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FACULTY OF SOCIAL SCIENCES

Institute of Political Studies

International Masters in Economy, State and Society

Master's Thesis

2024 **Yinuo Liu**

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Population Ageing and Economic Growth: An Analysis of Central and Eastern Europe

Master's Thesis

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Year of the defence: 2024

Declaration

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2. I hereby declare that my thesis has not been used to gain any other academic title.
3. I fully agree to my work being used for study and scientific purposes.

In Prague on Aug 1st 2023 Yinuo Liu

References

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Abstract

This thesis investigates the impact of population ageing on economic development in Central and Eastern Europe, focusing on its effects on savings rates, labour force participation, human capital, and technological progress. Using panel data from 11 CEE countries spanning 1995 to 2020, the study employs the neoclassical economic growth theory and the Solow model for theoretical analysis. Subsequently, it explores the mechanisms through which population ageing influences economic growth using mediation effects. The findings indicate that population ageing in the CEE region adversely affects economic development. As the degree of ageing intensifies, it directly or indirectly inhibits economic growth by reducing savings rates, shrinking the labour force, and impeding technological progress. This study provides comprehensive insights into the multifaceted impacts of demographic changes on economic growth in CEE and offers policy recommendations to address the challenges an ageing population poses. These recommendations include enhancing financial systems, supporting innovation, and formulating strategic measures to sustain economic growth amidst demographic shifts.

Abstrakt

Tato disertační práce zkoumá vliv stárnutí populace na ekonomický rozvoj ve střední a východní Evropě, se zaměřením na jeho dopady na míru úspor, účast pracovní síly, lidský kapitál a technologický pokrok. S využitím panelových dat z 11 zemí střední a východní Evropy v období 1995 až 2020 studie používá neoklasickou teorii ekonomického růstu a Solowův model pro teoretickou analýzu. Následně zkoumá mechanismy, kterými stárnutí populace ovlivňuje ekonomický růst pomocí mediace. Zjištění ukazují, že stárnutí populace v regionu střední a východní Evropy nepříznivě ovlivňuje ekonomický rozvoj. S rostoucí mírou stárnutí populace přímo nebo nepřímo brzdí ekonomický růst snižováním míry úspor, zmenšováním pracovní síly a brzděním technologického pokroku. Tato studie poskytuje komplexní vhled do mnohostranných dopadů demografických změn na ekonomický růst v regionu střední a východní Evropy

a nabízí politická doporučení k řešení výzev spojených se stárnutím populace. Tato doporučení zahrnují zlepšení finančních systémů, podporu inovací a formulaci strategických opatření k udržení ekonomického růstu v souvislosti s demografickými změnami.

Keywords

Population ageing, economic growth, savings rate, labour force, capital volume, technology progress, mediation effect, Solow model, CEE

Klíčová slova

Stárnutí populace, Ekonomický růst, Míra úspor, Pracovní síla, Objem kapitálu, Technologický pokrok, Zprostředkovatelský efekt, Solowův model, CEE

Title

Population Ageing and Economic Growth: An Analysis of Central and Eastern Europe

Název práce

Stárnutí populace a ekonomický růst: Analýza střední a východní Evropy

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Introduction

As a fundamental element of labour production in today's society, the population is one of the most essential resources for economic growth. Whether in primary, secondary or tertiary industries, the quantity and quality of population directly impact economic output and development potential. Population is not only a provider of labour but also a creator of consumer demand and plays a vital role in a country or region's economic structure, technological progress and market expansion. An adequate and high-quality labour force is the core driver of economic growth in a modern economic system. Growth in population size increases the supply of labour, driving the expansion of production and sustained economic growth. At the same time, a well-educated and highly skilled population can raise labour productivity and promote technological innovation and industrial upgrading. Hence, population dynamics include not only numerical growth or decline but also enhancements in quality and optimization of structure.

A country or region's economic development depends not solely on its resources and technology level but also on its demographic structure and population dynamics. Countries with a greater proportion of young individuals typically possess a greater capacity for economic expansion, as young people serve as a substantial workforce and constitute the future consumer demographic. Furthermore, the younger generation is more open to novel technologies and concepts, which propel advancements in technology and industrial innovation. However, increasing population ageing is challenging these traditional views. Population ageing means a gradual increase in the proportion of older persons in the total population. Some Western European countries were the first to reach the ageing threshold in the early 20th century, and the phenomenon has since spread globally, with more than 70 countries and regions in the world meeting the ageing threshold by the late 20th century. According to the United Nations, the number of older persons in the world is growing and is expected to exceed 2 billion by 2050, accounting for 22 per cent of the total global population. By 2060,

30 out of every 100 working-age people will be over 65, a ratio twice as high as in 2019 (Cascio, 2019). Population ageing has become an irreversible trend in the 21st century. Demographic change due to population ageing has been identified as one of the five major trends that will drive the future development of global business, social and economic growth, and one of the "Grand Challenges" subjects on which international business researchers should focus their attention (Buckley et al., 2017; Esposito & Tse, 2018). This trend poses new challenges and demands on the labour market, consumption patterns and social services and has far-reaching implications for economic policy formulation and implementation. An ageing society may lead to a reduction in labour supply, which in turn affects productivity and economic growth. In addition, with the growing percentage of older people, there would be a substantial increase in social security and healthcare costs, leading to heightened fiscal burdens. These changes make it imperative for governments and businesses to revisit and adjust their policies and strategies to cope with the multifaceted impacts of ageing. In light of this context, it is especially advantageous to analyze and evaluate the influence of population ageing on economic growth.

The relationship between economic output growth and ageing has been widely studied. However, most available analyses have focused on countries with a significant demographic dividend, such as China and India. The presence of many youthful workers in these countries has significantly boosted economic growth. Nevertheless, as the demographic dividend fades away, the issue of ageing is beginning to surface. In addition, many relevant concentrations are in developed countries, such as the United States and Japan, as well as countries in the European region, such as France and Germany, where the history of population ageing is more than 150 years. Age has long been an essential social and economic policy topic in these developed countries. But Europe is not a uniform entity, and more than a dozen countries in the Central and Eastern European (CEE) region, including Poland, Hungary, the Czech Republic, Slovakia, Romania and Bulgaria, exhibit notable differences from Western Europe in

terms of their level of economic development, social structure and demographic dynamics.

The CEE region has undergone various political and economic transformations throughout its history. As a result, the region's ageing population and economic growth patterns have become highly localized. Over the past fifty years, the older population in CEE has been growing quickly, leading to an enormous issue of population ageing. Since the 1990s, the transition from planned to market economies in these countries has led to a markedly different development trajectory from that of the rest of Western Europe, and the economic reforms of the 1990s, including economic restructuring, privatisation of public services, and price liberalisation, have brought about far-reaching economic and social changes. Among these, the climb in unemployment was particularly significant, with newly privatised firms shedding labour in order to improve efficiency. At the same time, price liberalisation led to a sharp rise in prices, the removal of government controls on prices and a sharp increase in the cost of living for the population. The emergence of migratory flows and declining birth rates further complicated the social structure, with the elderly population in most countries increasing by about 3% in the decade 1995-2004, with a concomitant decline in the labour force and the uncertainty of the economic environment increased the vulnerability of these countries. As these countries began accession negotiations with the European Union and implemented pre-accession reforms, their economies gradually stabilised. However, the global financial crisis of 2007-2008 once again exposed the weaknesses and economic vulnerabilities of the CEE countries, with the GDP of the Baltic States (Estonia, Latvia and Lithuania) plummeting by 14% in 2009 and that of a number of other countries (Hungary, Slovenia, Romania and Slovakia) declining by more than 5 per cent. At the same time, the population over 65 in each country grew even faster than in the previous 20 years, reaching a more alarming value, with a growth point of more than 4% in the 10 years immediately following, and ageing dynamics intensified.

However, more research is needed on the impact of population ageing on economic growth in CEE countries. Currently, most studies of population ageing focus on its causes, including factors such as declining fertility, increasing life expectancy and migration flows. This research has provided insight into the factors that contribute to the process of ageing, but their precise economic consequences have not been sufficiently investigated. Other researchers have endeavoured to investigate the patterns of population ageing and economic progress in a specific nation, like Hungary, or in countries that are being compared, such as the Czech Republic and Slovakia. This basic form of research, while useful in assisting the study countries, appears inadequate for understanding the economic dynamics of the region as a whole and for developing coherent policy measures. On one hand, examining single countries alone cannot fully capture the economic linkages among CEE countries. The economies, trade, and labor markets of CEE countries are highly interconnected and interdependent. Consequently, focusing solely on individual nations might only partially reveal the effects of population ageing on a country's economy, overlooking the significance of intra-regional spillover effects and policy coordination. Additionally, while population ageing impacts the economic development of individual countries, its broader effects on the region's economies through trade, investment, and labour mobility are substantial. A comprehensive study of the CEE region would provide a better understanding of the combined macroeconomic impact of population ageing, including the processes of intraregional economic integration and the operation of the common market.

A few researchers have also noted research gaps in the CEE region in areas of this nature. For example, by analysing population ageing and its impact on economic output in 10 CEE countries, Nicoleta argues that population ageing has a massive impact on the CEE region, as well as a substantial negative impact on productivity growth, and suggests that CEE countries should revise government measures and implement reforms to ensure the well-being of the old. The results provide a necessary theoretical foundation and empirical support for further exploration of population ageing in the CEE region. However, despite the valuable insights provided by Nicoleta's study, there

is a lack of comprehensive research on the specific mechanisms via which population ageing impacts economic development in the CEE region. The absence of such studies hinders a comprehensive understanding of the multifaceted impacts of population ageing on the region's economy and limits policymakers' scientific basis and decision-making capabilities when addressing the challenges posed by ageing populations. To effectively tackle the economic challenges associated with population ageing, there is an urgent need for more academic research and policy discussions that explore a broader range of impact channels and mechanisms.

Analyzing the channels through which ageing affects economic development can reveal the path of impact in the labour market, capital accumulation and technological progress, thereby providing a more targeted basis for policy formulation. Such an analysis can help to provide a comprehensive understanding of the multifaceted impacts of ageing on the economy, particularly in terms of the increase in the cost of employment due to labour market constraints, the impact of changes in the savings rate and investment behaviour on capital accumulation, the acceptance of technological advances by older workers as affecting the rate of innovation, the enormous pressure that ageing places on fiscal expenditure and the social security system, as well as the changes in consumption patterns and the structure of demand. By analyzing these channels in detail, it is possible to help governments and relevant institutions formulate more targeted coping strategies that take into account both short-term measures and long-term strategic planning to ensure economic stability and prosperity as they address the challenges of population ageing.

Therefore, this paper adopts the method of quantitative analysis and selects the panel data of Bulgaria, Croatia, the Czech Republic, Hungary, Poland, Romania, the Slovak Republic, Slovenia, Estonia, Latvia and Lithuania in the CEE region to conduct empirical analyses to explore the direction of the impact of population ageing on the economic development of the region. Due to data availability and to avoid the global impact caused by COVID-19, this paper selects the region 1995-2020 as the time

interval. At the same time, in order to dig deeper into the specific mechanism of the impact of population ageing on economic development, this paper also adopts Jiang Ting's mechanism research test through the analysis of interrelationships between different variables to reveal how population ageing affects economic development through the channels of savings, labour force, the amount of capital and technological progress. Further, based on the empirical analyses, this paper puts forward more targeted policy recommendations to cope with the challenges posed by population ageing.

The paper is structured as follows: In the second section, we summarise and generalise the relevant literature on population ageing, economic growth, and the channels of influence. The third section begins with a brief overview of the current situation of population ageing and economic growth in CEE and provides the theoretical foundation of the paper, using basic theory to provide a theoretical analysis of the impact of population ageing on economic growth and the channels through which it affects the economy, followed by the formulation of a number of hypotheses. The forth part describes the model setup and variable measurement and explains the relevant data sources. The fifth part tests the impact of population ageing on economic growth and analyses the results. In the sixth part, a mechanism analysis is carried out to determine how population ageing affects economic development in CEE. The final section concludes and makes some policy recommendations.

Chapter 1: Literature Review

1.1 Population and economic growth

The interrelationship between population and the economy is a core element in understanding and fostering societal development. As early as 1798, Thomas Malthus explored the potential of population growth and its long-term impact on the economy in his seminal work, *An Essay on the Principle of Population*. Malthus argued that the geometric progression of population growth, contrasted with the arithmetic progression of subsistence resources, could lead to a situation where the benefits of economic development are insufficient to offset the pressures exerted by population growth. This phenomenon, known as the "Malthusian trap," suggests that societal welfare may face persistent decline without adequate measures to control population growth. Malthus's insights provided a crucial theoretical foundation for subsequent economic research. Following Malthus, classical economic growth theories expanded on his ideas by systematically examining the complex relationship between population and economic development. These theories emphasise the dual impact of population changes on economic growth. On the one hand, an increasing population can expand the market size and drive economic development. On the other hand, if population growth outpaces the increase in resource supply, it can exert pressure on the economy, potentially stunting economic growth. Economists have employed mathematical models and empirical research to investigate how population-related factors influence both the rate and quality of economic growth, thereby providing a more nuanced understanding of this critical interaction.

Cross-disciplinary research on population and economic development is mainly divided into two parts. The initial section pertains to the correlation between the population's magnitude and the economy's advancement. A larger population size signifies a larger consumer market, which is conducive to the specialization of labour division and the development of industrial specialization, thereby gradually enhancing production efficiency and promoting economic development (Fu & Hong, 2011) Hence, the

attitude held by scholars such as Durkheim (1933) is that population growth has a positive effect on economic growth. Furthermore, Glover and Simon (1975) found through their studies that higher population density can increase economies of scale, leading to increased productivity. The aforementioned perspectives exemplify the demographic dividend. The concept of the "demographic dividend" was first introduced by Bloom and Jeffery (1998) in their investigation into the factors that led to the rapid economic development of Japan and the Four Asian Tigers after the war. This concept is the result of the interaction between population structure and economic development over a specific period of time (Mason & Lee, 2006), and this effect is referred to as the "first demographic dividend". Nevertheless, as the population reaches a certain threshold, its ability to contribute to economic growth would decline considerably, potentially even having a negative effect (Ke et al., 2014). In addition, it is important to point out that empirical studies that have been conducted on the influence of population expansion on economic growth in particular nations have yielded results that are conflicting. For example, Sethy and Sahoo (2015) found that population growth has a positive impact on per capita economic growth in India, as well as in the East African and South African regions, while Banerjee (2012) concluded that there is a negative correlation between population growth and per capita GDP growth in Australia.

The second part concerns the impact of population quality on economic growth. Human capital constitutes the core of population quality. Research by Mankiw (1992), Temple (1999), and Becker and Woessmann (2009) all suggest that the growth of human capital can promote economic growth. School education is a significant factor in the accumulation of human capital, while the increase in life expectancy and extension of working hours further contribute to the accumulation of human capital. Through an analysis of pertinent data from Finland, Pekka (2004) came to the conclusion that increased levels of education among workers, in conjunction with acquired job experience, would lead to an increase in labour productivity. Older workers are generally more productive compared to younger employees (Prskawetz and Guest, 2008) and have accumulated better skills, especially for those engaged in jobs where

language proficiency and experience are more important than cognitive abilities (Czaja and Sharit, 1998). However, some scholars hold different views, suggesting that the direction of the impact of human capital on economic growth is ambiguous. Ilona (2021) contends that the relationship between human capital, as measured by years of schooling, and economic growth has ceased to be a driving force. It is certain that as the amount of human capital increases beyond a certain point, the rate at which it accumulates will drop. This decrease is particularly obvious for older workers who experience decreased physical functions and reduced ability to learn (Le Carret et al., 2003).

