might threaten the economic development and efficiency of EU Member States. Based on the demographic projections, the EU's old-age dependency ratio (as proxies of population aging) will be almost double – from 31% in 2019 to 57% in 2100. This study focuses on the efficiency analysis of European Union Member States in the context of population aging. Utilizing Data Envelopment Analysis (DEA) and the Malmquist Productivity Index, we evaluated how demographic changes affect the economic efficiency of various EU countries. Our findings reveal that some states, such as the Czech Republic, Germany, and Luxembourg, demonstrate high-efficiency levels when considering demographic factors. The results suggest that technological advancement and innovation are crucial in addressing the challenges associated with population aging.

Keywords: *EU members states, population aging, data envelopment analysis, malmquist index*

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Introduction

Population aging is one of the key demographic challenges facing the European Union (hereafter EU), which affects practically all aspects of people's lives (Šídlo et al., 2020). This phenomenon results from the current increase in average life expectancy and decline in the birth rate in many EU Member States. Based on the projection of the European Commission (2018), the workforce (proportion of people aged between 20 and 64) will drop by almost 10 percent between 2016 and 2070. The population aging represented by the old-age dependency ratio (hereinafter OADR; proxy of population aging) in the EU Member States is predicted to increase from 29.6% in 2016 to 51.2% in 2070 (Bodnar and Nerlich, 2022). Hence, the research on population aging is a crucial part of the EU's framework programs.

The aging phenomenon represents a significant challenge to the efficiency of economies within the EU. As the population ages, the proportion of working-age people is declining, leading to a potential shortage of skilled and productive workers. This demographic shift can undermine the labor market by reducing the available labor force and holding back economic growth (Thalassinos et al., 2019; Klufová et al., 2021). In addition, increasing demand for health care, pension benefits, and other social services for the elderly can strain public budgets and divert resources that could otherwise contribute to productive investment and development initiatives. In this context, population aging threatens the ability of EU countries to maintain their economic progress and competitiveness (Bloom et al., 2015; Klufová et al., 2021; Bodnar and Nerlich, 2022) and significantly influences the efficiency of EU Member States economies as one of the most commonly applied tools to help identify the strengths and weaknesses of the evaluated countries. The efficiency of the EU Member States is the source of national competitiveness. Although the EU is one of the most developed areas of the world, there are significant economic, social, and territorial disparities that hurt the balanced development across the Member States, thereby weakening the EU's global performance context (Staníčková and Melecký, 2016).

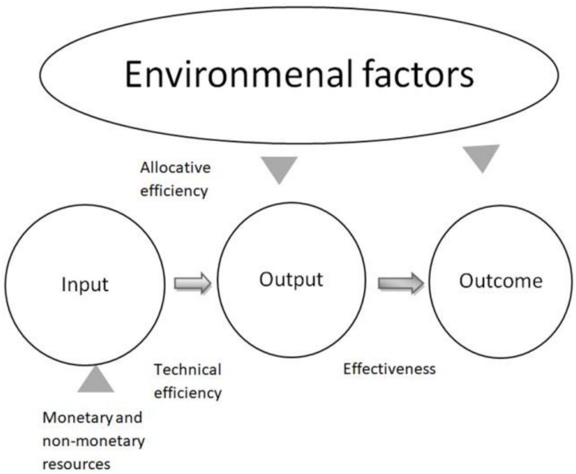
In recent decades, there has been growing interest in measuring the efficiency of the countries. The development of various approaches to assessing efficiency, including utilizing methods like the data envelopment analysis (hereafter DEA) technique and the Malmquist index for productivity, has been a significant outcome. The paper aims to investigate the potential impact of population aging on the efficiency of European Union Member States and assess how these anticipated demographic challenges could influence productivity in the future. This study analyzes the efficiency of EU Member States using the Data Envelopment Analysis (hereafter DEA) and Malmquist index data from 2013 to 2019.

1. Theoretical Background

1.1. Efficiency Analysis

Economic efficiency is represented by the relationship between the effects (as outputs) and the efforts (as inputs) (see Figure 1). The measurement of efficiency is a subject of different methods and data operationalization. Most of the scientific studies that research the concepts of efficiency analysis using DEA applied to the country, region, cities, and organizations. DEA is a non-parametric method initially proposed by Charnes et al. (1978), which is used to analyze the relative efficiency of multiple input and output decision units. DEA evaluates the performance of homogenous entities, which are in terms of DEA called decision-making units (DMUs) (Yan et al., 2019).

F i g u r e 1
Conceptual Framework of Efficiency



Source: Own processing according to Mandl et al. (2008).

According to Hermoso-Orzáez et al. (2020), this method has numerous applications for calculating efficiency and has become more crucial in recent years. Research studies apply DEA to analyze macroeconomic efficiency are Färe et al. (1994), Martić and Savić (2001), Ramanathan (2006), Mohamad (2007), Staníčková and Melecký (2016), etc. The disadvantage of the method is that it applys only data from the chosen year; therefore, it could be supplemented by the Malmquist index to add an overview of development over time. This method can be used for evaluating the national development quality and potential (Staníčková and Melecký, 2016). Malmquist (1953) originally proposed his index for measuring the living standards in consumption analysis. Over time, the Malmquist index has been used for production analysis as The Malmquist productivity index. According to de Castro Lobo et al. (2010), this index provides a measure of productivity change and is based on the measurement of productivity suggested by Caves et al. (1982). The Malmquist Productivity Index can be used to determine EU Member States' efficiency dynamics, as Ramanathan (2006) and Ustali and Tosun (2020) reported.

