DOES THE LABOUR FORCE PROGRESS THREATEN THE DEVELOPMENT OF SLOVAKIA INDUSTRY IN THE MEDIUM-TERM PERSPECTIVE?

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Cite as: *Hotkova, A., Jakubcinova, M. (2024). Does the labour force progress threaten the development of Slovakia industry in the medium-term perspective?, Ekonomicko-manazerske spektrum, 18(2), 50-60.*

Available at: *10.26552/ems.2024.2.50-60*

Received: 5 August 2024; Received in revised form 4 October 2024; Accepted: 19 November 2024; Available online: 31 December 2024

Abstract:
Research background: Population ageing is becoming a significant factor influencing technological innovation and the transformation of industrial models worldwide. However, labour supply shortages due to an aging population have led to a greater number of older workers within society.
Purpose of the article: The aim of the paper is to define theoretical approaches and options for addressing the population ageing impact on the labour market with a focus on the industrial sector. The study examines the ageing Slovakian population demographic trend, the size of the labour force and labour force projections, all with a focus on the industrial sector of the Slovak Republic.
Methods: To meet the objective, many statistical methods have been used to investigate ageing and the workforce size and structure in the industry sector. The Dynamic Economic and Reproductive Ageing Index methods were used to examine population ageing, the workforce and its volume, providing information on the dynamics of ageing in the Slovak Republic. Other methods used are the Labour Inflow, Outflow and Replacement Coefficient. They inform about the reproductive replacement of the labour force, the productive component and the projected volume of the labour force in the future. More specific future volume projections of the labour force were found based on the Boersch-Supan model.
Findings & Value added: The results suggest that the Slovak Republic is experiencing population ageing, the dynamics of ageing is accelerating, the burden on the productive component is increasing over time, the size of the industrial workforce is increasing at a low rate and the industrial sector does not show a need for a larger volume of additional labour in 2028. The increasing population share in the post-working age may lead to increased pressure on social and health systems and public finances. Slow growth in industrial workforce size may indicate a constraint in the competitiveness and innovation potential of industry. The absence of additional labour needs by 2028 may indicate that industry is able to use existing resources efficiently or that automated technologies are coming to the fore, which may reduce the need for manual human labour.

Keywords: population ageing; industry; Industry 4.0; workforce

JEL Classification: J21; O15; O25

1. Introduction

The study focuses on the analysis in the current state and evolution of the workforce in the Slovak Republic industrial sector, with particular attention to the interaction between demographic trends such as population ageing and the impact of Industry 4.0 on changes in the workforce. The main objective of the study is to define theoretical approaches and options for addressing the impacts of population ageing on the labour market with a focus on the industrial sector. It is assumed that this approach contributes to a deeper understanding of the dynamics shaping the future of the Slovak Republic labour market.

In the current macroeconomic environment, industrial development faces fundamental challenges that are reflected in labour market dynamics and population structure. One of the primary challenges is the transformation of labour supply, which has shifted from an almost unlimited surplus to a constrained and structurally deficient labour force (Cai, 2020). The population plays a key role in the modernization of the industrial structure, with its demographic characteristics fundamentally influencing economic development (Obadi et. al., 2019).

In recent years, the problem of an ageing population has become increasingly serious. With the growing proportion of the elderly population and the increasing population dependency ratio, demographic trends are reaching such a level that the potential of the demographic dividend is being exhausted (Bao, 2020). A rapidly aging population limits the viability of technological innovation and directly interferes with the economy's ability to adapt to new technologies (Liang et al., 2018). In the context of the new macroeconomic environment where we are facing an aging population and labour shortages, it is important to address these challenges to ensure sustainable and dynamic industrial development (Zheng, 2020).

The research originality lies in the application of advanced methods, the results of which provide a deeper insight and clarify the study context. The findings provide important evidence for strategic planning in the field of employment policy, labour market interventions and the creation of support systems by the State. The information obtained is also valuable for employers who are mapping the current labour market state in the Slovak Republic and forecasting its future development.