As society evolves, scholars have increasingly delved into and subdivided their research on the relationship between population and economic development, with population structure becoming one of the focal points. Currently, studies on the relationship between population structure and economic development are gradually transitioning from discussing the abundance and trends of demographic dividends to more detailed analyses, decomposing the impacts of population ageing and labour force structural shifts on the direction, extent, and mechanisms of economic growth (Du and Feng, 2021). It is noteworthy that population ageing is a significant challenge facing the world today. Changes in population structure are occurring in an increasing number of countries and regions as a result of rising life expectancy and falling fertility rates. These changes are principally represented by a growing proportion of old populations and a decreasing proportion of youth populations. Among the developed countries recognized by the United Nations (with a total population of 1.2 billion in 2005), the overall median age increased from 28 years in 1950 to 40 years in 2010 and is expected to reach 44 years by 2050. According to the 'World Population Prospects 2022', the growth rate of the population aged 65 and over exceeds that of the population under 65. The global population aged 60 and over has been increasing at an annual rate of 3% since 1960, with the number of people aged 65 and overreaching 771 million in 2022, three times the size in 1980 (258 million). In 2022, approximately 10% of the global population is aged 65 and over. The proportion of the elderly population is highest in

Europe and North America, where the proportion of those aged 65 and over is close to 19%. Projections indicate that by 2050, one-quarter of Europe and North America's population will be 65 and over. As a primary global concern, research on ageing has garnered significant attention from scholars worldwide.

1.2 Population ageing and economic growth

Population ageing refers to the process wherein the proportion of elderly individuals within the total population increases. Currently, there is no unified standard for defining population ageing internationally. As per the United Nations' definition, it is widely accepted by the global community that a country experiences population ageing when the proportion of individuals aged 60 and overreaches 10% or when the proportion of individuals aged 65 and overreaches 7%. If the proportion of individuals aged 65 and over exceeds 14%, the country is considered to have entered an aged society; if this proportion exceeds 20%, it signifies that the country has entered a super-aged society. Whereas the formulation of ratios related to the ageing of the population reflects the concern about the increase in the proportion of the elderly population in the overall demographic structure, the increase in the trend of ageing has also had a profound impact on all aspects of the socio-economic situation. In numerous studies, population ageing is measured through indicators such as the proportion of the population aged 65 and over or the elderly dependency ratio. The elderly dependency ratio refers to the ratio of the number of elderly individuals to the number of working-age individuals in a country or region's population. It serves as an economic indicator to gauge the impact of ongoing population ageing on a country or region. Economic growth, on the other hand, is measured by changes in a country's Gross Domestic Product (GDP), which can be decomposed into population and economic factors, represented as the product of population and per capita GDP (Peterson et al., 2017).

Currently, research conclusions regarding the impact of population ageing on economic growth can be broadly categorized into two main perspectives. Some scholars maintain

that population ageing is either ineffective or beneficial for economic development within a nation. On the one hand, population ageing may bring forth new opportunities and positive impacts on the economic development of a country or region. For instance, Prskawetz et al. (2007), based on empirical analysis of the Indian context, demonstrated that population ageing, leading to increased life expectancy per capita in India, contributes positively to economic growth. Prettner (2013) suggests that population ageing will generate growth effects on per capita output, surpassing the decline in per capita output resulting from declining birth rates, thereby promoting economic growth. On the other hand, some scholars argue that external factors influence population ageing and may not necessarily have a negative impact on economic development. For example, Futagami and Nakajima (2001) propose that while population ageing may affect various aspects of the economy, these effects may offset each other, ultimately not necessarily slowing down economic growth. Wang Guixin and Gan Yihui (2017) conducted empirical research on the impact of population ageing on regional economic growth in China from 1990 to 2015, based on Bloom's Harvard model. Their study indicated that the increase in the growth rate of the elderly population and the elderly dependency ratio did not affect China's current economic growth, suggesting that there is currently no significant relationship between the two factors.

The majority of academics, on the other hand, are of the opinion that the growing proportion of elderly people will invariably have a negative impact on economic expansion. For instance, Bloom and Williamson (1998) validated, based on panel data from rapidly developing East Asian countries between 1965 and 1990, using an economic growth model, that the gradual ageing of populations will hurt economic growth. Turner (1998) utilised a dynamic general equilibrium model to estimate the impact of population ageing on nations that are members of the OECD. The results indicated that population ageing would decrease the working-age population, thereby adversely affecting economic growth. Lindh and Malmberg (1999) examined the role of the population's age structure in OECD countries on economic growth, demonstrating that changes in the population's age structure affect per capita GDP, with

an increase in the population aged 65 and over inhibiting economic growth. According to Maestas and Mullen (2016), they collected data from a number of states in the United States in order to investigate the influence that an ageing population has on the growth of the economy in the United States. Ultimately, the findings of their quantitative investigation indicated that the ageing of the population has a detrimental impact on economic development in the United States, and that the ageing of the population also slows overall productivity growth. Cooley and Henriksen (2018) also found that population ageing is a primary driver of slower growth in most advanced countries. In addition, many other scholars, such as Lee and Shin (2021) share the same view.

Recent study has revealed that population ageing does not directly cause a decline in economic development. The progression of ageing can lead to alterations in multiple intermediary elements, which can impede the pace of economic development. Research by Kuznets (1967) also emphasizes that population ageing can affect economic growth through channels such as production, consumption, savings, and labour supply. Firstly, the process of ageing can lead dto a decrease in the number of people available to work, resulting in a decline in the overall productivity of the labour force. As noted by Bloom and Williamson (1998), the demographic dividend's quick increase in the work force contributed to the East Asian economy's explosive expansion towards the end of the 20th century. However, the rise of an ageing population combined with the reversal of the demographic dividend will result in significant population deficits, ultimately leading to a decrease in economic growth. Huang Zuhui et al. (2014) employed a computable general equilibrium model to examine the influence of population ageing on economic development between 2010 and 2030, using China's population figures projected by the United Nations. According to their research, the decrease in the number of people in the workforce as a result of the ageing population will have a negative impact on China's economic growth, causing it to slow down. In their study, Xiao Yiping and Yang Yanlin (2017) examined population census data from China spanning from 1987 to 2015. They found that in the context of population ageing, a 1% decline

in the share of the working-age population leads to a corresponding loss of 1.9% in per capita GDP, implying that increased ageing is detrimental to economic growth.

Secondly, population ageing negatively impacts the savings rate, consequently reducing capital accumulation and further leading to a deceleration in economic growth (Park & Shin, 2012). There is a correlation between one's age and their level of savings, as stated by Modigliani (1954) and his lifecycle hypothesis. The hypothesis posits that a rational economist will logically distribute their lifetime income, ensuring that the marginal utility values at each stage are equivalent, hence maximising their lifetime utility. During the period of working-age, individuals often have a surplus of savings as their income surpasses their consumption. Conversely, during the period of non-working-age, individuals tend to have a deficit of savings as their spending surpasses their income. Hence, a higher proportion of population ageing is associated with decreased savings accumulation. Kim and Lee (2007) point out that population ageing leads to an overall decline in the share of the working-age population and a consequent shrinkage in the size of the savings group, which in turn adversely affects the accumulation of savings by residents. Furthermore, Bloom et al. (2011) contend that the worsening trend of population ageing further diminishes labour force participation rates, concurrently weakening savings and ultimately leading to a slowdown in economic growth. Moreover, the economic performance of Australia from 1971 to 2014 can be interpreted as influenced by population changes and savings rates. As population ageing becomes increasingly severe, the advantageous population age structure will gradually weaken, ultimately exerting adverse effects on economic growth.

Thirdly, ageing tends to have a detrimental effect on productivity growth. In the seminal work The Wealth of Nations, Adam Smith, published in 1776, underscored the positive correlation between population growth and economic activity. He argued that a growing population increases the availability of labour and, when coupled with the division of labour, enhances worker productivity and spurs economic progress. Smith's insights on population and labour productivity provided a foundational perspective for

understanding how ageing impacts productivity. The Solow economic growth model has been employed in contemporary analyses to explore this relationship further. Lindh and Malmberg (1999) used this model to identify a hump-shaped relationship between the structure of the labour force and productivity. Their findings indicate that employees aged between 30 and 64 positively influence productivity. However, individuals aged 65 and older often exhibit a negative effect on productivity. This decline is linked to the diminishing percentage of employed individuals as the population ages, adversely impacting overall productivity growth. Further supporting this view, Feyrer (2007) found that labour productivity peaks between the ages of 40 and 49 in a study covering 87 non-oil-exporting nations. As populations age, the proportion of people in the productive age range decreases, reducing overall productivity growth. Maestas and Powell (2016) corroborate this perspective by analysing data from US states, while Aiyar, Ebeke, and Shao (2016) provide similar evidence from European countries. These studies collectively highlight the challenges ageing poses to maintaining productivity levels and economic development.

Fourthly, population ageing hampers the growth of total factor productivity (TFP) and impedes technological progress. Jones (2010) argues that elderly individuals tend to have lower innovation capabilities, resulting in lower levels of technological advancement in ageing economies. Derrien, Kecskés, and Nguyen (2018), as well as Aksoy et al. (2019), provide supporting evidence based on local labour force samples from the United States and OECD countries, respectively. Canton et al. (2002) pointed out that the ageing of the labour force is not conducive to technological progress because the benefits of technology have a certain time lag. Although the ageing labour force may possess the capability to engage in technological research, development, and innovation, it is highly probable that they will not be able to fully benefit from the outcomes of these new technologies within their remaining lifespan. Consequently, the ageing labour force lacks strong motivation to pursue the development of new technologies. As the proportion of the ageing labour force increases, the development and application of new technologies will face more difficult difficulties, which will

ultimately have a negative impact on economic development. Engbom (2019) developed a model demonstrating that labour force ageing leads to a decline in both business and worker dynamism, resulting in reduced economic growth due to diminished creative destruction. Fu Jianhua (2021) suggests that, at present, China's further economic development needs to transition from factor-driven growth to innovation-driven growth. Population ageing results in a steady rise in the average age of the workforce, which has a detrimental effect on technological innovation.

Lastly, the ageing of the population has an impact on the overall consumption of society. Some academics contend that the increasing proportion of elderly people in the population results in a decline in the general consumption of society, which in turn has an effect on the progression of socioeconomic conditions. Horioka and Wan (2007) used the lifespan theory as an analytical framework to examine provincial panel data from China from 1995 to 2004. They found that population ageing is detrimental to the increase in the average household consumption propensity. Furthermore, as the proportion of elderly individuals increases, the tax burden on the working-age population also increases, affecting their consumption demand. This demand, in turn, creates deflationary pressure, ultimately leading to an increase in unemployment rates and a decrease in real GDP (Katagiri, 2012). The decrease in per capita consumption caused by population ageing also leads to an increase in the capital-labour ratio and a decrease in investment returns, adversely affecting macroeconomic conditions (Tian et al., 2020). However, several academics contend that population ageing can have a beneficial effect on consumption. Bosworth and Chodorowreich (2007) conducted a panel analysis of 85 countries from 1960 to 2005. They found that an increase in the elderly dependency ratio significantly promotes an increase in the average household consumption propensity. Loayza (2000) also confirmed the promotion effect of population ageing on household consumption. In conclusion, the effect of an ageing population on consumption is a complicated phenomenon that calls for additional in-depth research in order to have a thorough understanding of the potential implications that this phenomenon may have for the economy.

1.3 Population ageing and economic growth in Europe

While population ageing affects economic growth through different channels, the extent and direction of the impact of ageing on the economy also has some regional variations due to the differences in the levels of population and economic development of different countries or regions. Maestas (2016) conducted a quantitative study by collecting data from various states in the United States to explore the impact of population ageing on economic development. The study ultimately concluded that population ageing has a negative effect on the economic development of the United States, as it reduces overall productivity growth. Similarly, Japan's ageing population, coupled with shrinking and ageing labour force issues, also limits the improvement of labour productivity, thereby impeding economic growth (Spyros & Emmanouil, 2019). However, based on provincial-level studies in China, Feng Jianfeng et al. (2019) argued that in the initial stages of ageing, population ageing could increase labour productivity, thereby promoting economic growth. As the degree of ageing deepens, the impact on labour productivity weakens, leading to a slowdown in economic growth. Yang Beibei and Liu Yi (2015) found that population ageing has a more adverse effect on labour productivity in coastal areas compared to inland regions. Thus, it is evident that the impact of population ageing on productivity exhibits regional characteristics, underscoring the necessity for specific studies targeting individual regions or countries.

Research on population ageing in Europe has underscored the significant impact of this demographic shift across the continent. Muysken and Ziesemer (2013) examined the Netherlands and highlighted how ageing negatively affects GDP. Their analysis revealed that the increasing proportion of elderly individuals has strained economic resources and reduced overall economic growth. Similarly, Hondroyiannis and Papapetrou (2000) predicted economic decline in Greece due to declining fertility rates and a rising dependency ratio. They observed that economic challenges intensify as the number of retirees grows relative to the working-age population. Smrčka and Arltova

(2012) reached comparable conclusions regarding the Czech Republic, noting that demographic shifts are contributing to economic difficulties. Blake and Mayhew (2006) voiced concerns about the long-term sustainability of the UK economy amidst an ageing population and declining fertility rates. They warned that these demographic changes could undermine economic stability and growth in the future. Lindh and Malmberg (2009) explored the economic impact of ageing in the EU-15 countries and found a correlation between slowing economic growth and an ageing population. Their study emphasized that GDP growth is susceptible to changes in the population's age structure, with certain age groups having a more pronounced effect on economic performance. Despite these insights, population trends in CEE have received less research attention than in Western Europe. Much of the European research is concentrated on Western Europe (Lindh & Malmberg, 2009) or focuses on specific Eastern European countries (Smrčka & Arltova, 2016). This disparity in research coverage highlights a gap in understanding the unique challenges CEE countries face due to ageing populations.

1.4 Population ageing and economic growth in CEE

With its unique historical, cultural, and economic background, the CEE region deserves significant attention as an ideal research field for exploring the interrelationship between ageing and economic development. Situated in the central-eastern part of Europe, the CEE region, according to the OECD definition, comprises Albania, Bulgaria, Croatia, the Czech Republic, Hungary, Poland, Romania, the Slovak Republic, Slovenia, and the three Baltic States: Estonia, Latvia, and Lithuania. Throughout the 20th century, the region underwent profound social, economic, and political transformations influenced by the Soviet Union's socialist era. In the early 1990s, following the dissolution of the Soviet Union, many countries transitioned to market economies and multiparty political systems. For instance, Czechoslovakia underwent a transition from socialism to capitalism following the ‘Velvet Revolution’ in 1989. After the split into the independent Czech Republic and Slovak Republic in 1993, both

countries chose the path of market economy and capitalism, achieving political and economic transformations.

Nevertheless, during the early stages of transition, CEE countries experienced a significant loss of the economic security pillars that were previously provided by the socialist system, as described by Standing (1996). Under socialism, individuals benefited from three main forms of economic security: (1) employment that was guaranteed from full-time work until retirement, offering a stable career path; (2) social protection that was secure and low-cost, administered by the government through various subsidies; and (3) a range of enterprise-based social welfare benefits, including housing, public childcare services, and healthcare. These elements collectively contributed to a stable and predictable economic environment. However, the transition away from socialism in the 1990s led to the dismantling of these systems. In addition, the implementation of extensive pro-natal family policies by CEE governments in the 1980s, aimed at increasing fertility rates, had notable impacts on countries with labor-intensive economies. Consequently, post-transition, CEE countries experienced an "economic shock" period, accompanied by delayed childbirth and decisions not to have children among CEE residents. After 2004, eleven CEE countries joined the European Union as part of the European integration process. Thus, it can be observed that post the 1990s, CEE countries still share certain similarities in their political and economic backgrounds.