1.2. Population Aging Context

Increasing economic efficiency and quality of products and services leads to long-term competitiveness, a vital determinant of the long-term increase in living standards and economic growth (Baciu and Botezat, 2014). Many researchers see population aging as the most critical challenge of the current century (see Šídlo et al., 2020; Zhao and Xie, 2023) and a possible threat to EU stability (Kluge et al., 2019) and prosperity.

Population aging in European countries is perceived negatively due to the sustainability of economic growth, pension, and healthcare system expenditures (Rechel et al., 2013). According to Maestas et al. (2016), aging causes decreasing labor productivity. On the contrary, elderly workers own significant knowledge, skills, and experience (Kuhn et al., 2018; Cristea et al., 2020). According to a global study by Bain & Company (2023), 150 million jobs will shift to workers over the age of 55 by 2030. On the other hand, older adults in Europe generate 3rd largest economy in the world – the so-called Silver economy, where older people are not a fiscal burden; on the contrary, population aging transforms into market and HR opportunities (Bojanić and Erceg, 2017). These facts show that population aging is a double-edged sword. A positive perspective on population aging is proved by studies Romer (1990), Acemoglu and Restrepo (2017), and Luo (2019). A summary of the findings of research studies on the impact of population aging on economic efficiency is provided in Table 1.

The existing state of research may not adequately inform theoretical advancements or guide the strategic direction of long-term policies within government programs. This gap underscores the need for our study's efficiency analysis of European countries in the context of population aging. Assessing the most recent data is vital, as the trend of an aging population is a relentless reality across all EU countries (Marešová et al., 2015). In recent decades, the EU has emerged as one of the world's oldest societies, a trend projected to not only continue but also intensify in the coming years (Šídlo et al., 2020; Walker and Malty, 2012). This demographic shift poses significant challenges for European society, policymakers, and the overall competitiveness of Europe.

T a b l e 1

Overview of Studies on Population Aging in the Context of Economic Efficiency

Authors	Findings
Romer (1990)	Population aging is beneficial for long-term economic growth.
Bloom and Williamson (1998)	There is a key relationship between population composition and economic change.
Lindh and Malmberg (1999)	Reported that the 50 – 64 age group was positively related to the GDP per capita, while the 65+ age group was negatively related to the GDP in 21 OECD countries for the period 1950 – 1990.
Brunow and Hirte (2006)	Differences in age structure induce differences in per capita output growth across European regions.
Tang and MacLeod (2006)	They found out the negative impact of demographic changes on productivity growth.
Bloom et al. (2008)	The effect of old age on economic growth is negative in the short run but insignificant in the long run.
Poot (2008)	The negative impact of population aging on regional competitiveness may be relatively small.
Oliver (2015)	In the population, 15 – 24, 25 – 34, 45 – 54, 55 – 59, and 75+ age groups are associated with increases in the real GDP per capita, while increases in the age group of 70-74 and the youth dependency ratio are associated with decreases in the GDP.
Maestas et al. (2016)	Population aging decreases the growth rate of GDP per capita.
Acemoglu and Restrepo (2017)	Countries experiencing more rapid aging have grown more rapidly because of the rapid adoption of automation technologies in these countries.
Luo (2019)	Economic growth (expressed by GDP per capita) is positively linked with the retired population.
Maestas et al. (2023)	Aging slows economic growth due to reduction arising from slower employment growth and slower labor productivity growth.
Bode et al. (2023)	Aging exhibits a stronger adverse correlation with productivity expansion in urban areas compared to nonurban regions.

Source: Own processing.

2. Methods

2.1. Model Setting

In analyzing the relationship between population aging and its economic impact, research often uses economic growth and its indicators as proxies of the economic perspective. Researchers have no agreement on a set of variables that characterize economic efficiency. In most scientific works, researchers use the following variables (see Table 2).

Economic growth is often expressed by GDPPP. The unemployment rate belongs to performance indexes, which belong to the four main targets of a nation's macroeconomic policymakers (Mohamad, 2007). It was used in several macroeconomic indexes (Okun's misery index, Calmfors index, and OECD Magic Diamond). General Government Gross Debt hurts economic growth. During the financial crises, the governments of the EU countries responded to the collapse of real estate markets by rescuing vulnerable banks and large-scale inflows of money into the economy, which led to an increase in general government gross debt. Gross capital formation rates lead to rapid economic growth (Choe, 2003). It enables sustainable economic growth of the demand and supply because an essential part of these costs is dedicated to renewing the firms' fixed capital.

T a b l e 2
Chosen Variables

Variables	Definition	Unit of measure	Apllied in research study	Input	Output
GDP per capita (GDPPP)	The sum of gross value added by all resident producers in the economy plus any product taxes (less subsidies) not included in the valuation of output, divided by mid-year population (World Bank, 2020).	Current international USD	Lindh and Malmberg (1999); Oliver (2015); Maestas et al. (2016); Luo (2019); Liu et al. (2023)		✔
Unemployment rate (UR)	It refers to the share of the labor force that is without work but available for and seeking employment.	ILO estimates, percent of the total labor force	Mohamad (2007); Färe et al. (1994); Wang and Le (2018)	✔	
General Government Gross Debt (GGD)	Gross debt consists of all liabilities that require payment or payments of interest and/or principal by the debtor to the creditor at a date or dates in the future (GFSM, 2001).	ILO estimates, percent of GDP	Mencinger et al. (2014)	✔	
Gross capital formation (GCF)	It consists of outlays on additions to the fixed assets of the economy plus net changes in the level of inventories (World Bank; 2020).	Current USD	Wang and Lee (2018); Sinha and Edalatpanah (2023)		✔

Source: Own processing.