The structure of the article is arranged as follows. The theoretical part contains an overview of findings and conclusions of scientific studies related to the population ageing from different perspectives and with regard to their possible impacts in the context of industry and Industry 4.0 and 5.0. Subsequently, the objective of the research and a description of the applied methodology are presented. The third part presents the quantitative analysis results focused on the Slovak Republic. The paper concludes with a brief discussion of the findings and the main conclusions formulation.

2. Literature review

Population ageing is becoming a significant factor influencing technological innovation and the transformation of industrial models worldwide. However, labor supply shortages due to an aging population have led to a greater number of older workers within society (Su, 2021). In the context of industry in the Slovak Republic, this topic is particularly relevant as an ageing workforce requires new approaches to work organisation and technology adaptation. According

to a study by Jing and Li (2024), ageing affects technological innovation through labour supply and investment in human capital. Traditional models of modernisation are proving unsustainable, especially in China, where population ageing has become an urgent issue. In-depth analysis shows that population ageing exacerbates labour shortages and affects the modernisation of the industrial structure, highlighting the need to promote independent innovation and improve domestic consumption and exports (Shen et al., 2022).

The ageing population also poses a serious challenge to the competitiveness of countries and regions. This demographic trend affects not only the economy, but also social and political structures, requiring adaptation to new labour market conditions. With a growing elderly population, who often face health problems and limitations, it is essential to find innovative solutions to enable this group to integrate effectively into the labour market. Industrial AI, as a new development model, has the potential to contribute to deep integration of industrial and innovation chains and improve national competitiveness. Wu et al. (2022) confirm that population aging has a positive impact on the technical intensity of exports. The introduction of industrial AI tools mitigates the negative effects of aging and promotes industrial upgrading, thereby increasing the technological maturity of exports. At the same time, automation frees workers from repetitive hard work, but older workers feel threatened by new technologies (Zhang et al., 2023).

Within the challenges posed by an ageing economy, Hu et al. (2021) identified four main challenges in the ageing industry: poor adaptability to technology for older workers, mediocre quality of shared services, the concept of redundant older people and a shortage of skilled professionals. Coping with these challenges is crucial for the effective adaptation and new technologies implementation.

Regarding the older workers, physical demands are limited, which can lead to a reduction in their work capacity and motivation. Many of these workers face health problems that make it difficult to perform physically demanding tasks. Therefore, incorporating age management practices is crucial (Calzavara et al., 2020) as these practices not only allow for the adaptation of the work environment but also the optimization of work processes to take into account the individual needs and demands of older workers. The use of wearable and smart devices to analyse working time and physical fatigue could become an effective tool (Berti et al., 2021). Older workers in industry show a positive attitude towards industrial innovation (Finco et al., 2020).

In further analyses by Gao et al. (2023) suggest that eastern and central regions benefit from technological innovation induced by population aging, while western regions face the opposite trend. Similarly, Angelini (2023) reports that population aging explains almost half of the increase in new technology adoption over the period 1995-2020, while projecting a decrease over the period 2020-2045. Automation and computerisation are key factors shaping the labour market. Phiromswad et al. (2022) point out that these factors have a statistically significant impact on employment.

Social support also has a significant impact on long-term innovative capabilities. Gao and Tian (2023) report that an ageing population and child population affect scientific and technological innovation, while investment in education has a positive impact on innovation (Liang et al., 2018). In the context of workforce diversity, it is important to consider age, gender and individual capabilities in productive systems (Katiraee et al., 2019). Older operators can mentor younger workers and positively influence the work environment (Berti et al., 2021).

Li and Zhao (2019) point to the long-term effects of aging on technological innovation, while at the same time suggesting that the dependency ratio of the elderly has a strong impact on scientific and technological innovation. In this regard, Zhang (2023) systematically reviews

the factors influencing older employees' attitudes toward technology, highlighting the complex relationship between their personal characteristics, technological factors, and social context.