The ageing process in most CEE countries began in the early 1980s and has intensified over the past half-century. The driving factors of population ageing in the CEE region mainly consist of three components: mortality rates, fertility rates, and migration (Andreas, 2008). The decline in mortality rates stems from improvements in life expectancy. World Bank data indicates a 5-year increase in life expectancy in the region between 1996 and 2003. The rise in the minimum retirement age across Europe and advancements in healthcare have promoted prolonged working lives and increased life expectancy, as detailed by Kinsella et al. (2005). The rapid decline in fertility rates leads

to noticeable ageing (Chesnais, 1992). If the proportion of young people declines in any particular society, the proportion of elderly individuals will consequently increase (Andreas, 2008). Moreover, CEE experienced an unprecedented sharp decline in fertility rates in the 1990s due to economic uncertainties during the transition to market-oriented societies. Furthermore, the substantial emigration of young people from their home countries has dealt a "double blow" to the CEE nations. Since young people are potential parents, their departure further diminishes the size of the new generation, thereby rapidly exacerbating population ageing (Nikolai, 2012). Migration also drains away part of the "demographic dividend" of the CEE countries, which would have helped them to better cope with the challenges of an ageing population. Driven by these three factors, CEE countries experienced a rapid increase in the proportion of the elderly population in the early 1990s, exacerbating the severity of ageing.

According to data from Eurostat, the proportion of the population aged 65 and over in CEE countries had already surpassed 7% of the total population by around 1980. This statistic indicates that many CEE countries were effectively entering the ageing phase of demographic transition by the 1980s. Notably, this demographic trend has become more pronounced in the group of eleven countries, including the Czech Republic and Hungary, that progressively joined the European Union after 2004. In these nations, the proportion of individuals aged 65 and over has now exceeded 15%, with some countries experiencing figures as high as 22%. The old-age dependency ratio was between 40% and 50% in each CEE country in 2019. The old dependency ratio of the population of each CEE country in 2019 is between 40 and 50 per cent, implying that a relatively large number of people in old age depend on the working-age population for their support, thus placing significant pressure on economic factors such as finances. Linking population ageing to the economy is a critical issue that the CEE region must deeply understand and quickly address.

Currently, research on aging or the aging economy in CEE primarily focuses on two main areas. Firstly, there's analysis concerning the causes of the rapid increase in aging

levels in CEE countries since the 1990s. For instance, Andreas Hoff (2008) attributes the aging of the CEE region to continuous increases in life expectancy, rapid declines in birth rates, and significant emigration of young people. Meanwhile, Nikolai Botev (2012) summarizes several characteristics influencing population aging processes and their social and economic impacts in the CEE region. He analyzes and summarizes factors such as excessively high male mortality rates, natural population decreases, net migration, disordered queue movements, interference between population changes and economic and political transitions, and relatively short generational lengths. Botev specifically identifies unique post-transition factors contributing to population structural changes in the CEE region and suggests partial mitigation measures. Secondly, research also delves into the relationship between population aging and economic development in different countries within CEE. Although some scholars, such as Nicoleta Iftimia and Nicoleta Panaite (2021), focus on the impact of aging on economic development in the CEE region as a whole, suggesting that increased aging may slow down economic output growth across the ten CEE countries, most scholars concentrate on individual countries or comparative analyses among different countries. For instance, Smrčka and Arltov (2012) analyze the Czech Republic and attribute its economic downturn to population aging, low birth rates, and a decrease in the workforce. These factors have had significant economic implications, including labor shortages, changes in economic composition, and potentially decreased innovation capacity. Similarly, Stepan Pekarek (2018) argues that declining fertility rates and increased life expectancy leading to population aging have dramatically increased the economic dependency ratio in both the Czech Republic and Slovakia, thereby increasing pressure on fiscal stability.

Therefore, this research is poised to contribute significantly to the existing literature by focusing on Europe's relatively underexplored CEE region. Given the accelerated population ageing in the aftermath of this region's political and economic transitions, there is a pressing need to assess the impact on economic growth. By employing neoclassical economic theory to deconstruct critical economic development indicators

and rigorous empirical analysis, this study endeavours to elucidate the mechanisms through which population ageing might impede economic progress in the CEE region. Ultimately, the aim is to furnish evidence-based recommendations that inform policy interventions and strategic initiatives to mitigate the adverse effects of population ageing on economic development in this context.

Chapter 2: Theoretical Analysis

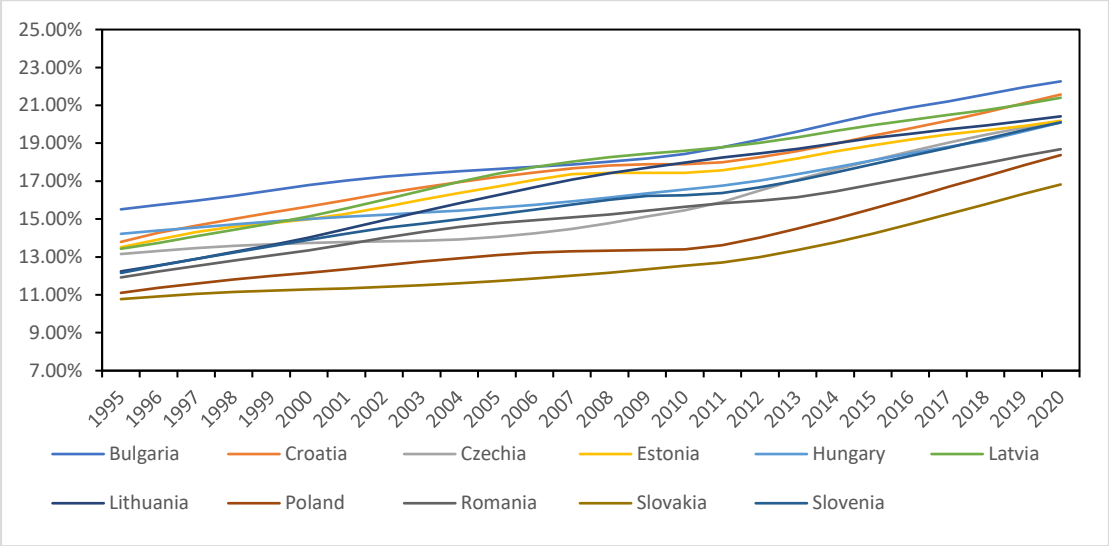
2.1 Background

2.1.1 Population ageing in CEE

2.1.1.1 Status of population ageing in the CEE region

Masud Chand's (2024) study highlights that CEE countries are experiencing the most rapid ageing and population decline globally, making them an invaluable subject for examining this issue in the present work. Based on United Nations forecasts, the three countries with the fastest declining populations worldwide and eight of the top fifteen populations will be in this region between 2020 and 2050 (Kiersz & Hoff, 2020). These statistics go beyond mere numerical values; they expose an imminent truth - the CEE region is progressively seeing a decline in its youthful population and an increase in the proportion of elderly individuals, which has significant consequences for the general progress of the nation.

Figure 1: Trends in the percentage of older people, 1995-2020

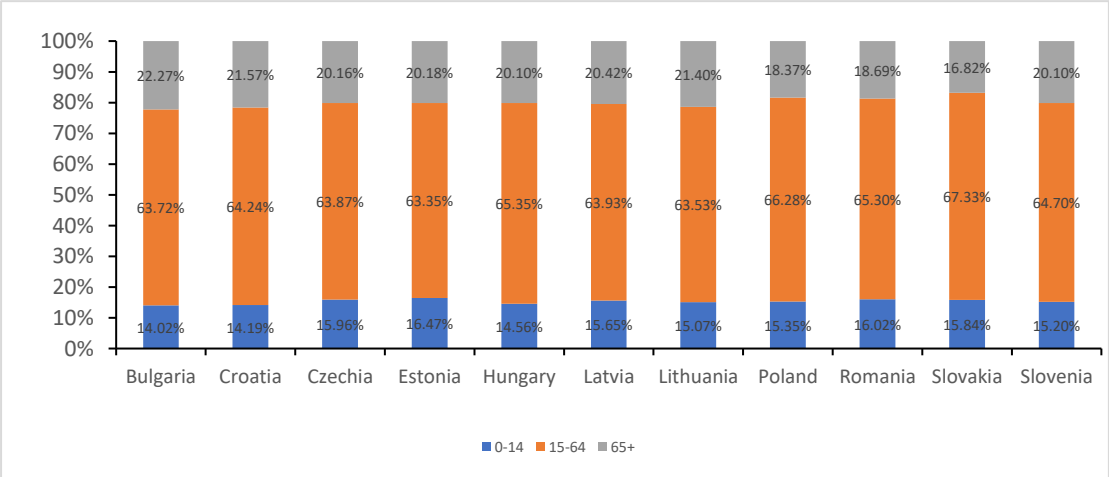


Source: WDI

Figure 1 illustrates the changing proportion of individuals aged 65 and above in relation to the total population in each of the CEE nations from 1995 to 2020. In general,

countries had already reached the ageing stage well before 1995, as the percentage of the population aged 65 and above was over 10%. The senior population in all countries is experiencing a consistent upward trend, with Bulgaria having a population of individuals aged 65 and above exceeding 15% in 1995. Over the 30 years from the late 1990s to 2020, data show that the proportion of persons aged 65 and over increased in all countries during this period. Following 2010, the percentage of elderly individuals increased rapidly in most countries. In 2011, Hungary's rate was 16.76%, which increased to 20.1% after ten years. By 2020, the proportion of older people in the CEE countries has risen to around 20 per cent of the total, meaning that almost all of them have entered into super-ageing societies, with only Poland, Romania and Slovakia not exceeding 20 per cent of the population over 65. A statistical examination of the data for these years reveals that no country has experienced a decline in the proportion of persons aged 65 and over, further confirming that population ageing is a persistent regional phenomenon. Overall, the ageing process in the CEE region over this period was significant and widespread across the 11 countries. However, the magnitude and rate of increase varied from country to country.

Figure 2: Demographic structure of the eleven countries of CEE in 2020

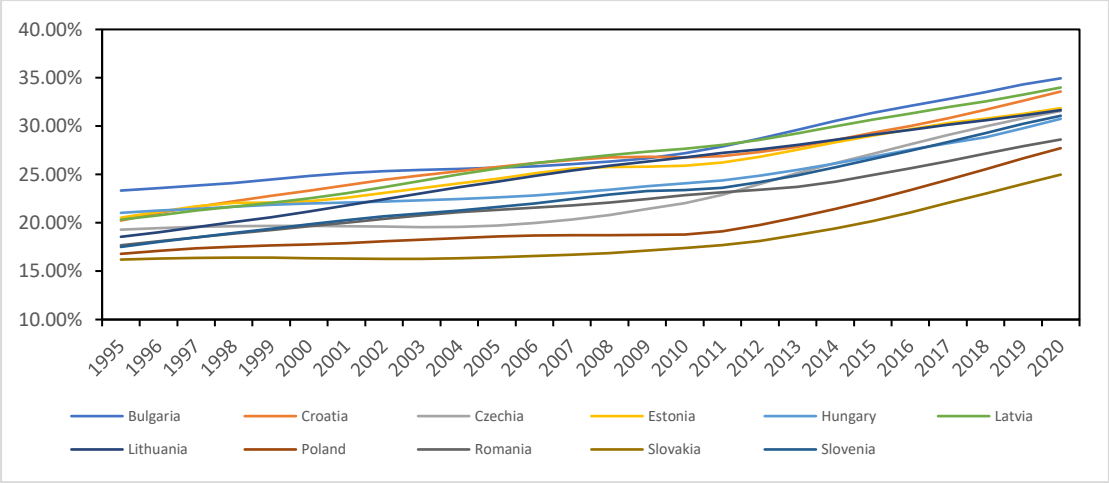


Source: WDI

The age distribution of the population in 2020 for 11 CEE countries is compared in Figure 2. The statistics regarding the population's age distribution in the CEE region in

2020 present a multifaceted depiction of the process of population ageing. In all 11 nations in the region, the share of the population aged 15-64 is roughly 65%, which is only around two-thirds of the total population, with a small proportion of the working population. The senior and child populations collectively make up one-third of the overall society. Precisely, the elderly population constitutes approximately 20%, while the child population accounts for only 15%. This relatively low percentage of children is observed across all countries, indicating a scarcity of the younger generation and an inadequate foundation for future labour force replacement. The data underscore a notable trend towards population ageing in the CEE region, particularly within the older age group of 65 years and above. Although the percentage of elderly individuals varies slightly from country to country, the overall pattern remains consistent. There is a significant ageing population coupled with a comparatively small number of young individuals. This demographic shift suggests potential long-term socio-economic implications, such as increased pressure on social security systems and healthcare services and a potential decline in the available workforce. Furthermore, the demographic composition indicates a potential imbalance in the dependency ratio, where a growing elderly population relies on a shrinking working-age population. This scenario could pose substantial challenges to economic growth, productivity, and maintaining robust social support systems.

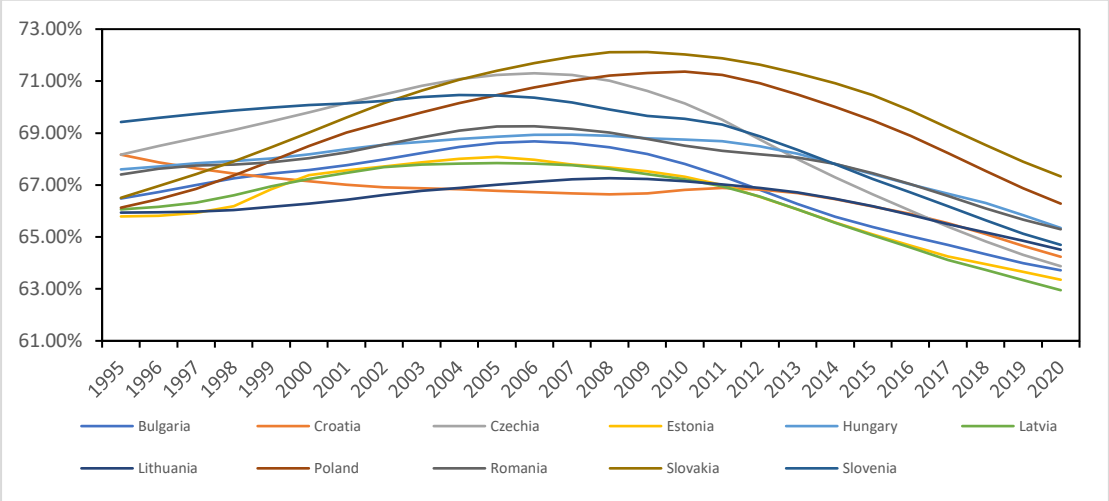
Figure 3: Trends in the old-age dependency ratio, 1995-2020



Source: WDI

On display in Figure 3 is the progression of the old-age dependence ratio in the nations of CEE from 1995 to 2020. The overall change has a similarity to the change in the share of the old population in each country, with an upward tendency over the last 30 years. As an illustration, Bulgaria's old-age dependency ratio rose from 23.34% in 1995 to 34.94% in 2020, indicating that the country's working-age population is burdened more. Further study of national data reveals that the growth in the old-age dependence ratio is not only considerable in absolute terms but has also accelerated dramatically since 2010, indicating that the ageing process is hastening. Specifically, the old-age dependence ratio climbed by 4 to 6 per cent in the majority of CEE nations between 1995 and 2010. In contrast, the growth rate in Poland and Slovakia was slightly slower, at less than 2 per cent. However, during the last decade, the old-age dependency ratio has climbed by almost 8%, particularly in the Czech Republic, where it surged from 22.05 per cent in 2010 to 33.57 per cent in 2020, indicating an abnormally high growth rate. These statistics underscore the growing burden on the working-age population in the CEE region to support and care for an increasing elderly population. This trend is indicative of the broader phenomenon of societal aging, which is becoming more pronounced over time.

