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ECONOMIC GROWTH UNDER THE INFLUENCE OF TECHNICAL AND TECHNOLOGICAL CHANGES OF INDUSTRY 5.0*

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Abstract. The *purpose* of the scientific research is to graphically present and scientifically analyse economic growth under the influence of digital production factors as a result of technical progress, technological improvement and the use of Industry 5.0 tools. The *object* of the scientific research is the ranking of data by world country according to various indices and sub-indices of the "Global Innovation Index 2023: Innovation in the face of uncertainty" of the World Intellectual Property Organisation (WIPO), Geneva, which reflect innovative and scientific and technological activities. They allow for a qualitative comparative analysis of countries and regions in terms of their technological activity and the identification of factors of leadership or lagging. WIPO's analytical materials provide a picture of the current state of innovation and digitisation, allowing for targeted and methodologically substantiated research. *Methodology.* The study employs a range of methodologies, including a graphical approach to analyse the impact of digital production factors on the production capability curve and economic growth in the country. Additionally, it examines the shift in the position of the production function curve under the influence of technical progress and technological advancement towards Industry 5.0. The comparative method helped to present the evaluation indicators of the Global Innovation Index in terms of country groups by income level. The methods of analysis, synthesis, induction and deduction are used in the presentation of the factors influencing the effectiveness of digital entrepreneurship. The method of concretisation found its manifestation in the development of the author's proposals in the part of finding the driving forces of innovative and digital development of the economy. *Results.* The paper reveals clear changes and adjustments in the partial priority of using economic growth factors, which are the drivers of economic progress in the 20th–21st centuries. It was possible to present a graphical interpretation of the production possibilities curve and economic growth under the influence of digital production factors; to analyse changes in the position of the production function curve under the influence of technical progress and technological improvement on the path to the formation of Industry 5.0. The Global Innovation Index 2023 is analysed in order to provide an overview of the rankings of countries according to income level in terms of income and sales from intellectual property, high-tech imports and exports. The authors present their vision of the content of the work of the owner of a digital enterprise, and indicate the role that this owner plays. *Practical implications.* A comprehensive review of the extant literature revealed that the factors conducive to economic growth encompass the expansion of human capital quantity and quality; technological progress, technological quality and digital entrepreneurship; the formation of financial capital and an increase in the volume of its offers; and the augmentation of natural resources quantity and quality. Thus, the drivers of the formation of Industry 5.0 based on digital entrepreneurship, formed under the influence of technical and technological changes, are

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hyperintelligence, hyperknowledge, hyperinformation and hypercommunication, updated under the influence of economic growth factors. *Value/Originality*. The VII technical and technological system is predicated on creative intelligence. The objective of implementing new technologies and technological enhancement is to facilitate the digitalisation of entrepreneurship and the establishment of a novel virtual reality conducive to expeditious and efficient business operations. Consequently, utilising a dialectical, systematic and graphic approach, the impact of technical and technological progress on the transformations in Industry 5.0 was investigated. This investigation determined the prospective reserve of innovation and digitalisation of entrepreneurship, with a view to achieving economic growth.

Keywords: economic growth, technical and technological changes, digital entrepreneurship, Industry 5.0, smart manufacturing, institutional approach.

JEL Classification: F43, L16, O33, P13

1. Introduction

The innovative activity of digital enterprises has been demonstrated to accelerate economic growth in the national economy. In post-industrial countries with an innovative and digital economy, enterprises have digitised business processes and effectively carried out innovative activities, producing new and updated goods and services at a dynamic pace.

This is happening as a result of the technical and technological modernisation of industry and production under the influence of the changes that have taken place in the first two decades of the 21st century. Prioritising the use of economic growth factors. In recent years, the share of economic entities with a high innovation-digital and technical-technological component has increased worldwide. Priority will be given to the development of productions with deep technological change and a high science-intensive component. Resource- and energy-efficient "smart" productions will receive grants and government support for partial digitisation.

The issue of the impact of scientific and technological progress and the changes it brings to economic processes, business development and people's everyday lives has been reflected in the work of many researchers and scientists. It has been possible to examine many issues comprehensively and in depth, identify the causes of digital transformations, analyse current trends and lay the foundations for future positive shifts in the direction of economic growth. However, there are still a number of unsolved issues, and therefore, based on existing scientific developments, an attempt will be made to supplement the theoretical and methodological foundations of economic growth under the influence of technical and technological changes on the basis of digital entrepreneurship (DE) and Industry 5.0.