In many studies, e.g., Bloom and Williamson (1998), Sanderson and Scherbov (2013), Marois et al. (2020), the old-age dependency ratio (ratio of older dependent people older than 64 to the working-age population those ages 15 – 64) is used as the standard indicator of population aging. According to the World Bank (2019), it is a primary indicator of population aging. This threshold is usually used in population aging analysis (Speder and Balint, 2013).

2.2. Methods

Best to our knowledge and in accordance with Staníčková and Melecký (2011), the EU has no system for analyzing the level of efficiency of Member States because of the heterogeneity of regions; there does not exist one general method for a competitiveness analysis.[2] It is not given which parameters should be taken into account, even their importance, i.e., which weights should be chosen if we would like to use multiple criteria decision-making methods. Therefore, we have decided to compare the European countries according to the above-chosen variables and apply the DEA. The DEA is a suitable method for the efficiency analysis of EU Member States, as many previous authors proved (see Färe et al., 1994; Martić and Savić, 2001; Ramanathan, 2006; Mohamad, 2007; Staníčková and Melecký, 2016; Jakšić et al., 2023; Sotiroski et al., 2023). Under such variables (also due to the standardization of variables per capita and into rates), the European countries (in terms of DEA DMUs) are supposed to be comparable; therefore, DEA methods are convenient. Since all of our chosen variables are per capita or rates, they are not directly influenced by the number of inhabitants or some other variable; applying the classical DEA-input-oriented CCR (Charnes-Cooper-Rhodes) model (see Charnes et al., 1978) is possible. Since both models – input and output-oriented-are, in fact, dual models, and we suppose constant returns to scales, the choice of the input- or output-oriented model has no impact on the results. Hence, we chose the input-oriented model. Moreover, two of our selected variables are benefit-type (GDPPP, GCF), and two are cost-type (UR, GGD); therefore, the classical input-oriented CCR model is the appropriate choice for such analysis.

What can the DEA model explain? The results of the DEA models show us if the states are effective in the sense that they have enough high GDPPP and GCF and enough low UR and GGD. More precisely, it shows us under which weights (with what importance of criteria) which countries are viewed in the best light compared to others according to the abovementioned variables. In this study, the DEA is applied to all 27 members of the EU.

First, we take 2019 as a reference year for DEA. Since the development is also important, we apply the Malmquist Index (Färe et al., 1992) to compare the changes between 2013 and 2019. The Malmquist index (hereafter MI) was developed to measure the efficiency change in time, considering the technical changes in time. It consists of two parts – Efficiency Change (ec) and Technological Change (tc), then MI = tc ec. Efficiency change is, in fact, only the ratio between efficiency in time t and efficiency in time s. Technological changes show the shift upward of the production possibility frontier (more outputs for the same or lower level of inputs).

Since we aim to consider population aging, we finally use correlation analysis to describe the relevance between population aging and economic efficiency.

2.3. Data

Data were obtained from the World Bank (2020) and the International Monetary Fund (2001). The reference period 2013 – 2019 is given to eliminate the effects of the financial crisis and the COVID period. The Covid-19 pandemic has negatively

[2] However, it should be mentioned the existence Global Competitiveness Index (World Bank, 2023) and European Regional Competitiveness Index (European Commission, 2023).

affected the economic development of EU Member States. The significant economic impact due to the ongoing crisis includes reduced economies, trade disruption, business closures, an increase in the unemployment rate, an increase of general government gross debt, the lower income of the population under the quarantine regime, and considerable health care costs and, thus government expenditures.

The average unemployment rate in the EU decreased since 2005. In 2008 (the beginning of the financial crisis), it started to increase, the peak was reached in 2013 (oscillating 11%), and the number of unemployed in the European Union was 26,334 million. From this point, it has been falling. The number of unemployed has decreased over the last five years in all European Union countries. In 2019, it was the lowest average unemployment rate in the previous decade (Eurostat, 2020).

From the perspective of the European Union, it is necessary to break the indebtedness of their members. In 2007, almost all EU members decreased their debt (the average of the EU was below 60% of GDP). Eight Euro area countries (Belgium, France, Italy, Malta, Germany, Portugal, Austria, and Greece) exceeded 60% of GDP, as did Hungary. However, the situation became critical in Belgium, Italy, and Greece, as they showed an extremely accumulated public debt. Italy and Greece exceeded 100% of GDP. In 2019, the deficit decreased in most EU countries (except Luxembourg, Cyprus, and Romania). Three of the EU's five largest economies are in debt over 98% of their GDP (Italy, France, Spain). Debt has grown the most in Greece within the last ten years, with debt rising by 75% of GDP. Portugal and Spain's public debts have increased by over 50% in the previous ten years. Debt reduction is not going well for the governments of the Iberian Peninsula – Italy, France, and Cyprus, which can be a problem in times of crisis when public debts are rising by tens of percent of GDP. Half of the EU countries do not meet the 60% limit enshrined in the Maastricht Treaty and other pacts that were supposed to regulate the state of the country's finances. Less indebted countries are generally located in Eastern Europe (Eurostat, 2020).