Figure 4: Trends in the working-age population, 1995-2020



Source: WDI

Figure 4 accurately represents the changes in the proportion of the working-age population (aged 15-64) in the CEE region from 1995 to 2020. The graph shows two distinct periods of change: 1995-2010 and 2010-2020. Most CEE nations had a rather steady percentage of the working population over the first period; in fact, several, like Bulgaria and Czechia, had a small increase, going from 66.47% to 67.82% and 68.17% to 70.14%, respectively. In contrast, the percentage of the working population in Croatia experienced a decline from 68.17% in 1995 to 66.81% in 2010. All CEE countries experience a substantial reduction in their labour force share during the second phase, 2010-2020. Among these countries, the Czech Republic exhibits the most precipitous decline, with its labour force share falling by over six percentage points from 70.14% to 63.87% over the decade. In the other nations, while the decrease in the share of the working-age population was not as significant as in Czechia, there was a constant reduction trend. The decreasing trend observed throughout the period indicates general shifts in the population's age distribution in the CEE region. It signifies a decrease in the available pool of human resources in the labour market. The correlation between the decline in the proportion of the labour force and the increase in the old-age dependency ratio together map the growth of dependency on the labour force and social dependency pressures as the proportion of the ageing population rises. Such demographic dynamics have direct implications for the labour market and social security systems, especially in the context of continued ageing.

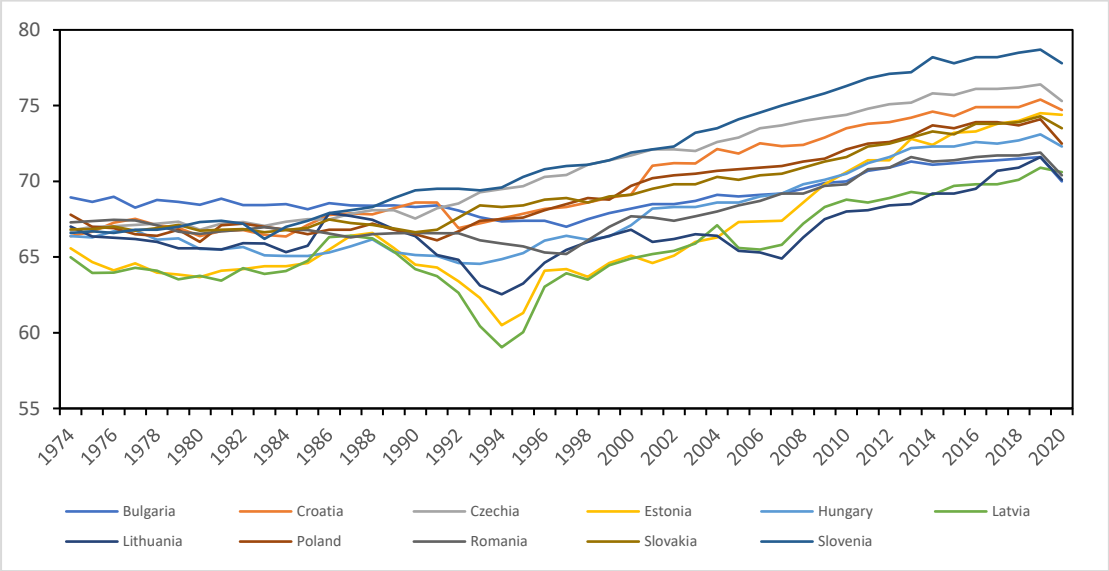
2.1.1.2 Causes of Population Aging in the CEE Region

The CEE region underwent significant political and economic changes in the early 1980s and the late 1990s, which affected society as a whole in several ways and led to inevitable fluctuations in the demographic structure of the population. The transition from a centrally planned economy to a market-based one, coupled with political reforms, brought about substantial shifts in societal norms, economic conditions, and public policies. These changes had direct and indirect effects on demographic trends,

contributing to the increase in the level of ageing in society. Consequently, many scholars have conducted extensive, multifaceted analyses of the causes of ageing in the post-transition CEE region. Among them, Andreas Hoff (2008) attributes the ageing population in the CEE area to three main factors: mortality, fertility, and migration.

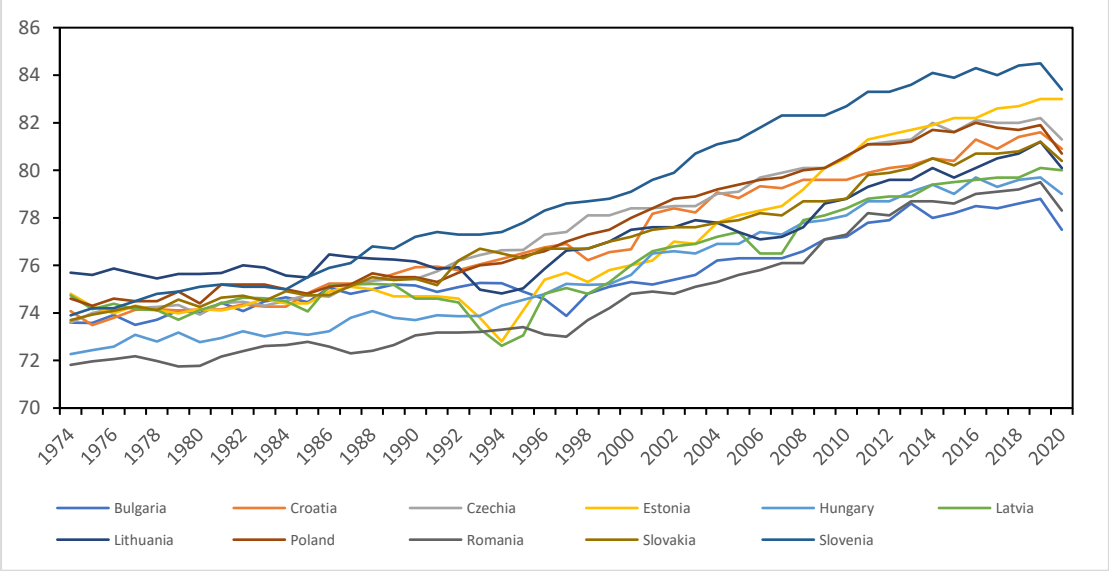
Mortality (life expectancy)

Figure 5: Male life expectancy at birth, 1974-2020



Source: WDI

Figure 6: Female life expectancy, 1974-2020

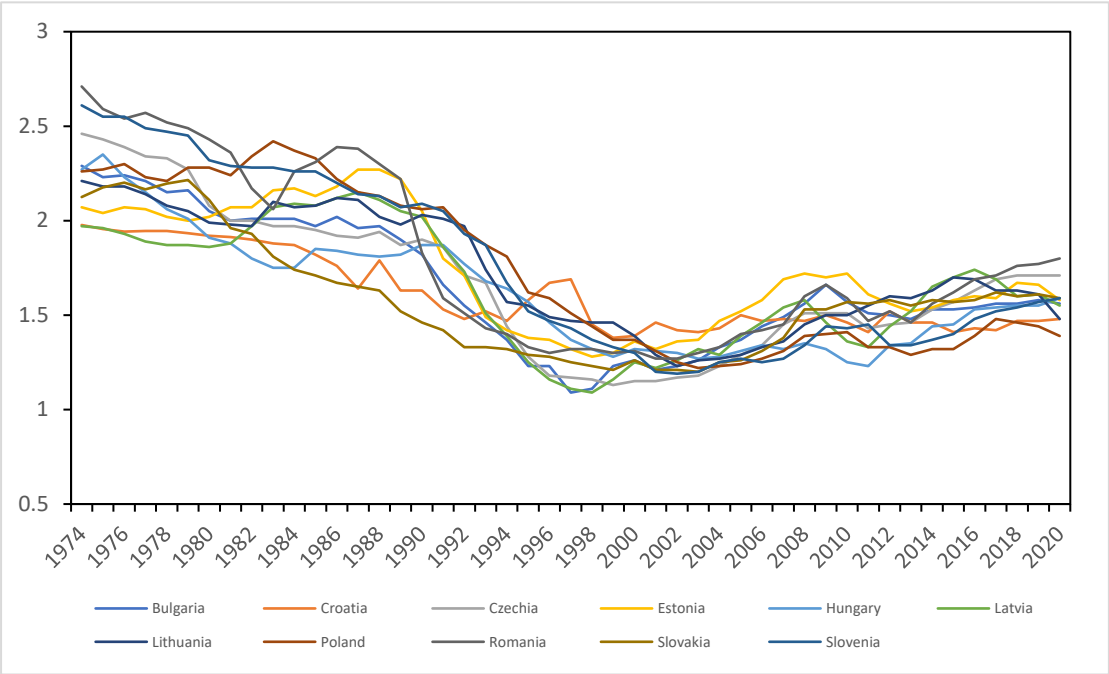


Source: WDI

The average life expectancy trends for males and females in the 11 CEE nations since 1974 are depicted in the two graphs (Figures 5 and 6) above. Examining the statistics reveals that despite some fluctuations in the final phases of the transition to communism, the average life expectancy for both males and females has consistently increased since 1974. In Bulgaria, the average life expectancy for men has risen from 68.93 years in 1974 to 74.7 years in 2019, while for women, it has climbed from 73.6 years to 78.8 years. The examined countries exhibit similar growth patterns, which can be attributed to advancements in healthcare, increasing living standards, and better social benefits. These factors have significantly improved overall quality of life (TH Tulchinsky, 2014). Nevertheless, the rise in life expectancy has concurrently resulted in a demographic transformation, specifically a surge in the elderly population, exacerbating ageing. Furthermore, the statistics show considerable gender differences. As an illustration, the life expectancy of women in Estonia has risen by 8.8 years, but that of men has only increased by 6.3 years. This suggests that, on average, women tend to have a greater life expectancy than men. This disparity not only underscores the contrasting health conditions between genders but also has implications for family dynamics, the job market, and the pension system. The extended lifespan of women necessitates modifications in the social and economic framework. To summarize, longer life expectancy is the primary cause of population ageing in CEE countries. In particular, the increased life expectancy of females may worsen gender disparities and socio-economic issues in the future.

Fertility

Figure 7: Total fertility rates, 1974-2020



Source: WDI

Figure 7 shows that the CEE region experienced a prolonged downward trend in the birth rate from 1974 until the beginning of the 21st century when it gradually began to stabilise. The birth rate in Latvia decreased from 2.71 in 1974 to 1.23 in 2002 but gradually recovered to approximately 1.6. Similarly, in the Czech Republic, the birth rate declined from 2.46 in 1974 to 1.13 in 2003, steadily rising to roughly 1.7. The substantial decrease in birth rates throughout the 1990s indicates that the reduction in birth rates has grown widespread throughout the region. Furthermore, this dramatic decline is also unprecedented in history (Andreas, 2008). The main reasons for this are the difficulties in the lives of the population caused by political and economic instability, which have led to delayed or reduced childbearing, as well as a significant weakening of government benefits and child-rearing support (Standing, 1996). And decreasing birth rates are a significant factor contributing to population ageing. When birth rates decline, the relative number of young people decreases, while the proportion of older people due to increased longevity increases. Over time, this shift in population composition results in heightened strain on the job market and a more substantial load on pension systems and social welfare.

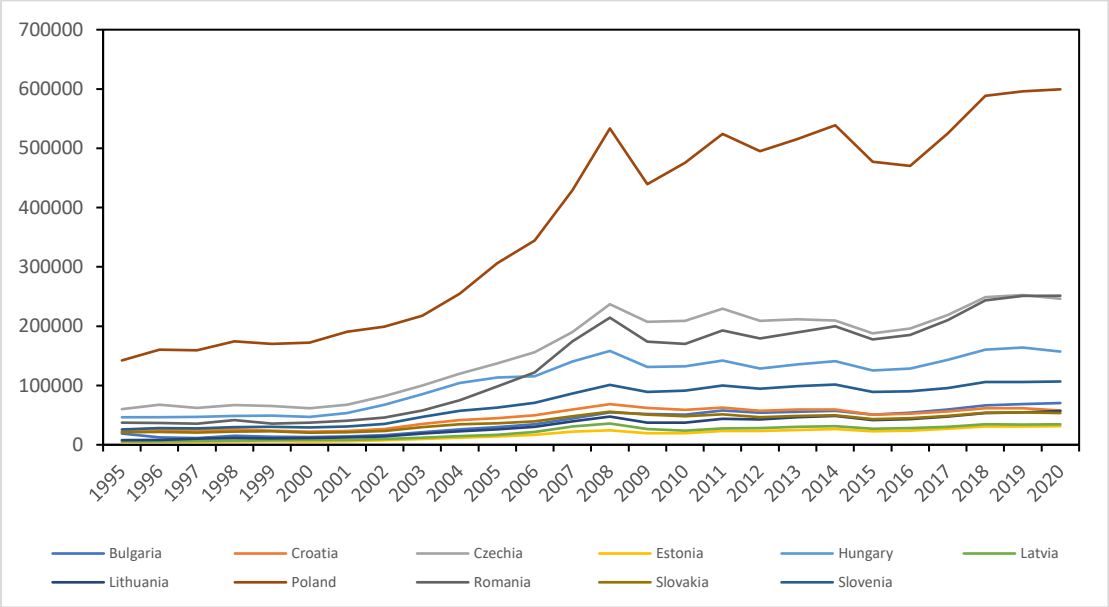
Migration

The migration process is becoming more widely acknowledged as a significant element that affects the ageing of a country's population, especially in the CEE region. Migration alters the population's size and impacts the age distribution, particularly when a significant percentage of individuals in their childbearing and working years relocate. Based on the Eurostat data from 2006, migration in CEE countries primarily occurs among individuals aged 25-39, considered the most industrious and efficient population segment. For example, since the collapse of the communist system, Lithuania and Poland have experienced a net outflow of population. This migration primarily consists of young adults, which has resulted in a shrinking labour market and a slowdown in natural population growth in these countries. Consequently, this has worsened the issue of population ageing. Furthermore, the return migration only partially alleviates the tendency to age. In Romania, about 45 per cent of migrants return in the short term. However, these individuals are typically older and no longer in their prime reproductive years. As a result, the act of returning does not substantially impact the increase in the number of young people or reverse the trend of population ageing. It suggests that CEE countries need long-term strategies that integrate migration dynamics and their impact on ageing to address the socio-economic challenges caused by population movements.

2.1.2 Economic development in CEE

The economic development history of the CEE region illuminates the opportunities and challenges faced by transition economies amid globalisation. As Kowalski (2021) points out, these nations have experienced profound structural economic changes and market liberalisation since transitioning from centrally planned economies in the early 1990s. Their successive accession to the European Union in 2004 and 2007 considerably accelerated their economic integration, leading to substantial capital flow and trade increases (European Economy, 2019).