2. Literature Review

The fifth industrial revolution, otherwise known as Industry 5.0, has the potential to offer opportunities for different aspects of inclusive sustainability, as it "has the potential to improve sustainability at both the firm and supply chain level" (Ghobakhloo, 2024). Industry 5.0 is seen as a necessity for today's businesses to achieve competitive advantage and a sustainable future, and "critical success factors such as implementing advanced technologies to create value in the Industry 5.0 paradigm, strong analytical capabilities for intelligent manufacturing, cost and financing during the transition from Industry 4.0 to Industry 5.0, aligning organisational strategy during the transition to Industry 5.0, and security and privacy to ensure effective digital transformation will contribute significantly to the digital transformation from Industry 4.0 to Industry 5.0 in smart manufacturing" (Sarkar, 2024). Concurrently, smart production is emerging under the influence of various paradigms. One such paradigm is Industry 4.0, which signifies the transition to digitisation and automation of processes. Another paradigm is Industry 5.0, which is developing and emphasises human-centricity (Golovianko, 2023).

Scientists A. Youssef, I. Mejri (2023) consider "Industry 5.0 as a new phase of industrialisation that focuses on people, sustainability and sustainability" and believe that it brings "significant changes in how we should think about industrial processes and the role of technology and workers in these industries. The combination of technology and human resources will give Industry 5.0 the potential to create more sustainable, efficient, and people-oriented industries to solve the problems of the 21st century." Researchers predict the emergence of Industry 5.0 by 2020, characterised by mass customisation and cyber-physical human intelligence and cognitive systems. It is noteworthy that the previous Industry 4.0 document refers to the year of its formation, 2010, which indicates that a mere 10 years have elapsed between it and the next one. This observation corroborates the dynamism and acceleration of production and business processes in recent decades. This is particularly remarkable given that almost

a century elapsed between the preceding stages of industrialisation (Industry 1.0 – 1784, Industry 2.0 – 1870, and Industry 3.0 – 1969) (Dordevic, 2023).

On the one hand, as Ghobakhloo (2024) argue, "Industry 5.0 is experiencing a rapid transformation, accompanied by great expectations… and has the potential to solve persistent socio-economic and environmental problems that are increasingly acute and pose a threat to the well-being of future generations." However, there are a number of Industry 5.0 development dissonances, including "the driving forces behind the accelerated momentum of Industry 5.0 agenda against the backdrop of the ongoing digital industrial transformation… and how the program's sustainability values can be effectively implemented." (Ghobakhloo, 2024) Industry 5.0 is being integrated into everyday business thanks to the speed of technological development and changes in the integration of human processes (Paschek, 2019).

When analysing the development of Industry 5.0, taking into account digitalisation, it should be noted that its emergence is associated with the use of cloud and mobile technologies, the Internet of IoT, AI and data analytics in production and business processes (Paschek, 2022). The socio-economic expectations of the development of the Fourth Industrial Revolution in the context of the development of sustainability, humanisation and sustainability of Industry 4.0 contributed to "the dynamic development of the Fourth Industrial Revolution, aimed at the implementation of Industry 4.0 technologies, caused the fears of governments and society about the dehumanization of the industry in the future... Concerns regarding the implementation of technologies of the Fourth Industrial Revolution became the basis for building assumptions about Industry 5.0." (Saniuk, 2022)

Comparing Industry 4.0 and Industry 5.0, it is noted that the latter demonstrates a systemic transformation that includes business innovations that contribute to the transition to a sustainable, human-centred industry. Concerns are raised about the balance between investment in digital technologies and the retraining of workers and managers in the context of human-robot co-operation (Borchardt, 2022). As a result of finding a balance in the transition from Industry 4.0 to Industry 5.0, it was noted that "the most appropriate way to combine the extremes of automation and human-controlled processes is to create a hybrid of Industry 4.0 and Industry 5.0, which inherits the most valuable characteristics of both – the efficiency of Industry 4.0 industry and the sustainability of Industry solutions 5.0. Digital cognitive clones, combining human behavior in decision-making, are presented as a favorable technology for the future hybrid and as an accelerator (a means of sustainability) of the convergence of the digital and human worlds." (Golovianko, 2023)