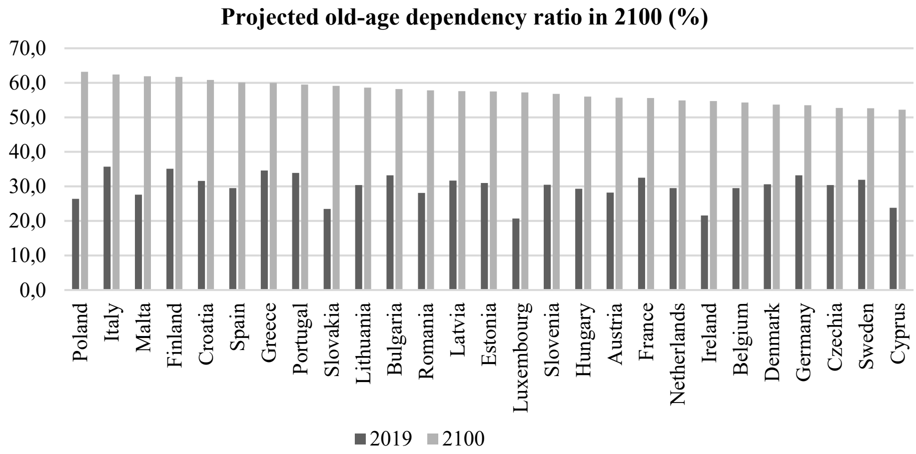
In 2019, the best performance in GDPPP reached Luxembourg, followed by Ireland, which has a GDP of 93% above the European average. The following groups are countries with GDP over 20% above average (the Netherlands, Austria, Denmark, and Germany). The United Kingdom, Italy, Malta, Spain, and Czechia have less than 10% below the EU average. The rest of the countries have a GDP under average level (Eurostat, 2020).

The accumulation of gross capital formation increases production capacity, resulting in decreasing unemployment (Pasara and Garidzirai, 2020). The indicator is the key to sustainable long-term growth since it incorporates the potential to expand production capacity and technological change. In the EU, the development of gross capital formation was influenced by the financial crisis in 2008, followed by a drop in all EU countries. In the New EU Member States, the gross capital formation dynamics have been reasonably differentiated in relation to internal conditions and the necessary adjustments made to ensure compatibility with developed Western European countries (Pavelescu, 2008).

Population aging is increasing in EU countries. According to the scenario, the EU's population will get older. The EU's OADR will almost double (from 31% in 2019 to 57% in 2100). By 2100, the OADR will be highest in Poland (63%), followed by Malta, Italy, and Finland (all 62%) as well as Croatia (61%). Figure 2 shows the development of OADR in EU Member States from 2019 to 2100.

F i g u r e 2

Projections of Development Old-Age Dependency Ratio by 2100



Source: Own research based on data on Eurostat (2020).

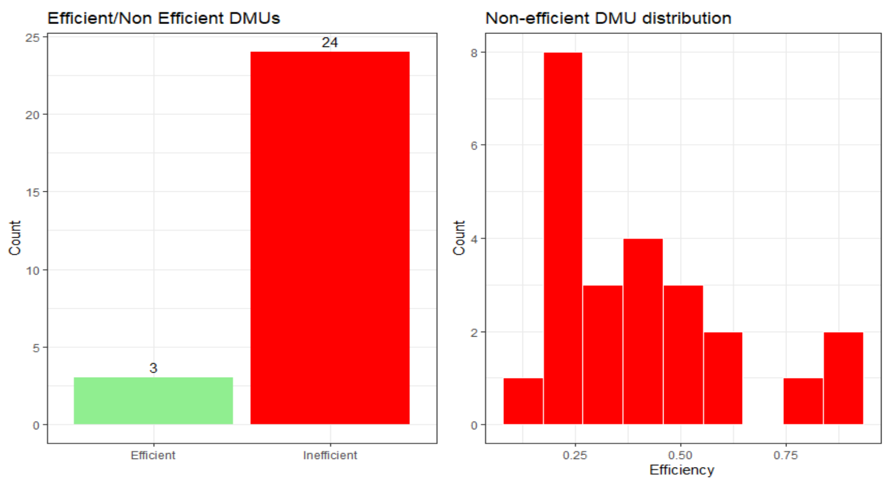
3. Results and Discussion

DEA (CCR input-oriented model; Charnes et al., 1978) was applied to data from 2019 for evaluating EU countries. The DEA identified three countries as the „efficient" – i.e., with the best possible combinations of inputs and outputs. (In the language of DEA, these countries are called „efficient.") Namely the Czech Republic, Germany, and Luxembourg. For every one of these three countries, there are weights under which the country is viewed in the best light; that is, the ratio of a weighted sum of GDPPP and GCF to a weighted sum of GGD and UR under these weights is the highest one among all EU countries (if we apply the same weights for all other EU countries, the ration will less than or equal to one). In other words, these countries have the „best" combination of considered variables. These countries have a high potential for effective performance.