Figure 8: Trends in GDP for 11 countries, 1995-2020

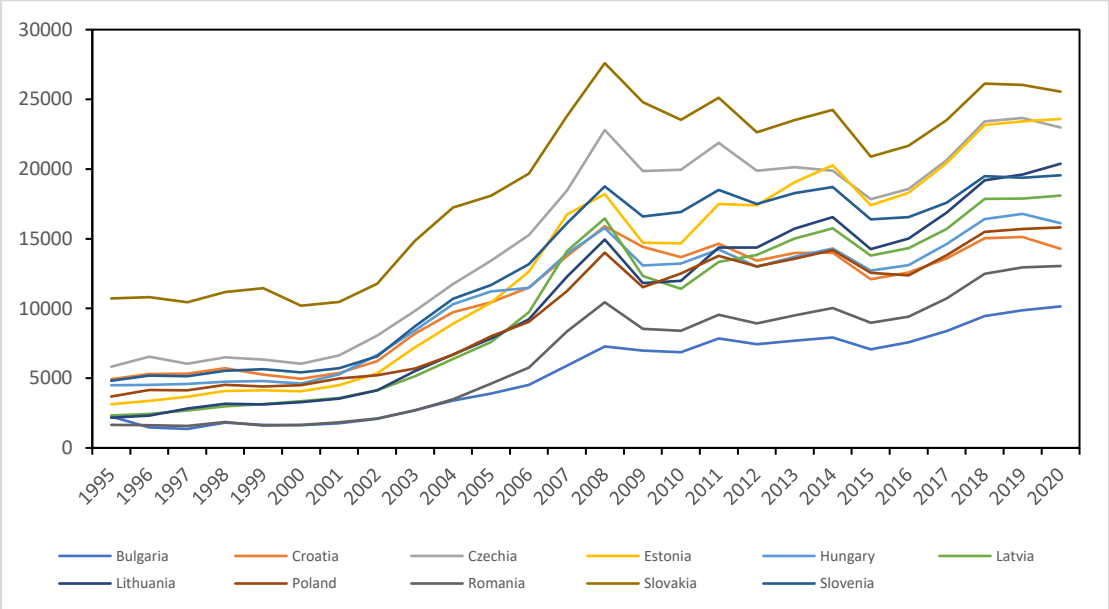


Source: WDI

The GDP development of the 11 CEE countries is shown in vivid detail in Figure 8 from 1995 to 2020. What can be noticed is that the CEE region has shown a more uniform growth profile, and the economic development over the last 25 years can be summarised in two phases: a period of rapid growth from 1995 to 2008 and a period of slow recovery and stable development after the financial crisis of 2008. Between 1995 and 2008, following the end of communism, the implementation of market economic reforms, and the new opportunities brought about by EU enlargement, CEE countries experienced robust economic growth (Dahlberg, 2015). During this period, Poland's GDP grew nearly fivefold, rising from $142,293 million in 1995 to $533,599 million, solidifying its position as the region's economic leader. Czechia also achieved substantial growth, with its GDP increasing approximately fourfold over the same period. However, the 2008 global financial crisis overshadowed the region's economic development, leading to stagnant GDP growth. Even in the later stages of the crisis and the subsequent years, CEE countries could not return to pre-crisis growth levels. In recent years, Poland's economy showed significant growth momentum, emerging as the standout performer among the 11 CEE countries with a GDP of approximately $599.442 billion in 2020. In contrast, Estonia, with a much smaller economy, had a

GDP of $31.37 billion, highlighting the stark economic disparity within the region compared to Poland.

Figure 9: Trends in GDP per capita for 11 countries, 1995-2020



Source: WDI

In terms of per capita GDP, the growth pattern in the CEE region mirrors that of total GDP. There was a rapid growth phase from 1995 to 2008, followed by a post-crisis recovery period from 2008 to 2020. Poland, consistently the leading economy in the region, has shown impressive growth in per capita GDP. However, the gap between Poland and other CEE countries has become less pronounced recently. Despite Poland's continued leadership, other countries are narrowing the distance in economic performance. Notably, Estonia has demonstrated remarkable progress, leveraging innovations in the digital economy and implementing open market policies. This strategic focus propelled Estonia's per capita GDP from $3,567 in the early years of the period to an impressive $23,595 by 2020. This growth underscores Estonia's successful economic transformation and highlights its promising future prospects. Conversely, Romania, despite its relatively high total economic output, has struggled with lower per capita GDP. In 2020, Romania's per capita GDP was recorded at only $12,307, positioning it second to last among the 11 CEE countries. This disparity indicates that

while Romania has achieved significant overall economic output, its per capita performance could be more robust, reflecting challenges in achieving equitable economic growth and improving individual income levels across the country.

2.2 Theoretical basis: neoclassical economic growth theory

The introduction of the Harrod-Domar model marked the establishment of classical economic growth theory, proposed independently by Harrod and Domar. This model attempts to build a long-term macroeconomic framework to analyze the impact of the capital-output ratio on economic growth. It argues that sustained economic growth relies on the savings rate and the capital-output ratio. According to the Harrod-Domar model, an increase in a country's savings rate leads to an increase in national income, thereby achieving balanced economic growth. However, if a country's capital-output ratio increases, its national economic growth will decrease. The theory further posits that to promote sustained and stable economic growth, the actual growth rate, the warranted growth rate, and the natural growth rate must all be equal. Since these three rates are independently determined and influenced by different factors, achieving this balance is extremely difficult.

In 1956, Solow modified the Harrod-Domar model, leading to the development of Solow model. This model provides valuable insights into the effects of fixed capital growth on GDP. It posits that capital and labor are perfectly substitutable and that production technology improves with the expansion of the labor force. When combined with the production function, the capital economy is determined by the interplay between physical capital (K), labor size (L), and labor efficiency. Solow model emphasizes resource scarcity and argues that growth solely based on physical capital accumulation has limits. Under unchanged technological and population conditions, the economy will soon reach zero growth.

2.3 Theoretical model construction

As previously mentioned, the neoclassical economic growth theory's Solow model attributes economic growth to capital, labour force participation, and technological progress. However, it does not distinguish between the variables of the labour force and the overall population, nor does it consider the influence of age structure on economic growth. Thus, this research incorporates population ageing into the Solow model for theoretical analysis.

Specifically, this study introduces the factor of population aging based on the Cobb-Douglas (C-D function) production function. The original basic expression of the C-D production function is:

$$Y = AK^{\alpha}L^{\beta}$$

Where Y stands for output, K for capital, L for labour, and A for total factor productivity, and the parameters α and β represent capital and labour elasticities respectively.

The Solow economic growth model builds upon the C-D production function by introducing the variable of technological progress. This paper further incorporates the factors of population aging and human capital into the basic Solow model. Firstly, the total population is denoted as N, the proportion of the population aged 0-14 years to the total population is P_{young}, and the proportion of the elderly population aged 65 years and above is P_{old}. Since the child population has not yet entered the labour market and the elderly population has already exited it, both groups are referred to as the non-working population. The 15-64 age group is called the working population, so the proportion of the working population to the total population is (1-P_{young}-P_{old}). Assuming a labour participation rate of μ, the population actively participating in economic activities is expressed as $\mu(1 - P_{young} - P_{old})$N. Thus, the impact of population ageing on the economy is realized by changing the population structure. In addition, the traditional Solow model does not distinguish between types of capital, so we incorporate the stock of human capital(H) into the model to comprehensively explore its economic impact. The final expanded Solow economic growth model expression is:

$$Y = AK^{\alpha}H^{\gamma}[\mu(1 - P_{old} - P_{young})\mathrm{N}]^{\beta}$$

In this equation, γ represents the elasticity coefficient of human capital investment. Under the assumption of constant returns to scale, $\alpha > 0$, $\beta > 0$, $\gamma > 0$, and $\alpha + \beta + \gamma = 1$. Let per capita physical capital be $k = K/\mu(1 - P_{old} - P_{young})$ N, and per capita human capital be $h = H/\mu(1 - P_{old} - P_{young})$N. Thus, it can have:

$$y = \frac{Y}{N} = Ak^{\alpha}h^{\gamma}\mu(1 - P_{old} - P_{young})$$

Y represents per capita GDP. From the derived formula above, it can be observed that an increase in population ageing reduces the proportion of the working-age population within the total population, thereby decreasing per capita output. Taking the derivative of per capita output with respect to population ageing:

$$\frac{\partial y}{\partial P_{old}} = -Ak^{\alpha}h^{\gamma}\mu < 0$$

Therefore, population ageing negatively impacts economic growth. Based on this, the first hypothesis is proposed:

H1: An increase in population ageing will negatively affect economic growth in the CEE region.

Subsequently, let $K(t)$ and $N(t)$ denote the functions of capital and total population with respect to time t, respectively, abbreviated as:

$$K^{*} = \frac{dK(t)}{dt}, N^{*} = \frac{dN(t)}{dt}$$

During period t, global population growth can appear to follow an exponential pattern (i.e., $N(t) = e^{nt+c}$, where c is a constant and n is the growth rate of the population), thus giving us $N^{*} = nN$. Additionally, let s represent the savings rate, and ρ represent the capital depreciation rate. According to the Solow growth theory, the change in capital stock is $K^{*} = sY - \rho K$. Let Y_{old} denote the expenditure required for elderly care, and Y_{young} denote the expenditure required for the 0-14 age group. $Y - Y_{old} - Y_{young}$ refers to the economic expenditure on the working-age population. The coefficient of the level of old-age dependency and the coefficient of the level of child dependency can be denoted, respectively, as:

$$\theta_{old} = (Y_{old}/P_{old}N)/(Y/N)$$

$$\theta_{young} = (Y_{young}/P_{young}N)/(Y/N)$$

Assuming that the non-working population does not engage in saving behaviour, the savings rate for the 15-64 age group is s_l. Thus, the total social savings amount is $s_l(Y - Y_{old} - Y_{young}) = sY$. Given that $Y_{old} = Y\theta_{old}P_{old}$ and $Y_{young} = Y\theta_{young}P_{young}$, substituting these values yields is $s_l(1 - \theta_{old}P_{old} - \theta_{young}P_{young}) = s$. It is easy to see that when s_l remains constant, the elderly population coefficient P_{old} is inversely proportional to the total social savings rate. As the degree of ageing deepens, the portion of economic output used for investment will decrease, further negatively impacting economic development.

After recalculating the above formulas, it can obtain the formula:

$$k^* = \frac{sy}{\mu(1 - P_{old} - P_{young})} - (n + \rho)k$$

When the economy achieves balanced growth, the per capita effective capital, $k^* = 0$. As a result, it can acquire:

$$k = (\frac{sAh^{\gamma}}{n + \rho})^{\frac{1}{\beta+\gamma}}, y = A^{\frac{1}{\beta+\gamma}}h^{\frac{\gamma}{\beta+\gamma}}\mu(1 - P_{old} - P_{young})(\frac{\mathrm{s}}{\mathrm{n} + \rho})^{\frac{\alpha}{\beta+\gamma}}$$

Based on the above equation, it can be found that the savings rate and capital per capita are positively correlated when the economy reaches a state of equilibrium growth, and the effect of population ageing on output per capita is negatively correlated. In summary, output per capita is affected by the level of technology, human capital, the labour force participation rate, the savings rate, the population growth rate and the level of population ageing.

2.4 Mechanism analysis

The influence of population ageing on economic growth is extensive and intricate. Therefore, understanding the mechanisms by which population ageing affects economic growth has become crucial. Population ageing affects the functioning of the labour market and the social security system and has a multifaceted impact on economic

growth, investment, consumption patterns and government finance. In this section of this paper, the impact mechanisms will be disentangled and analysed through both the supply and demand sides.

The impact of population ageing on economic growth through aggregate demand is manifested in the combined effects of consumption and savings. Modigliani (1954), illustrated by the Life Cycle Hypothesis, indicates that the relationship between age and savings suggests that young individuals in the labour force, owing to relatively stable income sources, tend to have income exceeding expenditure and are more likely to engage in substantial savings. Conversely, elderly individuals in non-labour force status, due to income instability or absence, typically incur expenses surpassing their income, hence leading to a decrease in savings. As a result, the gradual rise in the percentage of older people in the population causes a decrease in the number of people who save money, leading to a reduction in savings. In addition to immediately slowing down economic development by reducing savings, the decrease in savings also affects investment, hence having negative consequences on the economy. Moreover, owing to the limited sources of income, the purchasing power of elderly individuals relatively diminishes compared to the younger population. As the ageing process advances, the impact on the total societal consumption expenditure continually amplifies, further affecting economic development.

Based on the above mechanism analysis, we can propose the second hypothesis:
H2: Population ageing can dampen economic growth by lowering the savings rate

There are three ways in which the aging population affects factor supply-driven economic growth. According to neoclassical growth theory, when underlying economic and social institutions are relatively stable, economic growth in a phase is primarily influenced by factors such as population, capital, and technological progress. Firstly, the essence of population ageing lies in the transformation of the population age structure, notably characterized by the increase in the elderly population leading to a

reduction in the working-age population, thus resulting in a diminished overall labour force size and lower labour force participation rates. Consequently, this reduction in labour input elements during production adversely affects economic growth. Furthermore, when labour demand remains the same, a situation arises where the number of new entrants into the labour market is less than those exiting, leading to a labour shortage. This phenomenon implies an increase in labour costs and elevation in wage levels, ultimately contributing to the escalation of labour costs and thereby impacting economic growth. Secondly, population ageing also exerts a particular influence on capital stock. When a country or region's labour force size expands, investment is needed to increase to maintain a stable level of per capita capital stock. Thus, against the backdrop of ageing, the decline in the proportion of the labour force will lead to a decrease in the population's capital stock. Simultaneously, this will also influence the direction of investment in physical capital, consequently exerting adverse effects on economic growth (Su, 2021). Lastly, population ageing will also hinder technological progress, ultimately affecting economic development. As previously mentioned, the ageing process gradually leads to a decline in the growth rate of technological advancement, attributed to insufficient innovation among the elderly and the temporality of technological returns. Moreover, the necessity for governments to increase investments in social security for the elderly population will, to some extent, affect government spending on education for the younger population. Additionally, the declining birth rates lead to a gradual decrease in the proportion of young people, thereby negatively impacting the population base for innovation. These factors collectively contribute to the stagnation of technological progress, ultimately affecting economic development.

Based on the above mechanism analysis, we can propose these hypotheses:

H3: Population ageing dampen economic growth by reducing the labour force

H4: Population ageing dampen economic growth by reducing the volume of capital

H5: Population ageing dampen economic growth by impeding technological progress

Chapter 3: Methodology

In the analysis of specific methods, this paper employs mediation effect analysis. The current literature focuses on two analytical methods regarding the specific usage models of mediation effects. The first is the three-step regression method, which is widely adopted following the approach provided by Wen Zhonglin (2004). Firstly, a regression is conducted between the explanatory variable X and the dependent variable Y to calculate the impact of X on Y. Subsequently, a regression analysis is performed between X and the mediator variable M to assess the effect of X on M. Finally, controlling for M, a regression analysis is conducted on X and M to evaluate the effect of X on Y while accounting for the mediator's influence, as well as the effect of M on Y.

Despite its widespread use, the three-step method has notable limitations. One significant issue is the potential for endogeneity problems. When introducing the mediator variable M in the final step, it may be affected by unobserved variables or error terms, which can introduce endogeneity bias. This bias arises when the mediator variable M is influenced by variables not included in the model or measurement errors, leading to inaccurate estimation of the mediation effect. Additionally, reverse causality can complicate matters. In this context, reverse causality implies that the dependent variable Y could, in turn, influence the mediator variable M, creating a bidirectional relationship that muddles the causal inference and distorts the estimation of mediation effects. The simultaneous inclusion of X and M in regression analysis might also lead to multicollinearity issues, where X and M are highly correlated. Multicollinearity can inflate the standard errors of regression coefficients and reduce the statistical power of significance tests, ultimately affecting the precision and reliability of the results.

Therefore, this paper adopts the mechanism test method based on Jiang Ting (2022). After examining the relationships between X and Y and between X and M, Jiang Ting's method uses a literature review or relevant theories to confirm the relationship between

M and Y, thus indirectly proving the existence of the mediation effect. This two-step method avoids directly controlling for X and M in the model, reducing the likelihood of endogeneity bias and the impact of reverse causality on the model. Omitted variables often cause endogeneity issues, reverse causality, and measurement errors. By not directly regressing M on Y, these issues' cumulative effects on the model can be avoided.

Another significant advantage of the two-step method is that it reduces multicollinearity problems to a certain extent. By dividing the analysis into two independent steps, the collinearity impact between X and M can be effectively reduced, ensuring the stability and accuracy of the regression coefficients. Additionally, the flexibility of the two-step method makes it easier for researchers to handle complex data structures and variable relationships in practical applications.

Furthermore, the two-step method facilitates the introduction of instrumental variables. If an instrumental variable Z can be identified as related to X but not to the error term of Y, Z can be used as an instrumental variable in the first and second regression steps, thereby reducing the impact of endogeneity bias. The instrumental variable method is an effective solution to endogeneity problems. By introducing a variable related to the endogenous variable but not related to the dependent variable's error term, it can effectively isolate the actual effect of the endogenous variable, enhancing the reliability of the estimation results.

In conclusion, this paper opts for the mechanism test two-step method proposed by Jiang Ting (2022) in analysing mediation effects. This method not only provides high explanatory power theoretically but also demonstrates strong applicability in practical applications, offering a reliable approach for mediation effect analysis.