At the same time, the concept of Society 5.0 and Industry 5.0 is not just a continuation or an alternative to the Industry 4.0 paradigm, because "Society 5.0 aims to put people at the center of innovation, using the influence of technologies and results of Industry 4.0 with technological integration to improve the quality of life, social responsibility, and sustainable development" (Carayannis & Morawska-Jancelewicz, 2022). Recently, economic growth trends in high-tech regions have been significantly influenced by the skills of residents, their creative potential and the use of AI technology (Batabyal, 2024).

Researchers from different countries around the world are taking a more responsible approach to teaching digital skills to citizens to make them digitally literate and able to start their own digital business based on real practical cases (Botti (Ed.), 2021), to provide a methodological basis for mastering new knowledge and professions (Herold, 2022), and to provide a reasoned explanation of the main trends, drivers and prospects for the development of DE (Magliocca, 2021).

The researchers attribute a special role to the local supply of basic technologies, because it "facilitates the implementation of inventions of new technological origin by the regions, both in absolute and relative terms", and key basic technologies contribute to technological innovations, in particular "innovations that are more new to the region than new to the world, constituting a political lever that the regions can use to target the local reproduction of technological progress" (Montresor, 2022).

It is noted that "digital transformation is still slow... but is supported by the existing structure and interpretive structural model of digitalization and... depends on the competence of employees" (Hansen, 2024). It is important to be aware of the emergence of the digital divide as a result of technical and technological changes today because "developed economies prioritize technological achievements through a more comprehensive R+D+I (research, development, innovation) system for developing technologies and prioritizing efficiency throughout the supply chain. Developing economies pay attention to the sustainability and survival of the business. They don't prioritize being on the cutting edge of technology or understanding the entire supply chain with developing economies prefer the adoption or appropriation of technology, but they support innovative schemes and improvements in economic production and administrative operations." (Alvarez-Aros, 2021)

The digital economy has an impact on the income levels of the country's population, particularly through the assessment of the connectivity and quality of broadband internet. Access to and use of broadband

Internet increases the overall income level of the labour force, thereby widening the income gap between high-, medium- and low-skilled workers. The impact of broadband on income growth occurs by increasing the level of entrepreneurship and increasing the total number of professional and skilled workers. The growth of the high-skilled labour force in tech industries generates an income growth effect from them, and it will be higher than from the medium- and low-skilled labour force (Kong, 2023).

To overcome digital imbalances in the economy, it is worth working on the development of a digital entrepreneurial ecosystem, which "contributes to the acquisition of knowledge and opportunities for exchange, ... the development of entrepreneurial opportunities, ... the acquisition and exchange of knowledge with the help of a digital ecosystem of entrepreneurship, ... the development of entrepreneurial opportunities..." (Zhou & Weiren, 2024) It has been demonstrated that digitalisation contributes to the increased profitability of companies. However, entrepreneurs who are motivated by altruistic goals show a pronounced tendency to integrate digitalisation in sales. This suggests that the pragmatic utility of digitalisation extends beyond simply increasing profitability and growth, and that it may play a more integrative role in creating sustainable business practices and business models (Plecko, 2023). In addition, it has been asserted that "with the rapid development of information technology, digital platforms are becoming an indispensable aspect of the business landscape, which has a profound impact on business innovation and practice" (Xie, 2024). This has been shown to contribute to the creation of a more inclusive digital world of the entrepreneurial ecosystem, thereby helping to ensure its sustainability and social prosperity (Zhou & Weiren, 2024).

Technological transformations are taking place on the basis of 4.0 technologies and are a complete reality today, as "Industry 4.0 and the introduction of automation technologies are associated with regional economic growth, especially in those regions where such a specific transformation prevails...; the effects of digitalization are spreading to all European regions, and regions dominated by the transformation of the digital services economy do not have significant growth advantages compared to others." (Capello & Lenzi, 2023) However, "despite rapid technological progress in recent decades, income inequality has increased" (Urraca-Ruiz & Da Silva Lima, 2024), so it is worth looking for evidence on the relationship between technical change and income inequality, focusing on the role of heterogeneity.