With the advent of Industry 4.0, which requires new infrastructures and increased volumes of data, it appears that the implementation of new technologies such as robots can significantly improve efficiency and productivity in industrial processes (Mohamed, 2018). Various studies have focused on technological solutions that harness the flexibility and creativity of workers (Schlegel et al., 2017; Guo et al., 2017). The technologies associated with it are applied in complex industrial processes to increase task efficiency and productivity and can also be used to train workers (Jetter et al., 2018). An important part of modernisation is the consideration of age management, which appears to be key for older workers (Calzavara et al., 2020).

In the context of Industry 5.0, the focus is on the well-being of the human workforce and sustainability, allowing for a better integration of an ageing workforce into modern industrial systems (Aceta et al., 2022; Thorvald et al., 2021). This approach promotes the consideration of human factors and ergonomic aspects, thus ensuring a healthy and productive work environment. The combination of technological innovation and a humane approach is key to creating efficient and sustainable work systems that reflect the needs of all generations (Alves et al., 2022).

The ageing workforce in the Slovak Republic requires a comprehensive approach that combines technological innovation with a humane approach. These findings show that it is imperative to adapt industrial systems to reflect the needs of all generations to ensure sustainable and efficient growth of the industrial sector. A key element of this transformation is taking into account age management aspects, improving the quality of education and adapting the working environment to the needs of an ageing population. Attention must also be paid to innovative technologies that can improve the quality of work and living conditions of older workers, as well as their integration into modern work processes. Ultimately, sustainable and efficient growth of the industrial sector depends on a cooperation between technological progress and an approach that respects and supports the needs and preferences of all age groups.

3. Methodology

The main objective of the research was to define theoretical approaches and options for addressing the impact of ageing on the labour market, with a priority focus on the industrial sector.

Based on the method of expert estimation, the following hypotheses were formulated:

H1: We assume that the index of dynamic economic and reproductive ageing will show population ageing.

H2: We assume that labour force turnover will be reduced in the future. The average value of the replacement rate will be less than 0.900.

H3: We assume that the amount of additional labour force in industry will be lower in 2028. Industrial labour demand will be reduced by around 40,000 workers.

The empirical research includes a quantitative analysis focusing on demographic changes and transformations in the workforce. The analysis of the ageing population is extended by examining selected indicators that reflect the labour market situation and labour force availability in the context of an ageing population. The current situation and previous developments are complemented by assumptions on the development of the industrial workforce up to 2028. Eurostat and the Statistical Office of the Slovak Republic were used to obtain primary data.

 ISSN 1337-0839 (print) / 2585-7258 (online)

The index of dynamic economic ageing of working age reflects the speed of the population ageing process. The relationship is as follows

$$I_{esd} = \left[O_{(0-14)t} - O_{(0-14)t+n}\right] + \left[O_{(65+)t+n} - O_{(65)t}\right] \tag{1}$$

where $t = 1,2,\dots,T$ is the number of periods

n is the size of the statistical population

The Dynamic Reproductive Ageing Index is a modification of the previous index. The change consists in examining the age structure of the population in terms of reproduction. The relationship reads

$$I_{rsd} = \left[O_{(0-14)t} - O_{(0-14)t+n}\right] + \left[O_{(15-49)t+n} - O_{(15-49)t}\right] \tag{2}$$

Polynomial trends are used in trend following and help to define a trend function that has an extreme. Its shape is

$$Y_t = a_0 + a_1 t + a_2 t^2 + \cdots + a_k t^k \tag{3}$$

The inflow coefficient expresses the number of people aged 10-14 years per 100 people aged 15-64 years. It is denoted by the capital letters KP and expressed as a percentage. The ratio reads

$$KP_{\%} = \frac{P_{(10-14)}}{P_{(15-64)}} \cdot 100 \tag{4}$$

where $P_{(10-14)}$ is number of people aged 10-14

$P_{(15-64)}$ is number of people aged 15-64

The labour force outflow coefficient expresses the number of people aged 60-64 per 100 people aged 15-64. It is denoted by capital letters KO and its expression is in percentages. We find the resulting value as:

$$KP_{\%} = \frac{P_{(15-64)}}{P_{(60-64)}} \cdot 100 \tag{5}$$

where $P_{(60-64)}$ is number of people aged 60-64

$P_{(15-64)}$ is number of people aged 15-64

The coefficient of exchange is denoted by the capital letters KV, and its value is quantified as a percentage. Its relationship is

$$KV_{\%} = \frac{KP}{KO} \tag{6}$$

The average growth coefficient was used to find the average development of the indicator under study. The calculation is based on the geometric mean and its relationship is as follows

$$K_{(y)} = \sqrt[n-1]{\frac{y_n}{y_1}} \tag{7}$$

where $K_{(y)}$ is the average growth coefficient

$n-1$ is the number of observation periods minus 1

y_n is the value in the last period

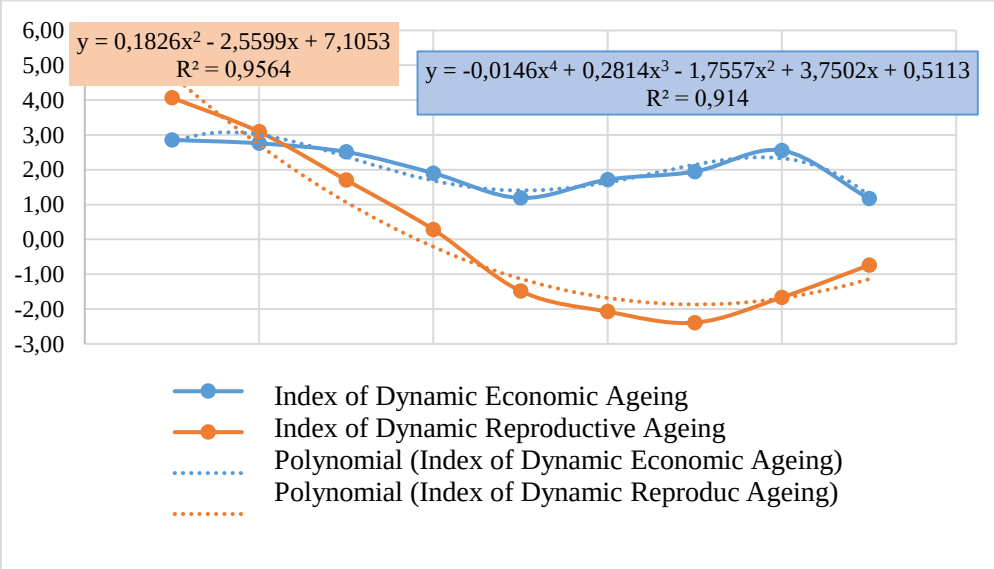
y_1 is the value in the first period

The Boersch-Supan model was used to identify the additional future labour requirements in selected industries. The selected model consists of identifying the expenditures of each population age group, identifying the number of people working in the selected sectors, estimating future expenditures, identifying the total population consumption, analysing the number of people employed in the selected sectors, identifying the future population forecast and then forecasting the amount of labour force in the selected sectors. On the basis of the analysis of demographic changes and the transformation of consumer preferences, the number of employees that will be necessary to produce the required volume, based on changes in the total consumption of the population, is determined. The information and data obtained from the model quantifies the change in the structure of the workforce in the economy and the data can be used for further investigation, such as the changing skill structure and much more (Kostrova, 2019).

4. Results

The following figure and tables show the results of the research, see Figure 1.