In the words of the DEA, the country has the best possible combination of inputs and outputs if its DEA efficiency equals one. A smaller DEA efficiency means a worse ratio of weighted outputs to weighted inputs compared with other countries when at least one country has a ratio of weighted outputs to inputs equal to one under the same weights. The weights show the country in the best light; there do not exist weights under which all countries have such a ratio less than or equal to one, and the ratio of this country is higher than its DEA index. For example, if the DEA score of the country is 0.8 (it is not equal to one), it means that the best possible ratio of a weighted sum of GDPPP and GCF to a weighted sum of GGD and UR of the country is equal to 0.8 considering all possible (nonnegative) weights under which the weighted sums for all EU countries are less than or equal to one. For the histogram of DEA efficiencies, see Figure 3; for exact values, see Table 3.

Figure 3

Histograms of DEA Efficiency Scores



Source: Own processing.

Table 3

DEA Scores of Efficiency

DMU	Efficiency	DMU	Efficiency	DMU	Efficiency
Czechia	1	Sweden	0,50966	Lithuania	0,26791
Germany	1	France	0,46923	Bulgaria	0,25789
Luxembourg	1	Poland	0,4485	Portugal	0,2552
Estonia	0,93348	Hungary	0,44535	Cyprus	0,24921
Netherlands	0,8415	Belgium	0,43631	Spain	0,24849
Ireland	0,80343	Slovenia	0,42818	Italy	0,22073
Malta	0,5825	Romania	0,36335	Latvia	0,2205
Austria	0,55579	Finland	0,34842	Croatia	0,19303
Denmark	0,55304	Slovakia	0,27014	Greece	0,07892

Source: Own processing.

According to our model, the Czech Republic is effective mainly due to the long-term low unemployment rate. The overall average unemployment rate in the EU was 6.8% in 2019. Among the EU countries, the overall general unemployment rate in the Czech Republic in 2019 was the lowest, the unemployment rate oscillating around 2%. The Czech Republic is also the 4th least indebted country in the EU. The share of the Czech general gross government's debt to GDP fell to 30.1% in 2019. Luxembourg, the only country in the Euro area that has fallen into the least indebted, has the third lowest debt in the EU. Its unemployment rate oscillates around 5%, below the EU average. The EU's largest economy, Germany, has a relatively healthy debt (61% of GDP).

In contrast, the Maastricht treaty specifies that indebtedness should not exceed 60% of GDP in all EU Member States. Czech indebtedness is thus safely below this limit. The average government gross debt is 78.8% of GDP in the EU (the reference year 2019), and within the Euro area, it is 83.5%. The unemployment rate in Germany is the 3rd lowest in the EU (oscillating around 3%) (Eurostat, 2020).

The rest of the EU countries (24) must achieve an optimal combination of GDPPP, GCF, UR, and GGD. Their score of efficiency in our model is lower than one. Estonia is significantly closer to an optimal combination of GDPPP, GCF, UR, and GGD (index 0.93 mainly due to low indebtedness; it is the least indebted country in the EU. Greece (16.8%) and Spain (14.1%) have the long-term highest unemployment rates in the EU. Year-on-year, unemployment fell in 20 of the 27 member states. It remained at the same level in the Netherlands and Portugal, while the unemployment rate increased in the other six countries (Eurostat, 2020). The most indebted EU countries are Portugal, Italy, and Greece, whose debt is already higher than double their entire GDP. All five most indebted countries are Euro area members (Eurostat, 2020).

As was already mentioned, DEA models explain only a static overview, i.e. these results refer only to the year 2019 and say nothing about the development or dynamic in these parameters, which is undoubtedly very important. Therefore, we applied the Malmquist productivity index to monitor efficiency development.

Our analysis displays the increase in GDP per capita and gross capital formation and the current unemployment rate decline. We analyze the overall change in efficiency that occurred in the EU between 2013 and 2019. The results of the analysis are shown in Table 4. The Czech Republic took 2nd place (5.07) as a country with an optimal combination of inputs and outputs; on the other hand, Germany (17th place/1.77) and Luxembourg (22nd place) finished in the second half among all EU countries.

T a b l e 4

Malmquist Index Score of Countries

DMUs	MI	DMU	MI	DMU	MI
Ireland	5,290326867	Malta	2,494645601	Estonia	1,75000808
Czechia	5,06589012	Slovakia	2,415563798	Finland	1,52434653
Hungary	4,198481637	Romania	2,277548978	Austria	1,37755049
Croatia	3,435233762	Lithuania	1,963996649	Luxembourg	1,33636071
Portugal	3,34195736	Greece	1,866498959	Sweden	1,31533281
Slovenia	3,265911624	Belgium	1,858070321	Spain	1,26301750
Cyprus	2,947983735	Denmark	1,829304723	Bulgaria	1,22304742
Netherlands	2,688390362	Germany	1,769837321	Italy	1,15127165
Poland	2,576644901	Latvia	1,753330957	France	1,04168895

Source: Own processing.

The dynamic DEA extended the MI analysis between 2013 and 2019. According to our results, two of the three best-evaluated countries, Luxembourg and Germany, constantly achieved the best DEA score over the period examined. Whereas the Czech Republic started with a low DEA score (score 0.29) that reached the value of one in 2019. It was caused mainly due to its improving unemployment rate and decreasing government's general gross debt level.

The differences between the growth dynamics of the new[3] and old[4] EU Member States might be caused by their different position in a global economy. The old members of the EU belong to the core territories of the world economy, which are characterized by high labor costs and other costs of production, which negatively affect their position in the world economy.