The researchers also provide targeted recommendations for "stakeholders to improve entrepreneurship education, simplify business rules, and introduce a national entrepreneurship zone using a digital platform" (Al-Housani, 2024), which are aimed at "significantly improving the entrepreneurial environment, simplifying access to important business information, supporting small business through allocated funds and the transition to a diversified economy based on knowledge" (Al-Housani, 2024), because it is about outlining the role of entrepreneurship in economic and social development, state policy for the development of entrepreneurship, its cultural and social dynamics, joint efforts for entrepreneurial success, and global entrepreneurship.

The pursuit of economic growth, predicated on technical and technological changes, necessitates an institutional approach, given that institutions have emerged as a catalyst for regional growth and innovative activity. Consequently, there is an increased interest in evaluating the mechanisms by which institutional structures can influence innovation. Institutional quality affects innovation potential and is "related to two fundamental institutional components: the quality of public services (government effectiveness) and the degree of association and social co-operation (voice and accountability)" (Mosconi & D'Ingiullo, 2021). Currently, work is continuing to identify the role of digital technologies in value creation, delivery and capture within sustainable entrepreneurship business models, noting that "the adoption and use of digital technologies is one of the most promising transformations for sustainable development, and sustainable entrepreneurship is the key to solving grand social and environmental problems" (Fuerst, 2023).

Previous scientific studies have already attempted to identify the influence of modern digital technologies, in particular AI, in the creation of Industry 4.0 and the transition to new levels of intelligent production (Kraus, 2022), the digital transformation of business processes of enterprises on the way to Industry 5.0 is characterised in an argumentative manner (Kraus, 2023[a]), and the activities of advanced digital platforms based on clustering and innovative development strategies for economic prosperity are described (Kraus, 2023[b]). In order to comprehend the phenomenon of economic growth in the context of digital entrepreneurship and Industry 5.0, it is imperative to explore the interplay between technological and technological changes.

The *purpose of the article* is twofold: firstly, to provide a graphic presentation and scientific analysis of economic growth under the influence of digital production factors as a result of technical progress, technological improvement, and the use of Industry 5.0 tools; and secondly, to lay the foundation for determining the basic drivers of progressive digital development in the industry of the future.

The tasks set out in the article include the following: to find out clear changes and adjustments in the partial priorities of the use of economic growth

factors, which are the drivers of economic progress in the 20th-21st centuries; to present a graphical interpretation of the production possibilities curve and economic growth under the influence of digital production factors; to analyse changes in the position of the production function curve under the influence of technical progress and technological improvement on the way to the formation of Industry 5.0; to analyse country rankings according to GII 2023 in terms of income groups of some countries in terms of intellectual property revenues and sales, high-tech imports and exports, in order to have an idea of the leadership among the countries of the world in high-tech exports and intellectual property revenues based on these rankings in order to study and adopt their experience in the future; to provide the authors' vision of the content of the work of the owners of digital enterprises and indicate what role they play.

3. The Place of Technical and Technological Change in Economic Growth

The formation of technical and technological structures and technological progress are important for improving the quality of life and accelerating the growth of living standards. It is the systematic emergence of inventions, the emergence of creative ideas and the diffusion of innovations, as well as the positive dynamics of technological achievements that lay the foundation for the formation and development of Industry 5.0 based on DE and the improvement of production capabilities. This fact should be adopted by most of the governments of the countries.

According to the research conducted by economists K. McConnell, S. Brue and S. Flynn (2009), the economic category of "technical progress" encompasses not only the development and implementation of new, innovative production technologies, but also the emergence of novel management methodologies and new forms of business organisation, as well as the improvement of the production process. The authors of the present study share the opinion of scientists that technological progress is associated with the emergence of new knowledge and scientific discoveries, as they make it possible to combine previously available resources in a new way in order to increase production volumes. The researchers concluded that following the emergence and implementation of new knowledge, the majority of entrepreneurs and businesses have access to it at relatively lower prices. There is mounting evidence to suggest that technological progress disseminates throughout the economy, thereby increasing productivity and driving economic growth. This assertion is corroborated by empirical evidence from innovative leading countries.