3.1 Model setting

Based on the above theoretical analysis and the literature review, the basic model of this paper is constructed based on the relevant model of Yue Liu and Liming Chen to analyse the relationship between population ageing and economic growth empirically.

$$pcgdp_{it} = a_0 + a_1 age_{it} + a_2 cv_{it} + u_i + \varepsilon_{it}$$

where i represents the country; t represents the year; the explanatory variable pcgdp represents the level of economic growth; the explanatory variable age is for the aging population; cv refers to a series of control variables, including government intervention gov, the level of financial development fin, the level of private payment expenditures per, and the level of openness to the outside world open; u_i is the intercept term representing the heterogeneity of the individuals; and ε_{it} is the random error term.

3.2 Data

Dependent Variable

Economic growth (pcgdp) is measured using per capita GDP. Various indicators can be used to measure economic growth, including GDP, per capita GDP, and GDP growth rate. Among these, per capita GDP is a more effective tool for reflecting the overall macroeconomic performance of a country or region. In international comparisons, per capita GDP is more commonly used to measure the economic development levels of different countries. This allows for an objective comparison of scientific development across countries or regions. Therefore, this paper analyses economic growth using the per capita GDP of 11 CEE countries from 1995 to 2020.

Independent Variable

Population ageing (age) is measured by the proportion of the population aged 65 and above. According to the United Nations' definition, a country is considered to have entered an ageing society when the proportion of its population aged 65 and above exceeds 7%. Therefore, analyzing the proportion of the population aged 65 and above from 1995 to 2020 can effectively reflect the extent to which a country has become an ageing society.

Control Variable

Government intervention(gov) is measured by the proportion of government expenditure to GDP. Government expenditure is a crucial component of a country's economic activities. The government can help maintain the smooth operation of market economic activities through reasonable and appropriate fiscal interventions. Therefore, including gov as a measure allows for assessing its impact on economic growth.

Financial development(fin) is measured by the relative rankings of countries in terms of the depth, access, and efficiency of their financial institutions and markets. Financial development can influence various aspects such as resource allocation, corporate behaviour, income distribution, macroeconomic stability, and international competitiveness. It is a multidimensional and comprehensive economic factor. Using it as a control variable helps to more accurately understand the drivers and mechanisms of economic development, thereby enhancing the reliability of the research findings.

The degree of openness(open) is measured by the ratio of total imports and exports to GDP. International trade is an indispensable part of the modern economy. Positive international trade can facilitate introducing and transferring technology, thereby promoting economic development. Moreover, openness to international markets increases the level of market competition. Under the pressure of international competition, companies may be compelled to improve efficiency, enhance product quality, and continuously innovate, contributing to economic growth.

The Table 1 below reflects the dependent, independent, and control variables mentioned earlier in the text and the data sources.

Table 1: Summary of the data

Variables	Variable name	Measurement	Data Source
pcgdp	Economic growth	GDP per capita	WDI

age	Population aging level	The proportion of the elderly aged 65 and above in the total population	WDI
gov	Government intervention	Total general government expenditure	Eurostat
fin	Financial development level	a relative ranking of countries on the depth, access, and efficiency of their financial institutions and financial markets	IMF
open	Level of openness	Total exports and imports as a percentage of GDP	WDI

This study specifically examines eleven nations in CEE: Bulgaria, Croatia, the Czech Republic, Hungary, Poland, Romania, Slovakia, Slovenia, Estonia, Latvia, and Lithuania. Various crucial considerations determine the choice of these countries. Firstly, all these nations are part of the CEE region and joined the European Union after 2004. This commonality means they share significant similarities in economic policies and regulations, which enhances the consistency of the study. Secondly, these countries experienced a transition from socialism to capitalism in the early 1990s, leading to substantial changes in their economic systems. This period of transformation provides a unique context for examining the impacts of economic reforms. Additionally, these countries entered an ageing society around 1990 and have since developed into nations facing significant ageing challenges. Studying the ageing populations in these countries can provide crucial data for exploring the relationship between economic development and demographic changes.

The study examines data from 1995 to 2020 to gain a comprehensive understanding of the long-term trends and changes in these eleven countries within the context of economic transition and population ageing. The selection of data from the period after 1995 is based on the fact that the information provided by the WDI, EUROSTAT, OECD, and IMF databases is more comprehensive and dependable starting from that year. In order to maintain the consistency and dependability of the analysis, the study

incorporates data up until 2020, therefore circumventing the possible swings and uncertainties brought about by the COVID-19 pandemic.

After completing the data collection and collation, the descriptive statistics of the main variables required for this paper are shown below.

Table 2: Descriptive statistics

variable	observation	mean	Sd	min	max
pcgdp	286	11,276	6,421	1,361	27,596
age	286	0.161	0.0264	0.108	0.223
gov	286	0.422	0.0584	0.318	0.603
fin	286	0.330	0.111	0.0955	0.571
open	286	1.116	0.340	0.437	1.898

Source: generated by author

Chapter 4: Econometric tests

4.1 Empirical results

Table 3: Regression results for population aging and gdp per capita of CEE

VARIABLES	(1) lnpcgdp	(2) lnpcgdp	(3) lnpcgdp	(4) lnpcgdp
age	-6.432***	-3.056***	-4.214***	-3.948***
	(-5.50)	(-2.74)	(-3.49)	(-3.57)
gov		3.370***	2.490***	1.899***
		(9.04)	(5.41)	(4.01)
fin			0.905***	1.059***
			(3.07)	(3.78)
open				0.526***
				(9.92)
Constant	2.119***	0.177	0.507*	0.279
	(9.24)	(0.65)	(1.71)	(1.00)
Observations	286	286	286	286
R-squared	0.694	0.755	0.767	0.807
F test	0	0	0	0
r2_a	0.663	0.729	0.741	0.786
F	19.96	28.88	30.76	38.57

Source: generated by author

The results of the baseline regression on the impact of population ageing on economic development are presented in the Table 3. We begin by analysing the explanatory variables, then add the three control variables of government intervention(gov), level of financial development(fin), and level of openness to the trade(open), and estimate the parameters obtained in the above steps. The advantage of this approach is that while testing that the explanatory variables are all robust, it is also possible to verify how these three control variables affect the explanatory variables. Based on the regression analysis carried out step by step, it can be seen that the first column obtained a significantly negative result when using population ageing in a separate regression on the level of GDP per capita. It indicates that in the context of ageing, it negatively impacts a country's economic development. Columns 2 to 5 of the table, which are obtained after the gradual addition of the three control variables mentioned above, show

that the sparse positive and negative signs and the significance of the explanatory variables do not change significantly, which suggests that the data on the selected explanatory and control variables are somewhat robust, thus concluding that population ageing has a specific inhibitory effect on the economic development of the CEE region. This finding is consistent with our hypothesis and suggests that ageing has become an essential constraint on economic growth in these countries.

Among the control variables, government intervention shows a positive and significant effect on GDP per capita, indicating that government intervention positively impacts economic development and can mitigate the adverse effects of population ageing to some extent. On the one hand, the government can directly stimulate economic growth through fiscal policy and public expenditure. On the other hand, it can also intervene to stabilise market expectations in times of economic crisis or market failure, thus maintaining the smooth operation of the economy. For CEE countries, particularly, macroeconomic policies played a crucial role in stabilising the economy and mitigating shocks in the face of imperfect market mechanisms and external economic fluctuations during the economic transition process at the end of the 20th century. In addition to this, after joining the EU, CEE countries have benefited from the EU's structural funds and regional development policies, and government interventions have been remarkably effective in promoting the coordinated development of regional economies and narrowing regional gaps. These funds and policy support have improved infrastructure conditions, enhanced local economies' competitiveness, and promoted balanced overall economic development.

The positive coefficient on the level of financial development also indicates that the development of the financial system in CEE countries has had an essential contribution to economic growth. On the one hand, the reform and development of the financial system in CEE countries during the transition process has significantly improved the efficiency of capital allocation. For example, the reforms of the banking sector and capital markets in Poland and the Czech Republic have enabled capital to flow more

efficiently to high-efficiency investment projects, thus contributing to increased productivity and overall economic growth. In addition, the diversification of financial institutions and the popularisation of financial services in these countries have enabled more enterprises, tiny and medium-sized enterprises (SMEs), to obtain the necessary financing support, contributing to the growth and development of enterprises and enhancing their innovative capacity. The opening up financial markets and attracting foreign investment has also brought a large amount of inward investment and advanced technology to CEE countries. Since joining the EU in 2004, these countries have benefited from more unrestricted capital flows and foreign direct investment, further promoting rapid economic development and optimisation of industrial structure. In the course of financial development, sound regulatory and risk management mechanisms have also enhanced the stability and risk resistance of the financial system, providing a guarantee for sustainable economic development. At the same time, the development of financial inclusion has made it possible for more low-income groups and marginalised areas to have access to financial services, enhancing society's overall economic vitality and income level. For example, Romania has expanded the coverage of its financial services through inclusive financial policies, enabling more farmers and small and micro enterprises to obtain loan support and promoting the development of the rural economy and income growth (World Bank).

Similarly, the level of openness has a significant positive effect on GDP per capita, suggesting that the expansion of the level of openness to the outside world will have a favourable impact on the economic development of the CEE region. After successive accession to the EU at the beginning of the 21st century, eleven CEE countries benefited from trade liberalisation policies within the EU, which reduced trade barriers and tariffs and enhanced the free flow of goods and services, thus increasing GDP per capita. In addition, accession to the EU has brought in more FDI, which provides much-needed capital and introduces advanced technology and management experience, enhancing the competitiveness and productivity of local enterprises. At the same time, regional cooperation and trade agreements have also brought new opportunities and

development for CEE countries to open up to the outside world, such as the "16+1 Cooperation" between CEE and China and the free trade agreements signed with other countries in the region, which not only expand the size of the market, but also increase trade and investment opportunities, and promote regional economic integration and synergistic development. These cooperation and agreements have expanded market size and increased trade and investment opportunities, promoting regional economic integration and synergistic development. According to the World Bank and the International Monetary Fund data, CEE countries have seen their economic growth speed up significantly after joining the European Union, and their per capita GDP continues to grow. This data shows that opening up to the outside world has not only brought about an increase in the total volume of the economy but also improved the living standards and welfare of the people. In summary, the increased level of openness in the CEE region has significantly impacted economic development by promoting trade, attracting investment, fostering economic reforms and strengthening regional cooperation.

4.2 Endogeneity Issues

By using OLS to study the impact of population ageing on economic development in the CEE region, this paper cannot avoid the issue of possible endogeneity between the variables, especially since the process of demographic transition is endogenous to economic development and has long been explicated by theories of demographic economics. In order to solve the problem of possible endogeneity in the model, the instrumental variables approach to endogeneity is a relatively effective method. Endogeneity may be due to different reasons. One is due to the process of population ageing will negatively affect the economic development of the next period or the following two periods, which will lead to the possibility of contemporaneous or inter-period effects between the variables, so the lagged one-period and lagged two-period of the core explanatory variables of population ageing are used as instrumental variables for the model test. The results are shown in columns (1) and (2) in Table 4.

Among them, the Weak identification test shows that the Cragg-Donald Wald F-value is greater than the Stock-Yogo's 10% level critical value, and the model passes the Weak identification test, the Underidentification test of Anderson canon. Corr. LM statistic rejects the original hypothesis at the 1% level. It satisfies the identifiability of the instrumental variables, and secondly, it is due to the possible bidirectional causality between population ageing and economic development. Therefore, the external instrumental variable life expectancy was chosen, which has a strong correlation with population ageing, and one of the primary reasons for the continued deepening of population ageing in the CEE region, as described in the previous section, is the increase in life expectancy. At the same time, there is almost no correlation between life expectancy and economic development, and the results are shown in columns (3) and (4) in Table 4. The Weak identification test and Underidentification test were also conducted for the same, and both confirmed the validity of the instrumental variables through the tests. According to the results shown in the table, both the lags of population ageing and the exogenous variable life expectancy as an instrumental variable show that the regression results are consistent with the baseline results, with no change in significance or direction, which leads to the conclusion that population ageing inhibits economic development in the CEE region.

Table 4: Regression Results of Instrumental Variables Endogeneity Test

VARIABLES	(1) firstage lag1 and lag2	(2) second lag1 and lag2	(3) firstage life	(4) second life
lag1	1.9914***			
	(8.35)			
lag2	-1.0332***			
	(-4.33)			
life			-0.0033***	
			(-4.86)	
age		-4.2007***		-54.3917***
		(-3.41)		(-4.92)
gov	-0.0045	1.8670***	-0.1183***	-4.5780***
	(-0.80)	(4.43)	(-6.00)	(-2.59)

fin	0.0033	1.0701***	0.0610***	3.1967***
	(1.11)	(4.88)	(5.37)	(4.31)
open	-0.0016*	0.5259***	0.0013	0.4445**
	(-1.75)	(7.79)	(0.38)	(2.43)
Constant	0.0079**	0.3241	0.4152***	9.2397***
	(2.11)	(1.14)	(8.34)	(4.56)
Anderson canon. corr. LM statistic	267.444***		24.121***	
Cragg-Donald Wald F statistic	1837.644***		23.579***	
	(19.93)		(16.38)	
Observations	286	286	286	286
R-squared		0.807		-0.402

Source: generated by author

4.3 Robustness Test

In addition to the endogeneity test, the robustness test can help this paper obtain more reliable regression results. Therefore, this paper will test whether the previous regression results are different due to how the core variables are constructed by replacing the core explanatory variables. As mentioned in the previous section, population ageing will be measured by the proportion of the population over 65 years old or the old age dependency ratio. Therefore, this paper replaces the population ageing indicator with the old-age dependency ratio, which is the proportion of the population over 65 divided by the working-age population aged 15-64 and re-runs the regression analysis. Through this robustness test of replacing the core explanatory variables, this paper hopes to confirm the regression results' robustness and consistency and ensure that the conclusions obtained have a high degree of credibility and generalisability. The final regression results obtained are shown in Table 5, further validating this paper's hypothesis that population ageing significantly impacts economic growth in the CEE region.

In terms of the core explanatory variables replaced, the old-age dependency ratio has a significant negative effect on economic growth, which is broadly consistent with the

results of the baseline regression when the share of the elderly population is utilised as an explanatory variable, suggesting that the impact of population ageing on economic growth in the Eastern European region in the previous section is significant and robust. Specifically, increasing population ageing leads to increasing old-age dependency ratios, which increases the economic burden and reduces the resources available for productive investment and innovation. Further analysis shows that an increase in the proportion of older persons leads directly to a relative decline in the working-age population and indirectly affects labour productivity and economic dynamism. As more resources are channelled towards the health and well-being of the older population, the structure of public expenditures also changes, weakening the potential for economic growth. In addition, ageing may also lead to a decline in the savings rate and changes in consumption patterns, thereby affecting capital accumulation and economic stability, as Leff's (1969) study confirmed. In terms of other control variables, the direction of the effects of government expenditure, the level of financial development, and the level of openness to the outside world are consistent with the previous section and remain significant, which suggests that the results of the previous benchmark regression are robust. These results collectively show that population ageing negatively impacts economic growth, and this effect remains consistent across different measurement methods, further validating the hypothesis of this paper.