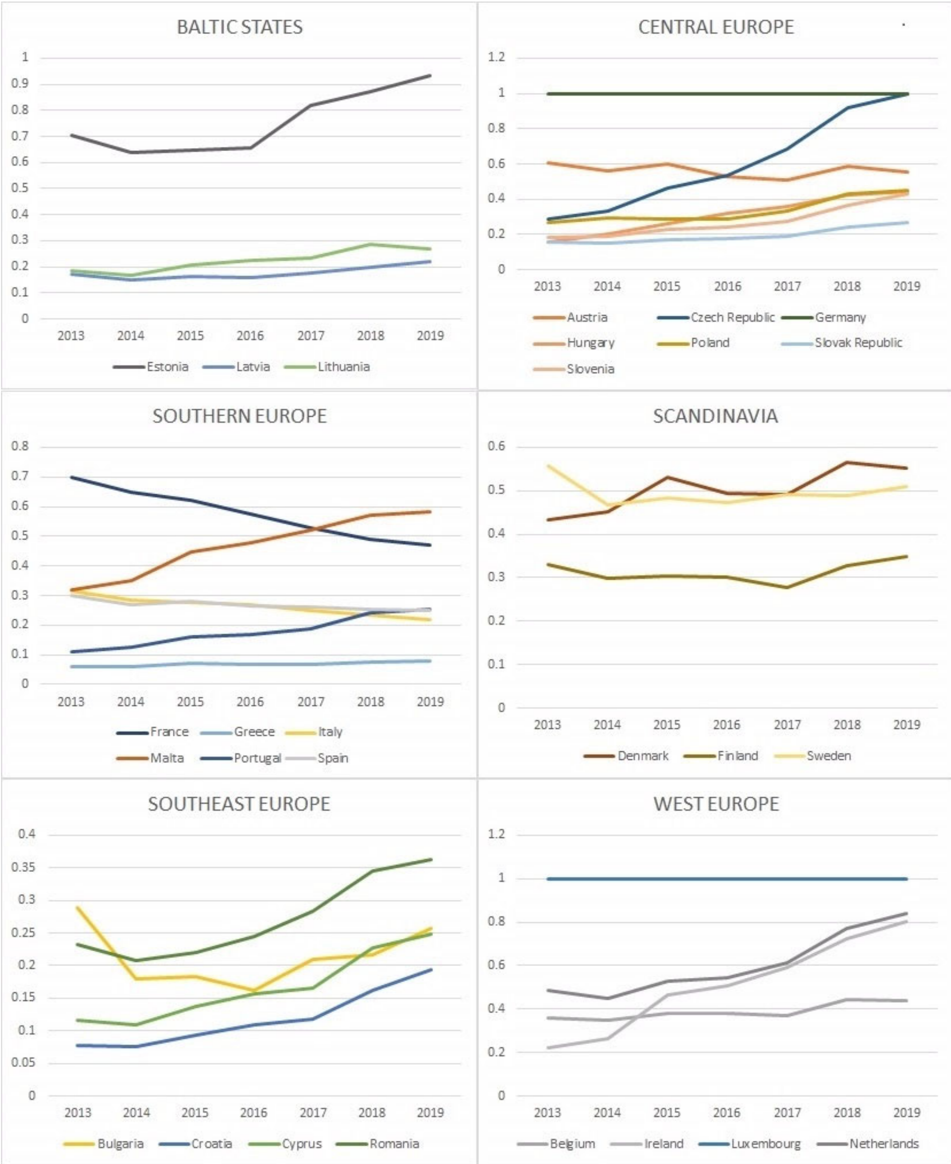
Multinational companies move their branches from these countries to regions with lower labor and production costs (e.g., regions of new EU members). Different dynamics of new and old members are caused by capital inflows, technological progress, and faster growth of aggregate factor productivity (Fagerberg and Srholec, 2008).

The subsequent analysis of the productivity and efficiency of EU Member States is based on the hypothesis, which assumes that territories with higher productivity have better conditions for achieving a higher degree of competitiveness. The new EU Member States are the primary beneficiaries of the integration process and thus benefit most from membership in this integration grouping, and therefore show comparable productivity as the originally developed EU Member States (Melecký et al., 2019).

[3] New EU Member States: Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, the Slovak Republic, Slovenia, Bulgaria, Romania, Croatia.

[4] Old EU Member States: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden.

F i g u r e 4
Development of the DEA Indicator in EU Regions from 2013 – 2019



Source: Own processing.

The last part of our analysis involves comparing results on countries' „efficiencies „and population aging. Figure 5 shows the relation between the old-age dependency ratio (OADR) and achieved efficiency (2019). No general relationship is seen from the figure, so we check the observation by computation of a correlation coefficient.