Figure 1: Index of dynamic economic and reproductive ageing 1993-2028



Source: own processing based on the Statistical Office of the Slovak Republic (2023)

The index of dynamic economic ageing took on positive values throughout the period under review, indicating population ageing. A higher value of this index indicates a faster dynamic process. The regression coefficient also shows a positive value, indicating that the index had an increasing trend throughout the period. This indicates that the dynamics of the process is steadily increasing. Population ageing in terms of reproduction is denoted by the index of dynamic reproductive ageing, whose values change over the time frame under study. The overall assessment indicates a downward trend, which is influenced by the increase in life expectancy, the increase in the age of women at first birth and the general postponement

of family formation and family life among young people. Based on the results obtained, it has been assessed that population ageing in the Slovak Republic is ongoing and will continue to accelerate in the future. H1 has been confirmed.

Table 1 presents results reflecting generational labour turnover based on inflow, outflow and replacement coefficients.

Table 1: Projection of the KP, KO, KV to 2028 in the Slovak Republic

	2024	2025	2026	2027	2028	Average
KP	8.301	8.300	8.339	8.450	8.546	8.387
KO	9.504	9.596	9.598	9.549	9.482	9.546
KV	0.873	0.865	0.869	0.885	0.901	0.879
Reduced labour force reproduction in all periods						

Note: KP Coefficient of inflow, KO Coefficient of outflow, KV Coefficient of exchange
Source: own processing based on the United Nations (2024)

The average value of the KP in 2024-2028 is detected at 8.387, which means that there are approximately eight children aged 10-14 years for every 100 people aged 15-64 years. The value of the KP increases over the projected time series, which can be seen as a positive manifestation of demographic development.

The value of the average KO for the period 2024-2028 is 9.546. The resulting value means that there are approximately nine to ten people of post-working age for every 100 people of working age. The unfavourable fact is that the average value of KO is higher than the average value of KP.

The average KV has taken on a value of 0.879. A value less than one means that the outflow is higher than the inflow of labour. We are talking about the reduction in the reproduction of the labour force, which tends to increase. These figures mean that the share of the productive and post-productive population exceeds the share of the pre-productive group. This gives rise to a situation on the labour market where there is a risk of labour shortages because there is no exchange between the post-productive and pre-productive components of the population. H2 has been confirmed.

Table 2 shows the results confirming the need for additional labour in 2028 in selected sectors.

Based on the results obtained from the Boersch-Supan model, the industries were divided into two groups. The first group includes sectors where additional labour is expected to be needed, and the second group includes sectors where the demand for workers is expected to decline. The sectors with an existing need include information and communication technology. Conversely, sectors with declining demand include industry, transport and financial and insurance services. An additional need of 12 950 persons is expected in the information and communication technology sector.

Table 2: Additional labour needs in 2028 in the Slovak Republic based on population consumption

Indicators sector	Employment in 2023	Need in 2028	Difference
Industry	480,000	440,250	-39,750
Transport	110,000	98,125	-11,875
Information and communications	55,000	67,950	12,950
Financial and insurance services	53,000	52,125	-875

Source: own processing

The second group of sectors in which the additional labour needs are projected to decrease includes industry, where a decrease of up to 39 750 persons is estimated. The decline in demand in the transport sector is attributed to the increasing number of drivers and cars, as well as to a reduced interest in public transport, which is becoming less convenient and less frequent. The

final sector experiencing a decline in demand is financial and insurance services. H3 has been confirmed.

Based on extensive data, it can be concluded that Slovakia's population is ageing, the process is accelerating, the reproduction of the labour force is decreasing and there is a shortage of labour on the labour market. Future projections are unfavourable, and labour resources are exhausted.

5. Discussion

The Slovak Republic is currently in a complex demographic context characterised by an ageing population and changes in the workforce. Based on the findings of the previous analysis, several key aspects can be identified that are crucial for the future of the industrial sector.

The first important fact is that the working age population is declining while the number of people of post-working age is increasing. This trend is consistent with the finding that an ageing workforce leads to a shortage of skilled labour (Su, 2021). The consequences of this decline are not only felt in the labour market but also in overall economic development, as the ageing population directly affects the modernisation of industrial models (Shen et al., 2022).