Table 5: Regression Results of Robustness Test

VARIABLES	(1) lnpcgdp	(2) lnpcgdp	(3) lnpcgdp	(4) lnpcgdp
dep	-3.959***	-1.888***	-2.391***	-2.176***
	(-5.89)	(-2.94)	(-3.46)	(-3.44)
gov		3.335***	2.516***	1.940***
		(8.93)	(5.45)	(4.12)
fin			0.860***	1.013***
			(2.94)	(3.63)
open				0.524***
				(9.90)
Constant	8.959***	7.070***	7.330***	7.091***
	(41.89)	(27.16)	(26.05)	(26.82)

Observations	286	286	286	286
R-squared	0.696	0.755	0.766	0.807
F test	0	0	0	0
r2_a	0.666	0.730	0.741	0.785
F	20.80	29.46	31.15	39.07

Source: generated by author

4.4 Heterogeneity Analysis

In the overall study of CEE, there is no doubt that population ageing negatively and significantly impacts economic growth. However, the heterogeneity of the CEE region is necessary because of the differences in ageing in different countries and because the level of economic development varies from one region to another. Due to the unique historical background and economic and political development of the CEE region, which make a simple geographical division an inaccurate reflection of the complex relationship between ageing and economic development across countries. Therefore, this paper opts for a heterogeneous division of countries according to whether or not they had a population ageing ratio of 13 per cent in 1995. Bulgaria, Croatia, the Czech Republic, Estonia, Hungary, and Latvia, which had a proportion of their populations over 65 years of age of more than 13 per cent in 1995, are classified as Group1, and the sample results are shown in columns (1) and (2) of the Table 6. The other countries are grouped into Group 2; the sample results are shown in columns (3) and (4).

Based on the results for each sample in Table 6, there is no significant difference in the dampening effect of population ageing on economic development in CEE, either in regions with relatively high or relatively low levels of ageing. This result may be due to the fact that the CEE countries have adopted similar policies and measures in dealing with ageing, such as raising the retirement age and increasing investment in healthcare and social security for older people. In addition, these countries face similar economic transition and structural adjustment challenges, such as the transition from a planned to a market economy, which makes the pattern of the impact of ageing on economic

development somewhat joint across countries. Cultural and social factors, such as family structure and traditional attitudes, may also have played an essential role in mitigating the negative impact of ageing on the economy, making differences across countries in this respect insignificant. As a result, the negative impact of population ageing on economic growth in the CEE region, as verified in this paper, is universal and standard.

Table 6: Regression Results of Heterogeneity Analysis

VARIABLES	(1) Group1	(2) Group1	(1) Group2	(2) Group2
age	-26.209***	-26.440***	-13.720***	-15.692***
	(-10.73)	(-9.37)	(-7.73)	(-5.90)
gov		2.587***		-0.670
		(6.52)		(-0.58)
fin		-1.351***		0.701**
		(-5.40)		(2.01)
open		-0.132		-0.370***
		(-1.47)		(-3.34)
Constant	4.930***	4.218***	2.960***	3.608***
	(12.94)	(7.07)	(11.12)	(4.90)
Observations	156	156	130	130
R-squared	0.853	0.888	0.754	0.801
F test	0	0	0	0
r2_a	0.823	0.863	0.693	0.743
F	25.75	47.63	10.12	13.47

Source: generated by author

Chapter 5: Mechanism test

This section delves into the mechanisms through which population ageing hinders economic growth in the CEE region, focusing on four key dimensions: savings rate, labour force, capital stock, and technological progress. According to Jiang Ting's (2022) mechanism test, after verifying that these mechanism variables influence economic development, variables related to the savings rate, labour force, capital volume, and technological progress are incorporated into the original model as explanatory variables. The resulting regression analyses can then be used to determine whether these factors serve as the mechanisms through which population ageing impacts economic growth. This approach allows for a detailed examination of how each variable contributes to the overall economic effects of an ageing population, providing valuable insights for policymakers and researchers.

5.1 Savings rate

From the supply side, the continued development of population ageing will notably affect savings rates. As population ageing increases, the proportion of older people in the CEE region is rising, leading to changes in the savings behaviour of society as a whole. Firstly, older people typically save less and begin to use their retirement savings and pensions for consumption, which may lead to a decline in society's overall savings rate. As more of the population enters retirement, the overall savings capacity of society weakens, thus exerting some pressure on economic development. In addition, population ageing has important implications for household savings rates. CEE countries have experienced a rapid ageing process over the past decades, and social security systems have come under significant financial pressure, resulting in households needing to save more to cope with future uncertainty. As governments may not fully cover the old-age and healthcare needs of older people, households often need to make up for potential shortfalls by increasing their savings. The younger generation, while facing the challenge of supporting the elderly, also needs to save for future living and health needs, which further squeezes the disposable income and spending power of

households. Increased ageing complicates savings behaviour for the CEE region, which is transitioning from traditional manufacturing to knowledge-intensive industries.

As a critical variable in the constant national income equation, the saving rate has an undisputed impact on economic development. As early as 1956, Solow emphasised the importance of savings to economic growth by stating that a higher savings rate promotes more investment, improving productivity and boosting economic growth.McKinnon (1973) further reinforced this view by arguing that savings are crucial to a country's economic development because they increase the funds available for investment, thereby accelerating the process of economic growth. Anoruo and Ahmad (2001) explored the causal relationship between economic growth and the rate of growth of domestic savings through the use of cointegration and Vector Error Correction Models, and the findings suggest that there is a long-run positive correlation between the rate of growth of the economy and the rate of growth of savings. Although there are fewer studies on savings and economic growth in the extraordinary region of CEE, empirical studies by some scholars still confirm the close relationship between the two. For example, Ioan (2020), through his study of CEE countries, finds that transition economies must combine vital savings and stable capital formation to achieve higher economic growth by attracting FDI. His study shows that savings are not only an essential source of domestic investment but also the basis for attracting FDI, which plays a crucial role in these countries' economic transformation and growth.

After establishing that the savings rate impacts economic growth, we replace the original explanatory variable with the savings rate for further analysis. Table 5 presents the OLS results of the effect of population ageing on the savings rate. The analysis indicates that a rise in the proportion of elderly individuals in the population has a substantial adverse effect on the savings rate. Specifically, a higher proportion of older adults leads to a decline in the savings rate, likely due to increased consumption and reduced savings by seniors. This result validates Hypothesis 2.

In terms of the control variables, the results indicate that government intervention has a significant negative impact on the savings rate. It suggests increased government intervention is associated with lower savings rates because public sector expansion displaces private savings opportunities. On the other hand, financial development significantly impacts the savings rate, implying that more developed financial systems encourage higher savings rates, likely because they offer more opportunities and incentives for saving. Additionally, trade openness is positively correlated with the savings rate. This result indicates that more open economies tend to have higher savings rates, potentially due to the more excellent economic opportunities and income growth brought about by trade.

Table 7: Mechanism test: Regression results for population ageing and savings rate

	(1)	(2)
VARIABLES	sav	sav
age	-0.695***	-0.807***
	(-4.77)	(-5.77)
gov		-0.213***
		(-3.92)
fin		0.256***
		(9.88)
open		0.104***
		(13.38)
Constant	0.288***	0.254***
	(10.85)	(7.15)
Observations	286	286
R-squared	0.196	0.559
F test	2.69e-05	0
r2_a	0.115	0.509
F	2.740	14.72

Source: generated by author

5.2 Labour force

As mentioned earlier, the continuing demographic ageing of the population will directly affect changes in the supply and structure of the labour force. For the CEE region, this effect is particularly significant. As the population ages, the proportion of people of working age continues to decline, leading to a shortage of labour market supply. In addition, changes in labour force participation rates in ageing societies are also of great concern. As the elderly population increases, more and more people are withdrawing from the labour market and entering retirement, further reducing the available labour resources. This situation is particularly the case in the countries of CEE, which have experienced a remarkable demographic transition over the past decades, with faster ageing and more tremendous pressure on social security systems. In addition, ageing may also contribute to skills and experience gaps in the labour market. Younger generations of workers need more time and training to take over the experience and skills accumulated by older generations, and this intergenerational transmission gap may lead to lower productivity and lagging technological innovation. This issue is particularly pressing for the CEE region, where the structure of the economies is shifting from traditional manufacturing to knowledge-intensive industries and where there is an apparent demand for highly skilled labour.

The contribution of the labour force to economic growth is readily seen. Numerous studies have consistently shown that the workforce's composition substantially influences the overall economy. For example, Beaudry and Collard (2003), using data from several countries over different periods, show that the growth of the labour force population between 1960 and 1974 contributed to the increase in labour productivity. Bloom and Williamson (1998) also confirm that, in the European economic growth between 1965 and 1990, the core labour force population explained nearly 20% of the economic growth. The findings of Guest (2005) suggest that the distributional effect of the age of the labour force is crucial for economic growth. On the other hand, many scholars have also confirmed that the labour force participation rate affects economic development to a certain extent. Duval et al. (2010) point out that a complete and efficient labour force can promote economic development. For developing economies,

Blomstrom, Lipsey and Zejan (1992) argued that labour force participation and education have a meaningful impact on the growth rate of low-income developing countries. Shahid (2014) studied Pakistan, and Yakubu, Akanegbu, and Jelilov (2020) studied Nigeria; their studies show that labour force participation has a negative but significant impact on economic growth in both the short and long run. Regarding studies on CEE, Prochniak (2011) analysed economic growth from 1993 to 2009, identifying more than a dozen of the most important factors of economic growth in these economies, including demographics as measured by the share of the working-age population. Together, these studies show that the labour force's quantity, quality and participation rate are all key factors influencing economic growth.

Therefore, according to Jiang Ting's (2022) mechanism test method, if population ageing in CEE suppresses the expansion of the labour force or the increase in labour force participation rate, it indirectly indicates that the labour force is a crucial mechanism affecting economic development in this region. The impact of population ageing on the labour force is shown in the Table 6. When the dependent variable is the labour force participation rate (lpr), population ageing is significantly negative at the 1% level. This indicates that as population ageing intensifies, the labour force participation rate significantly declines, highlighting the negative impact of population ageing on the labour market. When the dependent variable is replaced by the proportion of the working-age population (pwp), this conclusion remains unchanged, thus validating Hypothesis 3.

Regarding the control variables, government intervention significantly negatively impacts labour force participation, indicating that increased government intervention may be associated with lower labour force participation rates. This could be due to the expansion of the public sector, which is crowding out employment opportunities in the private sector. The impact of financial development on labour force participation could be clearer-cut, as a well-developed financial system typically promotes economic growth. However, in certain circumstances, it may reduce overall labour force

participation by increasing the proportion of capital-intensive industries and reducing labour-intensive job opportunities. On the other hand, trade openness has a significantly positive effect on labour force participation, suggesting that more open economies generally create more employment opportunities, attracting more people into the labour market and thereby increasing labour force participation rates.

Table 8:Mechanism test: Regression results for population aging and labour force

	(1)	(2)	(3)	(4)
VARIABLES	lpr	lpr	pwp	pwp
age	-0.689***	-0.873***	-0.678***	-0.689***
	(-6.73)	(-8.47)	(-23.08)	(-21.65)
gov		-0.276***		-0.003
		(-7.00)		(-0.26)
fin		-0.093***		0.043***
		(-4.37)		(7.71)
open		0.037***		0.003**
		(6.47)		(2.00)
Constant	0.678***	0.818***	0.758***	0.748***
	(37.25)	(29.31)	(120.68)	(93.89)
Observations	286	286	286	286
R-squared	0.159	0.493	0.785	0.836
F test	0.000119	0	0	0
r2_a	0.0743	0.436	0.764	0.817
F	2.522	17.09	59.16	71.76

5.3 Capital Volume

The theoretical analysis in the previous section concludes that population ageing also affects economic progress by influencing the amount of capital. The amount of capital can be classified into physical and human capital based on its nature and how it contributes to the production process. Physical capital consists of tangible assets such as machinery, equipment, and buildings, which are the material basis of productive activities. As the population ages, the savings rate is likely to fall as more people begin to retire and consume their savings, which will lead to a slower accumulation rate of

physical capital, which will affect economic growth. Human capital, on the other hand, comprises intangible assets such as the skills, knowledge and experience of the labour force. Ageing reduces the total amount of human capital, as retirees take with them a wealth of experience and expertise. At the same time, younger workers need time to accumulate the appropriate skills and knowledge. This loss of human capital reduces productivity and hinders technological progress, thus negatively affecting economic growth.

Both physical and human capital are crucial to economic growth (John W Kendrick, 1994). Garzarelli and Limam (2019) conducted a regression analysis revealing that physical capital is the primary driver of economic growth in the Central Region, accounting for 80% of the growth. Similarly, Xu and Xie (2018) emphasized that physical capital remains crucial, contributing up to four-fifths of the economic growth. However, more scholars' related research is still placed on the synergistic study of human and physical capital. Fleisher et al.'s (1997) research shows that human capital and physical capital, if not adequately allocated, will hinder physical capital in the long run. Sun and Dong (2007) utilized econometric modeling to develop vector autoregressive, long-term, and short-term equilibrium models. The results show that human capital, physical capital and economic growth are in long-term equilibrium.

Compared to physical capital, most scholars focus on human capital and economic development research. Schultz formally pointed out the academic concept of human capital in 1961, which triggered a research boom in the field as he first argued for the role of human capital as a catalyst for national economic development by analysing the linkage between human capital and economic development. Mankiw (1992) et al. also pointed out that the capital workforce diminishes the dominant role in continuous economic advancement and explains the dilemma of income differences between countries. Mehrara and Musai (2013) studied developing countries and found evidence of a long-term relationship between human capital and GDP. Bassanini and Scarpetta (2001) took 21 OECD countries and found that human capital accumulation

significantly positively affects per capita output growth. Kıvanç Halil ARIÇ (2022) et al. confirmed that the quality of maths and science schools has a positive impact on economic growth in CEE countries by examining the impact of human capital factors on economic growth in European countries over the period 2008-2017.

Therefore, numerous related studies by many scholars can help this paper determine that physical and human capital have a specific impact on economic development. To further analyse their specific roles, this paper replaces per capita GDP with physical and human capital as the dependent variables for regression analysis. The results are as follows. When the dependent variable is physical capital, the analysis shows that the degree of population ageing has an insignificant effect on physical capital. This result indicates that increasing ageing has not significantly hindered the accumulation of physical capital. This result might be due to the relatively stable investment and accumulation of physical capital in CEE, supported by other factors such as technological progress and external investment, despite the socio-economic pressures brought by population ageing.

When the dependent variable is replaced with human capital, the analysis reveals that ageing has a significant negative impact on human capital. It may be because, in an ageing society, the labour force participation rate decreases, and the transmission of skills and experience is impeded, thus affecting the accumulation and enhancement of human capital. Particularly in CEE, the issues of labour shortages and skill gaps due to ageing are prominent, further confirming the role of human capital as a critical mechanism in economic development. Thus, Hypothesis 4 is validated. However, it is essential to note that within the context of capital volume, human capital is the key mechanism through which population ageing affects economic development. In CEE, population ageing does not significantly impact overall economic development by hindering physical capital accumulation but primarily restricts economic growth by reducing the quality and quantity of human capital.

The absence of a substantial impact on human capital by government intervention in the control variables suggests that the role of government intervention in this domain may be restricted. Financial development has a substantial positive effect on human capital, indicating that an enhanced financial system can aid in the development of human capital. This is likely due to the fact that improved financial services and resource allocation contribute to the investment in education and training. Trade openness also has a substantial positive effect on human capital, suggesting that more open economies can improve human capital levels by facilitating international exchange and knowledge transfer.