"Technological competitiveness and the latest technologies are necessary in the organisational strategy to cope with industrial progress and improve the national economy. In this sense, technological innovations, computer developments, smart devices and other technologies constitute new industrial revolutions," notes the researcher E. Alvarez-Aros (2021). "Technological competitiveness is different – in countries with developing economies, it is necessary to work hard on the state policies of science, technology, and innovation because they don't contribute to the significant development of these countries at the moment. In addition, there are no funding programs that can provide the impetus and direction, so governments are concerned about developing a shared ecosystem between themselves and society, business, and the education for the development of nations." (Alvarez-Aros, 2021)

It should not be forgotten that different innovations influence the development of industries in different ways. Thus, there is a group of innovations that ensure the saving of financial capital, but the majority of innovations and changes are aimed at saving human resources. DE manages to increase the profits of digital companies in relation to the reduced wage base, thanks to innovations that replace human labour and "overlay" it with digitised business processes. At present, the Fourth Industrial Revolution vividly demonstrates the "replacement" of man by machine, or the "convergence" of man and machine, which in some places demonstrates their "fusion". Technological progress is deep and rapid, and the VI technical and technological order brings rapid qualitative and effective digital and institutional-structural changes in the economy, innovation and modernisation of production and industry towards the development of Industry 5.0.

In order to facilitate an economic growth, it is necessary to consider the following factors: growth in the quantity and quality of human capital; technological progress, technology quality, and DE; formation of financial capital and growth in the volume of its offers; increase in the quantity and quality of natural resources (Hypothesis 1).

The common features of Industry 4.0 and Industry 5.0 remain a strong technological base, digitalisation, real-time analytics and connectivity. However, there are also a number of differences, including the fact that Industry 5.0 focuses on people and their balance with machines, emphasises the need for sustainable and ecological solutions, embraces humanistic values and strives to create a society where people are valued, and also considers it necessary to adapt the workplace to the individual needs of employees (Dordevic, 2023). The scientific community has identified several potential benefits of the transition from Industry 4.0 to Industry 5.0. These include the

enhancement of existing digital technologies, the rejection of conventional digital technologies, and the focus on revolutionary technological achievements. Furthermore, the transformation of Industry 4.0 technologies is expected to occur through a hybrid approach (Ghobakhloo, 2024).

It is emphasised that "Industry 4.0 will benefit most from the values of economic and environmental sustainability at the level of the organisation and the supply chain", but it should not be forgotten about its negative impact on the micro- and meso-social values of sustainability, especially social or economic growth (Ghobakhloo, 2024). "The era of Industry 4.0 and 5.0 and the transition from society 4.0 to 5.0 bring significant changes both to the economic structure and to the social context at the global level. The challenges associated with these changes range from ethical and environmental to social and economic." (Dordevic, 2023)

World-renowned economists (Samuelson & Nordhaus, 1998; McConnell (Ed.), 2009), the Nobel laureates who have been involved in highlighting issues of economic growth, have concluded that the engine of economic progress is the four drivers of economic growth (Figure 1), regardless of whether it is a rich or a poor country.

From this, it is clear that "the world is facing many technological, economic, and geopolitical changes, as well as in the way of thinking and worldview. Every change creates new opportunities but at the same time challenges and problems. Globalization and ICT technologies contribute to the widespread digitization of processes. Today, the industry is focused on the implementation of systems focused on the use of autonomous, intelligent machines and devices, but not in all areas of economic service." (Saniuk, 2022)

The economists P. Samuelson and W. Nordhaus (1998) provide a mathematical interpretation of the interrelationships between economic growth factors using the cumulative production function (1). This function describes the relationship between the national volume of digital production and industry with resources and the latest equipment and technologies.

$$Q = AF(K, L, R), \quad (1)$$

where, Q – volume of digital production; K – capital used in the digital production process; L – human resources involved in digital production; R – natural resources involved in the digital production process; A – level of technical development, technology; F – production function.