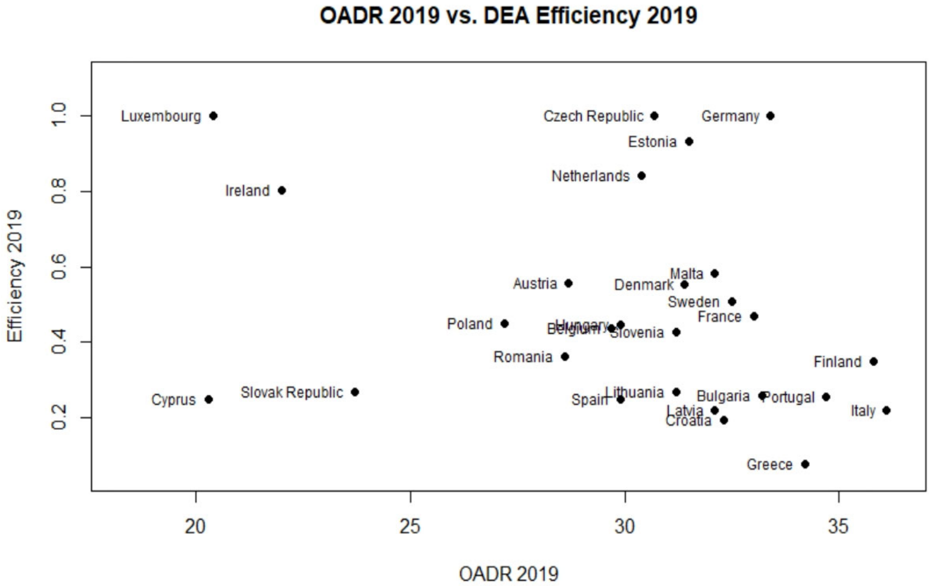
The correlation coefficient between the old-age dependency ratio and the DEA Efficiency score of DMUs in 2019 is insignificant; more precisely, it does not significantly differ from zero (p-value 0.2). Interestingly, the Czech Republic and Germany achieve the highest efficiency despite the high level of the OADR index. On the other hand, Cyprus, with the lowest OADR index (20.3%), also achieves a low DEA score. However, most analyzing EU Member States have low efficiency and high value of the OADR index, see Figure 5. On the other hand, countries with the highest DEA scores differ in OADR (two of them (Luxembourg and Ireland)) have low OADR index; four of them (Czech Republic, Germany, Estonia, and Netherlands) have high OADR. These findings deny most previous research on both the positive and negative impact of aging on economic growth. Two main questions emerge.

Considering the question „Is population aging an urgent threat?“ requires careful deliberation. Our analysis suggests that in the future, population aging could pose a significant burden on the economies of EU member states, potentially leading to a decline in social security, challenges in public healthcare services, and increasing expenditures on pension systems. These conclusions are consistent with the findings of Bloom et al. (2008), who demonstrated that the effect of aging on growth is negative in the short term but insignificant in the long term. Poot (2008) reports that the negative impact of population aging on competitiveness might be relatively small. Dalgaard and Kreiner (2001) state that population aging does not significantly impact economic growth. Our study expands these discussions by providing a detailed analysis of the current situation and projecting future trends, which could be crucial for formulating effective policies and strategies to address these challenges.

The query, „How is it possible that efficient states achieve high scores despite population aging?“ invites a deeper analysis of underlying factors beyond technology. While technology plays a critical role, as evidenced by advancements improving the quality of life for older people and supporting their needs (Pollack, 2005), other mechanisms are also at play. For instance, in the labor market, productivity, and economic growth, technology can substitute labor up to a certain „tech-unreplaceable labor inflection point“. Germany and Czechia, both with high levels of population aging and efficiency, exhibit high robot densities above European and global averages (IFR, 2020), illustrating this point.

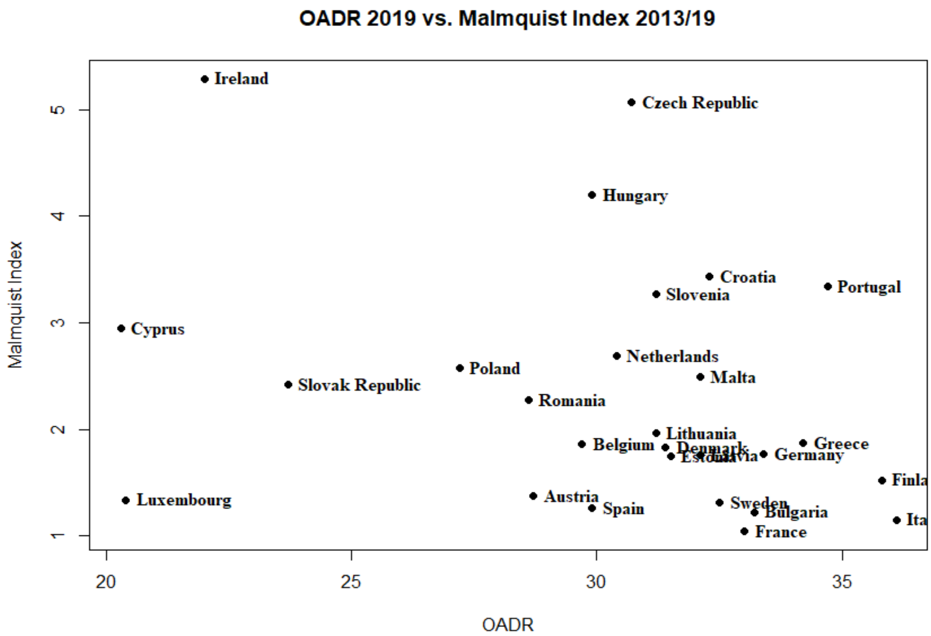
States that demonstrate adaptability in their economies and labor markets, societal resilience, and proactive aging policies tend to mitigate the challenges associated with demographic changes better. The dynamic development of advanced technologies, including sensors, biosensors, quantum computing, AI, etc., certainly reduces the negative impacts of population aging on the workforce and economic development. Yet, it is the combination of these technological advancements with other socio-economic and policy factors that truly enables certain states to maintain efficiency amid demographic shifts.