Table 9: Mechanism test: Regression results for population aging and capital

	(1)	(2)	(3)	(4)
VARIABLES	pc	pc	hc	hc
age	-0.145	-0.179	-6.120***	-5.930***
	(-0.93)	(-1.30)	(-11.53)	(-14.14)
gov		-0.093		-0.220
		(-1.41)		(-1.30)
fin		0.006		0.642***
		(0.17)		(6.82)
open		0.036***		0.353***
		(4.41)		(12.39)
Constant	0.233***	0.249***	3.748***	3.388***
	(8.88)	(8.07)	(39.83)	(29.27)
Observations	286	286	286	286
R-squared	0.231	0.279	0.520	0.709
F test	2.40e-07	0	0	0
r2_a	0.154	0.198	0.471	0.676
F	3.408	4.375	12.67	45.70

Source: generated by author

5.4 Technology progress

In addition to these mechanisms, theoretical analyses suggest that population ageing also inhibits technological progress to some extent. As the proportion of older people

increases, the proportion of young, skilled workers in the labour market declines, and the incentives for innovation and technological development diminish. Ageing societies are frequently accompanied by increasing risk aversion, which may result in lower company and government investment in R&D and innovation projects, decreasing the pace of technological progress. In addition, ageing may lead to labour market rigidities, reducing the mobility and adaptability of the workforce, which can be detrimental to technological progress and the diffusion of new technologies. In the CEE region, many countries are experiencing this challenge. Hungary and Poland, for example, are facing severe population ageing. Hungary's population is ageing faster, with the working-age population declining yearly, which puts pressure on its labour supply for high-tech industries. Poland is also facing ageing and slowing technological progress. The country has been trying to address these challenges in recent years by attracting skilled foreign talent and increasing investment in education. In addition, while the Czech Republic has invested more in scientific and technological research and development, the increase in its ageing population has made the labour market less flexible, with a growing shortage of skilled workers. The Czech Government has been compelled to implement more reforms to its labour market regulations to incentivize more significant participation of older individuals in the workforce. Additionally, efforts are being made to improve vocational training and skill development to ensure the uninterrupted advancement of technology.

The relationship between technological progress and economic development has been a hotly debated topic among scholars. Howitt (1992) argued that technological progress will promote product quality improvement, and high-quality products will replace the original products, leading to continuous economic growth. This view is supported by many studies in which TFP can be used to indicate long-term technological change or dynamism in an economy (Ayres et al., 2002). Total factor productivity is often regarded as the proper driver of economic growth (Lee, 2019), as it reflects the contribution of technological progress and efficiency gains to economic output. In a related study for the CEE region, Pece (2015) and others confirmed the role of

innovation as a driver of the region's economic development by using a variety of relevant variables, such as the number of patents and R&D expenditures. These studies show that technological progress not only improves production efficiency but also enhances the competitiveness and development potential of the economy by introducing new products and technologies.

Based on the inherent connection between technological progress and economic development, the OLS results after replacing the dependent variable with TFP are shown in columns (1) and (2) of Table 8. When all control variables are included, population ageing is significantly negative at the 1% level, indicating that population ageing significantly inhibits technological progress. This result may be due to the severe ageing phenomenon in CEE, leading to a shortage of skilled workers and further limiting these countries' innovation capacity and productivity improvement. When the dependent variable is replaced with the annual number of resident patent applications (columns (3) and (4)), the results confirm that ageing not only hinders the improvement of TFP but also directly affects the level of innovation activity, negatively impacting technological progress. Therefore, Hypothesis 5 is validated.

Regarding the control variables, the impact of government intervention on technological progress is not statistically significant, suggesting that the role of government action in this area may be limited. In contrast, financial development has a significant and positive effect on both TFP and the number of resident patent applications. This indicates that a more developed financial system can promote technological advancement by providing better access to financial resources for research and development activities. Conversely, trade openness has a significant negative effect on technological progress. This implies that more open economies may face increased competition, which could potentially discourage domestic innovation efforts.

Table 10: Mechanism test: Regression results for population aging and technology progress

VARIABLES	(1) tfp	(2) tfp	(3) lnpat	(4) lnpat
age	-0.755*	-1.223***	-31.926***	-37.626***
	(-1.95)	(-3.13)	(-6.88)	(-16.25)
gov		-0.233*		0.018
		(-1.69)		(0.02)
fin		0.382***		5.291***
		(5.32)		(11.73)
open		-0.069***		-2.391***
		(-3.13)		(-11.91)
Constant	0.773***	0.903***	9.972***	11.364***
	(12.86)	(9.86)	(13.77)	(17.99)
Observations	286	286	286	286
R-squared	0.063	0.195	0.194	0.656
F test	0.888	0.000988	0.00435	0
r2_a	-0.0309	0.104	0.113	0.617
F	0.671	2.137	1.968	27.05

Source: generated by author

Conclusion and Policy Implications

Conclusion

Using data from eleven CEE countries spanning from 1995 to 2020, this paper employs static panel data models and mechanism-testing models to empirically investigate the effects of population ageing on economic growth in the region, along with the underlying mechanisms supported by theoretical analysis. This study utilises detailed economic statistical data and various control variables, including government intervention, financial development levels, and level of openness. Through comparative analysis and regression models, it delves into the multifaceted effects of population ageing on economic growth. The countries selected for the study include Bulgaria, Croatia, the Czech Republic, Hungary, Poland, Romania, the Slovak Republic, Slovenia, Estonia, Latvia, and Lithuania. These countries share similarities in economic development, demographic structure, and policy environments, ensuring the general applicability of the research findings. The conclusions are as follows:

Firstly, population ageing has a significant negative impact on economic growth. Our empirical analysis indicates that the deepening process of population ageing adversely affects economic growth in the CEE region, exhibiting a pronounced inhibitory effect. By incorporating control variables such as government intervention, financial development levels, and level of openness, we can more comprehensively understand the mechanisms through which population ageing influences economic growth. These control variables can somewhat mitigate the negative impact of ageing; however, the overall inhibitory effect of ageing on economic development in the CEE region remains significant. Therefore, through regression analysis, we conclude that the negative impact of population ageing on economic growth in the CEE region is both significant and enduring.

Secondly, population ageing inhibits economic development in the CEE region through various channels:

1. Savings Rate: An increase in the senior population has an impact on GDP growth via changing the savings rate. In an ageing society, older people typically reduce savings and increase consumption, leading to a decline in the overall social savings rate, thereby reducing the funds available for investment and further limiting economic growth. After retirement, the elderly's propensity to save decreases as they begin to use their savings to cover living and medical expenses. At the same time, a reduced proportion of young labour means an overall decline in savings, reducing funds available for investment and development and thus inhibiting economic growth.

2. Labour force: Population ageing results in decline in the labour force, which hampers economic growth. As population ageing progresses, the proportion of the working-age population decreases, resulting in a constrained labour market. This shortage hampers productivity and places additional social burdens, further stalling economic development. With a growing retired population and a shrinking working-age cohort, the labour market faces inadequacies that lead to labour shortages for businesses, rising production costs, reduced competitiveness, and slower economic growth.

3. Capital Volume: Population ageing also impacts GDP growth by changing the volume of capital. Ageing significantly reduces both the quality and quantity of human capital. The increase in the older population leads to a loss of experience and skills, hindering technological innovation and productivity improvement. The increase in the elderly population not only takes away valuable experience and skills but also requires the younger generation to bear more caregiving responsibilities, reducing their investment in education and skill enhancement, affecting the overall quality and quantity of human capital and obstructing long-term economic development.

4. Technological progress: Slow economic growth due to constraints on technological progress. In an ageing society, the drive for innovation and R&D weakens, and investments in R&D by enterprises and governments decrease, further limiting the pace of technological progress and weakening the potential for economic growth. As ageing progresses, social risk preferences decline, investments in innovation and R&D by enterprises and governments decrease, and the speed of technological progress slows, resulting in insufficient economic growth momentum. Enterprises facing rapidly

changing market demands and technological advancements need more innovation drive and resource investment, leading to a decline in productivity and competitiveness.

Policy Implications

Based on the impact of demographic changes on economic growth, policymakers should promptly introduce various policies to address "active ageing," including the following aspects:

Firstly, governments need to accelerate economic development and transform the mode of economic development. Drawing on relevant research on Western European countries, the economic strength of a country is key to alleviating the problems posed by population ageing. Therefore, at the macroeconomic level, efforts should be made to shift towards an innovation-driven model by increasing investment in R&D and technological innovation, encouraging enterprises to upgrade technologies and transform industries. Simultaneously, governments should improve intellectual property protection systems, create an environment conducive to innovation, and attract more high-tech talent and innovative enterprises. This can help governments maintain or further improve existing social welfare levels and ensure necessary material reserves to address the increasingly severe demographic imbalances.

Secondly, governments should improve and adjust fertility policies. In response to the specific circumstances of CEE countries, governments can adopt various measures to encourage childbirth and family development. Firstly, by providing childcare subsidies, extending maternity and paternity leave, and reducing the economic burden on young families, governments can incentivise higher fertility rates. Secondly, governments should enhance support for childcare services, increasing and improving the quantity and quality of nurseries and kindergartens to enable parents to better balance work and childcare. Additionally, policies promoting shared childcare responsibilities between genders can foster gender equality, reducing the dual pressures faced by women in

families and workplaces. Governments can also provide housing subsidies, education subsidies, and other measures to lower the costs of raising children. Implementing fertility policies can help increase birth rates and, in the long run, alleviate the social pressures brought about by population ageing.

Thirdly, countries need to support the high-quality development of emerging ageing industries. Although population ageing will impact high-labour industries, it can simultaneously promote the development of emerging industries. CEE countries can turn challenges into opportunities by vigorously developing elderly care services, the elderly health industry, and the market for products designed for the elderly. Governments can encourage enterprises to research and produce high-tech products suitable for the elderly, such as smart home devices, health monitoring equipment, and assistive living tools through policy support and financial investment. Additionally, governments can promote the professionalisation and diversification of elderly care services, improving the quality of services provided by nursing homes and community elderly care service centres to meet the diverse needs of the elderly. Meanwhile, governments should strengthen the training of personnel in the elderly care industry, improving their professional quality and service levels through vocational education and training. Collaborations with higher education institutions and research institutes can advance research in areas such as elderly health, rehabilitation, and care, driving technological innovation and progress in the ageing industry. Governments can also encourage investment in the ageing industry through tax incentives and subsidies, promoting the rapid development of the market. Establishing ageing industry clusters and industrial parks can attract related enterprises to develop collectively, forming scale effects and enhancing industry competitiveness. In summary, supporting the high-quality development of emerging ageing industries can not only address the challenges brought by population ageing but also create new economic growth points, driving sustainable economic development in CEE countries.

Fourthly, governments should improve pension security and service systems. Increased investment in pension security systems is necessary to ensure the sustainability and coverage of pension systems, guaranteeing the basic living needs of the elderly. Governments can introduce multi-tiered pension insurance systems, combining basic pension insurance, corporate annuities, and personal savings pension insurance to provide more comprehensive protection for the elderly. Additionally, governments should promote the construction and optimisation of elderly care service systems, increasing the number of elderly care institutions and community elderly care service facilities, and enhancing the quality and professionalisation of elderly care services. Governments can encourage social capital to participate in the elderly care service industry through policy support and financial subsidies, promoting the joint development of public and private elderly care service institutions. Furthermore, governments should strengthen vocational training for elderly care service personnel, improving their professional skills and service levels to ensure high-quality care and services for the elderly. By establishing standards and evaluation systems for elderly care services, governments can regulate the elderly care service market, enhancing service transparency and credibility. Lastly, promoting smart elderly care development through technologies such as the internet, big data, and artificial intelligence can construct intelligent elderly care service platforms, providing services like health monitoring, emergency rescue, and telemedicine, thereby improving the efficiency and convenience of elderly care services. Through these measures, governments can comprehensively enhance the pension security and service systems, ensuring that the elderly enjoy a dignified and happy life in their later years.

Lastly, governments should improve the elderly employment market to expand the labour force. The labour market shortages caused by population ageing may be mitigated by developing the elderly employment market. Firstly, governments can gradually extend the statutory retirement age, encouraging delayed retirement. This can not only ease the pressure on the labour market but also fully utilise the experience and skills of the elderly, alleviating labour shortages and promoting economic development.

Secondly, promoting flexible employment arrangements, such as flexible working hours and remote work, can help the elderly continue working more easily. Such arrangements can meet the elderly's living needs and improve their job satisfaction and productivity. Additionally, providing vocational retraining and lifelong learning opportunities can help the elderly adapt to new job positions and technological requirements. By enhancing the skills and knowledge levels of the elderly, they can better perform their roles at work, further contributing to economic growth. These measures can stimulate the work enthusiasm of the elderly, improve their employment rates, and bring more vitality and innovation to society and the economy.

Limitation and research prospects

Due to limitations in scope and data, we did not include all CEE countries, such as Montenegro, Albania, and Ukraine. These countries have unique demographic structures and economic backgrounds, and including their data might significantly impact the research results. Additionally, this paper only selects data from 1995 to 2020. While this timeframe has certain representativeness, it may not fully reflect the longer-term trends of demographic and economic changes. Future research should consider including more CEE countries to provide a more comprehensive analytical perspective. Extending the data timeframe to cover earlier and more recent periods could better reveal the long-term impacts of demographic changes on economic growth. Furthermore, our data collection primarily relies on existing statistical data, which might have certain lagging and incompleteness issues. Further field investigations and data updates would enhance the reliability and applicability of the research. The research methods and analytical techniques also have their limitations, as some complex socio-economic factors might not have been fully considered. Future research could adopt more diverse methods to thoroughly explore the comprehensive impact of demographic changes on economic growth.

Additionally, not all control variables have been fully considered. This paper currently includes three control variables: government intervention, financial development levels, and openness to foreign trade. While these variables are important, they do not comprehensively cover all potential factors influencing the relationship between demographic changes and economic growth. For instance, education levels, technological innovation capabilities, and infrastructure development might also significantly impact the research results. Excluding these variables from the model might lead to some biases and limitations in the research conclusions. Future research should consider more control variables to reflect the multidimensional factors affecting the relationship between demographic changes and economic growth more comprehensively. This could enhance the precision and reliability of the research and provide policymakers with more comprehensive decision-making bases. Additionally, using more complex statistical methods and models, such as multilevel models or dynamic panel data models, could better capture the complex relationships and dynamic changes among variables, providing more in-depth analysis and insights.

It is also worth noting that this paper lacks individual country analyses and comparative analyses. Although we conducted an overall analysis of the CEE countries, individual countries have distinct characteristics in economic structure, policy environment, and demographic dynamics that might significantly impact the research results. Not conducting individual country analyses prevents us from understanding each country's unique economic and demographic change patterns in-depth. Additionally, the lack of comparative analyses limits our ability to identify which countries' policies and practices are most effective in addressing population ageing and promoting economic growth. Future research should consider conducting detailed case studies for each country to capture the unique experiences and challenges of different countries in responding to demographic changes. Comparative analyses could reveal similarities and differences among countries, providing more valuable policy insights and helping other countries learn from successful experiences. Further data refinement and

multidimensional analyses would enhance the depth and breadth of the research, providing more comprehensive and precise conclusions.

Besides the mentioned limitations, several areas for future research can be further explored. Firstly, the focus can be placed on the impact of population ageing on the quality of economic growth. Current research mainly focuses on the quantity of economic growth while neglecting the issue of growth quality. For instance, ageing might affect labour productivity, innovation capacity, and industrial upgrading. Future research could delve into the specific impacts of ageing on the quality of economic growth, including productivity changes, innovation investment, and economic structural transformation. Secondly, exploring the impact of ageing on different economic sectors might be beneficial. For instance, services and manufacturing might be affected differently by ageing, and sectoral analyses could more accurately understand the multidimensional impacts of ageing on the economy. This would help formulate more targeted policies to address the specific challenges faced by various sectors. Additionally, research on digital economy substitution and population ageing is worth exploring. With the rapid development of digital technologies, the digital economy is rising globally and gradually becoming an important engine for economic growth. The rise of the digital economy provides new solutions for mitigating labour shortages caused by ageing. For instance, automation technologies, artificial intelligence, and robotics can partly replace labour, enhancing productivity. Future research could explore the potential and challenges of the digital economy in addressing population ageing. On one hand, the application of digital technologies can significantly improve productivity, reducing dependence on labour quantity and alleviating the negative impacts of ageing on economic growth. On the other hand, the development of the digital economy might bring new socio-economic issues, such as digital skills shortages, technological unemployment, and the digital divide. Research can further analyse the policies and practices of different countries in digital economy development, learning from successful experiences and formulating digital economy development strategies suitable for national contexts. Measures such as enhancing

digital infrastructure, strengthening digital skills training, and promoting technological innovation could enhance economic resilience and address ageing challenges.

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