The importance and key role of technologies and state-of-the-art techniques is manifested in the increase in the productivity of the factors used/involved in digital production and "smart" industry. The productivity of DE is expressed as the ratio of production volumes to the weighted average number of factors used in digitalised production (Samuelson & Nordhaus, 1998). Constant technological improvement, driven by the constant emergence of new inventions and ideas, or the borrowing of technological innovations from innovatively developed countries, has resulted in new opportunities for the production of innovative products and the provision of better quality digital services, utilising the same number of digital production factors.

4. Economic Growth and Factors of Digital Production

It is important to note that "technological progress and revolutions are happening faster, so business needs a clear vision of the company's development, as well as clear thinking for transformation. A company must be able to sustain the unknown and take steps to prepare the business for the future... A company must recognize that success will come to those who are more innovative and responsive to market changes to provide quality products and services to customer demands." (Paschek, 2019)

The formation of Industry 5.0 can take place on the condition that companies and enterprises achieve innovative digital technological frontiers, characterised by an effective level of application of digital technologies and the latest techniques. The clarity of the components of economic growth as a result of technological progress and the formation of Industry 5.0 is presented in Figure 2. These factors can be considered as tools of innovative and digital development, expanding physical and technological

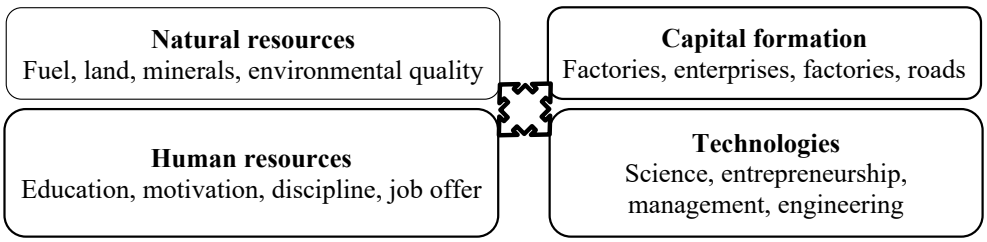


Figure 1. Economic growth factors that drive economic progress

Source: grouped on the basis of (Samuelson & Nordhaus, 1998)

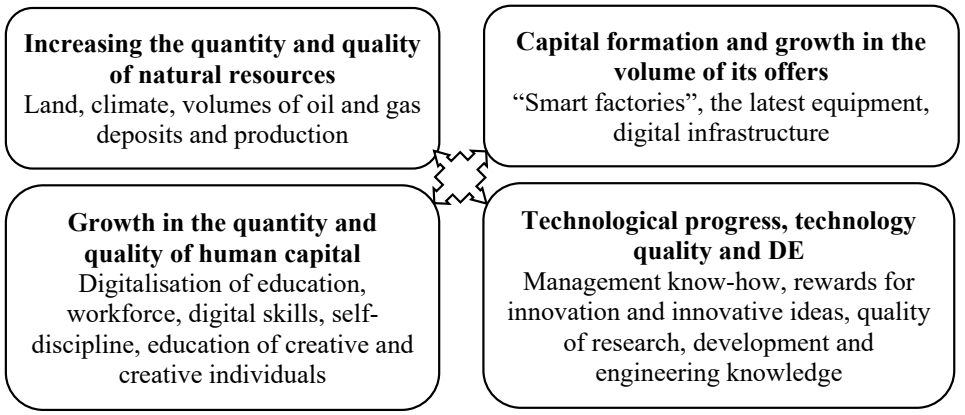
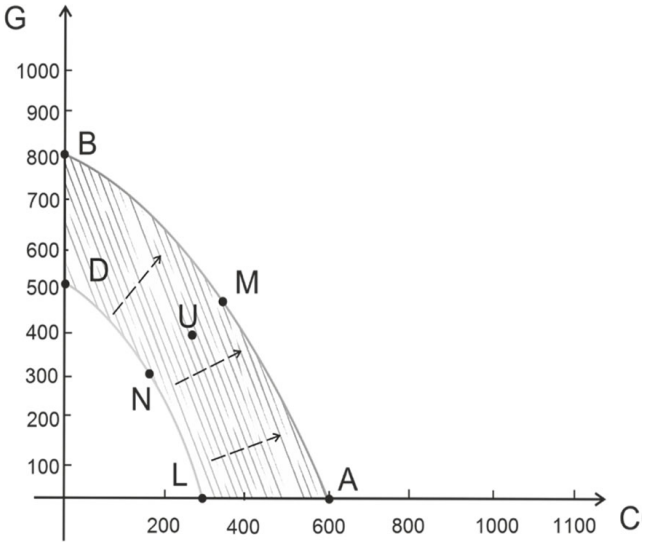


Figure 2. Clarification and expansion of the components of economic growth as a result of technological progress and the formation of Industry 5.0

Source: grouped on the basis of (Samuelson & Nordhaus, 1998; McConnell, 2009) and the authors' own observations

digital production, which increases the potential GDP of the country.