Figure 5
Relationship between the Old-Age Dependency Ratio and the Efficiency of EU Countries in 2019



Source: Own processing.

Figure 6
Relationship between OADR 2019 and Malmquist Index 2013/2019



Source: Own processing.

As the next step, we applied correlation analysis on OADR in the EU Member States and the MI of DMUs in 2013/2019 (as we have mentioned, we applied the Malmquist productivity index to monitor efficiency development).

We got the same result as in the previous case. The correlation coefficient does not significantly differ from zero. Hence, there is no significant correlation between the OADR index and the Malmquist index, as in the case of the correlation between the DEA and the OADR indexes.

Conclusion

Population aging is a challenge in the 21st century that might affect all sectors of the economy.

Within the last decades, industrialized countries faced decreasing birth rates, whereas life expectancy increased. Consequently, the demographic structure is shaping, so the future influence on economic growth is unclear and needs to be clarified (Prettner and Prskawetz, 2010).

The paper aimed to investigate the potential impact of population aging on the European Union member states efficiencies and assess how these anticipated demographic challenges could influence productivity in the future. The empirical results of DEA on the unemployment rate, general government gross debt, gross capital formation, and GDP per capita in 2019 highlighted three EU Member States as effective DMUs (in DEA language), specifically the Czech Republic, Germany, and Luxembourg.

For the remaining EU Member States (24), so-called peer units (countries) exist that achieve better combinations of explored variables. Since DEA models explain only a static overview of efficiency, we also applied the Malmquist productivity index, which was developed to measure efficiency over time. Our analysis displayed the increase in GDP per capita and gross capital formation and the current decline in the unemployment rate. We analyzed the overall change inefficiency in the EU between 2013 and 2019. Of the countries with an optimal combination of GDPPP, GCF, UR, and GGD, the Czech Republic took 2nd place, Germany took 17th place, and Luxembourg took 22nd place. After applied analysis, we examined the relationship between population aging and efficiency. There was no significant correlation if we used correlation analysis on the old-age dependency ratio in the EU Member States and the Efficiency score DEA of DMUs in 2019. We did not prove the significant relationship between population aging and the efficiency of chosen countries. However, the Czech Republic and Germany achieved efficiency despite the high OADR index level, which is quite interesting.

The results of our research are consistent with the results of the studies mentioned above by Bloom et al. (2008), Poot (2008), and Dalgaard and Kreiner (2001). Our findings have concluded that it is not possible clearly to link population aging and efficiency development.

In concluding our study, the relationship between population aging and efficiency development emerges as complex and multifaceted. Our findings indicate a clear and direct link between these two factors cannot be established. This contrasts with previous studies that have either found a significant impact of population aging on economic efficiency or, conversely, minimal to no effect.

For instance, studies like those by Bloom et al. (2008) and Poot (2008) suggest varying impacts of population aging on economic growth and competitiveness. Bloom et al. (2008) found a negative short-term effect but an insignificant long-term impact, whereas Poot (2008) reported a relatively small negative impact on competitiveness. On the other hand, Dalgaard and Kreiner (2001) argue that population aging does not significantly affect economic growth.

Our study contributes to this ongoing discourse by providing a nuanced analysis incorporating multiple factors influencing efficiency in an aging population. We highlight the importance of considering country-specific contexts, including policy frameworks, technological advancements, healthcare systems, and social structures, which can mediate the relationship between population aging and economic efficiency.

Therefore, our research adds to the existing literature by illustrating the complexity of this relationship and underscoring the need for multifaceted approaches in policy formulation and strategic planning. It challenges the notion of a straightforward correlation between aging populations and economic efficiency, prompting a broader consideration of the myriad factors that influence this dynamic.

Even countries such as Cyprus or Slovakia, which have a relatively low old-age dependency ratio, achieve the lowest levels of the efficiency score. However, the impact of population aging on states' economies is enormous and multifaceted (e.g., a decline in productivity and economic growth, lack of labor workforce, decreasing social security, problems with public healthcare service, increasing pension expenditures, and fiscal imbalance). Therefore, it can be crucial for countries that achieve (according to our model) a high old-age dependency ratio and a low-efficiency index. According to our analysis, it counts 19 out of 24 EU Member States (Poland, Austria, Romania, Hungary, Belgium, Slovenia, Malta, Denmark, Sweden, France, Spain, Lithuania, Latvia, Croatia, Bulgaria, Portugal, Finland, Italy, Greece).

The pressure of population aging on government expenditure will be a challenge in upcoming decades. For the long-term economic growth of EU countries, it is crucial to support innovation and technology implementation (see result of score of Czechia and Germany).

Our research has many limitations. In the future, it could be crucial to set up the methodology for measuring efficiency in European Union Member States because there is no one general method. The consequences of population aging should be the subject of research studies; the cooperation between the public and academic sectors is crucial. Due to a turbulent period, the EU Member States must deal with many extreme changes that could now neglect the population's aging problems. This study enhances understanding of the factors influencing the efficiency of EU member states in the context of population aging, offering valuable insights for formulating policies and strategies to address the needs of aging populations. For future research, it is a question of which macroeconomic indicators should be included in the analysis; it should be helpful to include the current values of indicators and their trends.

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