The dynamics of population ageing is accelerating, which is an alarming signal not only for industry but for all sectors of the national economy. In line with this observation, it is becoming increasingly evident that the demand for adaptation to new labour market conditions is becoming inevitable. A rapidly ageing population limits the scope for technological innovation and interferes with the economy's ability to adapt to new technologies (Liang et al., 2018).

The findings regarding labour force reproduction are also crucial as they reveal the challenges that the SR industry will have to face in the coming years. With labour force reproduction projected to decline by 2028, the SR industry needs to prepare for major changes in the employment structure. The upcoming changes require careful analysis and adaptation to the new conditions to ensure competitiveness. Another critical aspect is the projected reduction in the need for an additional workforce of 39 750 persons by 2028. This alarming trend not only indicates a possible surplus workforce, but also changes in the employment structure, whereby traditional positions may be abolished or transformed. It is imperative that employers begin to prepare for these anticipated developments and plan strategically for the deployment and adaptation of the available workforce. This trend corresponds with arguments that automation and technological innovation may reduce the demand for manual labour (Mohamed, 2018). With the increasing use of robotics and AI in industry, traditional jobs are becoming less and less desirable. The consequence of this is not only a reduction in the number of employees in certain areas, but also the need to retrain and upskill those who will continue to be in the labour market. This opens the debate on the need to develop new approaches to work organisation that take account of the individual skills and needs of older workers. Given the ageing population and the projected number of younger workers, it is crucial to create a working environment that is inclusive and adapted to different age groups.

The final analysis shows that a comprehensive approach that combines technological innovation with a humane approach and takes account of demographic change is essential to ensure the sustainable development of the Slovak industry. It is necessary to look for innovative solutions that effectively integrate older workers into modern work processes, thus ensuring not only their active participation but also the overall competitiveness of the industry. It should be stressed that the creation of innovation is closely linked to human capital and therefore, even in the context of a declining need for additional labour, it remains crucial

to ensure that industry has a sufficiently skilled workforce capable of generating innovative solutions.

6. Conclusions

The main objective of the research was to define theoretical approaches and options for addressing the impact of ageing on the labour market, with a particular focus on the industrial sector. The research analysed the population ageing in the Slovak Republic and the size of the workforce in the future.

The key finding is that the working-age and pre-working age population is declining, while the number of people of post-working age is increasing. This trend is a clear indicator of the ongoing population ageing in the Slovak Republic, which is characterized by accelerated dynamics. For 2023, a reduced reproduction of the labour force has been recorded and the projections for the period 2024-2028 indicate that this trend will continue. Despite the average increase in industrial employment, the need for additional labour is projected to decrease by 39 750 people by 2028.

The limitations of this research are that the analysis is based on available demographic and economic data, which can be influenced by a variety of external factors such as economic crises, policy decisions and technological innovation. In addition, the lack of specific forecasts and estimates regarding future labour market developments may affect the accuracy of the predictions.

The results of this research underline the importance and urgency of the need to develop comprehensive and sustainable employment policies that take demographic changes into account and increase the competitiveness of Slovak industry. Given that the aging of the population and the decline in the number of people of productive age create challenges for the labour market, it is necessary to create policies that not only respond to the current situation, but also to anticipated developments. These policies should include measures to support a flexible and adaptable labour market, as well as consider the needs of different age groups of employees. In connection with technological progress and the concepts of Industry 4.0 and 5.0, it is important to integrate innovative technologies such as automation, robotics and AI into work processes. These technologies can increase efficiency and productivity, while relieving workers of physically demanding tasks, allowing them to focus on more valuable and creative activities.

Author contributions: All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

Funding: The paper receives no external funding.

Data Availability Statement: Data available in a publicly accessible repository that does not issue DOIs. Publicly available datasets were analysed in this study. This data can be found here: https://ec.europa.eu/eurostat/data/database, ttps://slovak.statistics.sk/wps/portal/ext/Databases, https://population.un.org/wpp/Download/Standard/MostUsed/.

Conflicts of Interest: The authors declare no conflict of interest.

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