Figure 3 attempts to graphically interpret the change in the curve of production possibilities and economic growth as a result of the influence of digital production factors. The curve of production possibilities LD in Figure 3 shows the various maximally possible combinations of products that DE is capable of producing under the conditions of the given quantity and quality of natural, capital and human resources and the current technical and technological level of functioning. An improvement in any of the factors of digital production shifts the production possibilities curve of a digital firm to the right. Figure 3 shows the movement of the curve from position LD to position AB. It is clear that moving the economy of a digital firm from point N (on the LD curve) to point M (on the AB curve) requires an increase in the total cost of digital business. The efficiency factor of digital production indicates that it is necessary to minimise production costs and optimise the position of the AB curve in terms of resources for the production of digital goods and services. This is due to the fact that these resources make the maximum possible contribution in monetary terms to the total volume of digital products.



where, gray shaded area of LABD – economic growth under the influence of DE factors; IG – investment goods, products of DE; CG – consumer goods, products of DE.

Figure 3. Graphical interpretation of the curve of production opportunities and economic growth under the influence of digital factors of production

Source: built on the basis of (Samuelson & Nordhaus, 1998; McConnell, 2009) and the authors' own observations

The potential for enhanced redistribution is realised through the augmentation of digital production of each innovative product, thereby ensuring that the marginal benefits from it are equal to the marginal costs (McConnell, 2009) associated with the production of digital products/services. As illustrated in Figure 3, the optimal combination of consumer innovative goods/services and investment in latest goods/services is represented by point M. Accelerated innovative and digital development and economic growth are possible in the presence of the factors indicated in Figure 2, the changes of which shift the production possibilities curve from the basic state LD to the state AB.

A more profound examination of the domain of business model innovation is imperative in the present age for the integration of organisations into Industry 5.0, thereby addressing the challenges of sustainable development and human-oriented approaches to employee qualification and safety. New economic orientations and business models, issues of sustainable development, and human-centred approaches are becoming formidable challenges for all economic agents (Borchardt, 2022).

It is hypothesised that the "healthy" competition that will take place between digital enterprises will, in every way, contribute to innovative and digital activity in the middle of Industry 5.0 ecosystem. In order to achieve "healthy" competition, digital business owners must act (Figure 4). It is imperative to emphasise that innovation is a dynamic characteristic of a digital entrepreneurs, determined by the individual. Digital business owners consciously and purposefully implement new digital production methods with the aim of expanding and improving it, in particular. These entrepreneurs pursue the goal of reducing costs and developing new types of products to increase their income.

Digital enterprises are deliberately seeking to alter the prevailing cost-to-revenue ratio, with the objective of enhancing profitability. However, it is imperative to acknowledge that not every new product or service introduced to the market will inevitably meet with success. At the stage of designing a new digitised production, it is unfeasible to predict whether expectations will be fully realised for the implemented new accounting software or a new machine with digital working functionality. An owner of a digital enterprise does not know for sure whether the innovation will deliver the expected cost savings or whether the digital enterprise will incur losses from the innovation. It has been argued that "the part of economic profit that is focused on innovation can be considered as a reward for those who are ready to take risks and are not afraid of the uncertainty caused by the process of innovation" (McConnell, 2009) in the operation of a digital enterprise.

Expanding the understanding of the spheres of entrepreneurship, the importance of the DE ecosystem in the digital era and the influence of external environmental factors on the development of entrepreneurial opportunities are emphasised, as "the digital entrepreneurial ecosystem violates the existing boundaries and content of innovative entrepreneurial activity, restructuring the entrepreneurial landscape" (Zhou & Weiren, 2024).

5. Technical Progress and the Formation of Industry 5.0

Economic growth is impossible without technological renewal and expansion, the emergence and application in production of inventions and the latest technologies. In the process of innovation and digitalisation of the economy, the demand for digital technologies can be traced. Technological improvement opens up new opportunities for capital investment in the business processes of digital companies. A visual demonstration of the positive changes for an enterprise as it digitises its business activities is shown in Figure 5.

Technological improvement, renewal and progress are manifested in the improvement of business processes, their digitalisation, the appearance of innovative products and the modernisation of existing

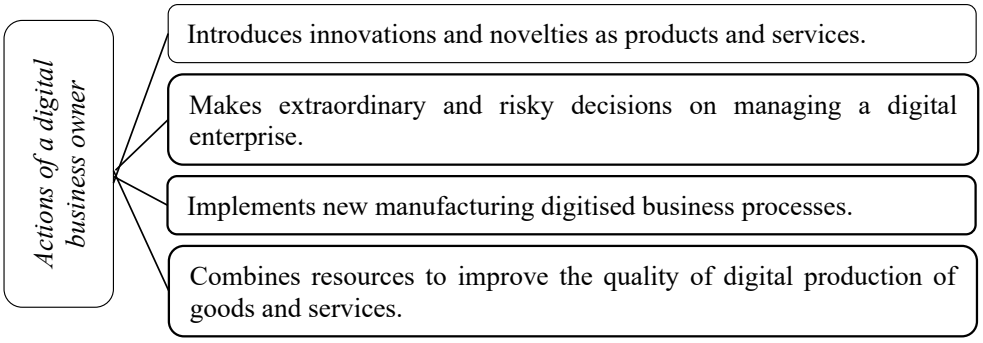


Figure 4. The content of the digital enterprise owners' work and the role they play

Source: grouped on the basis of the authors' own observations

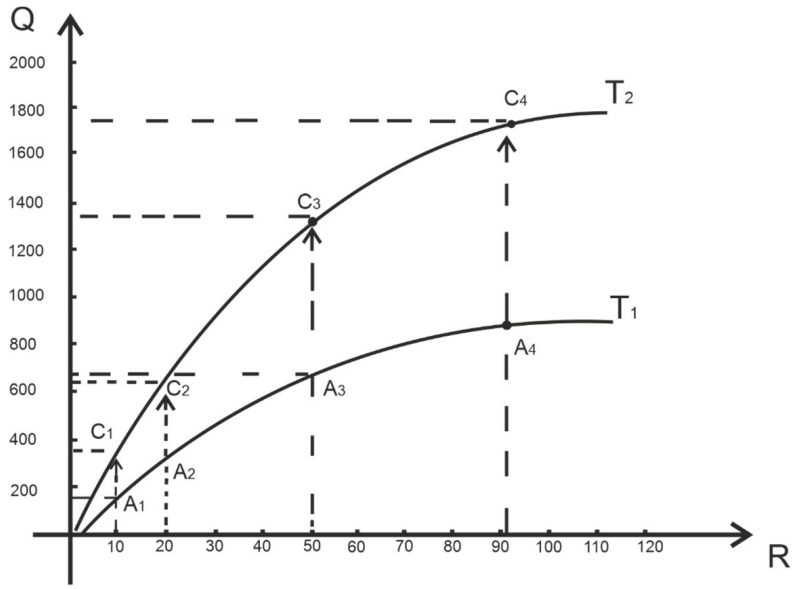
equipment. The shift of the curve from position T_1 to T_2 in Figure 5 shows the impact of technological progress through inventions, ideas and innovations on the increase in the volume of innovative goods and digital services produced. In the first two decades of the 21st century, technological progress is represented by, for example, electronic modelling of crop yields in the agricultural sector, digital monitoring, virtual management of production processes in the industrial sector, interactive modelling of real estate objects and interactive services. There are forms of technological progress that make it possible to optimise the work of companies, such as the modular construction of buildings, the virtual management of logistics and sales processes, and the electronic management of the life cycle of innovative products and digital services.

Since "innovation is both a process and a product", it is worth remembering that these are complementary components (Samuelson & Nordhaus, 1998). Innovation as a process makes it possible to improve the production technology of existing goods/services produced by a digital enterprise. If the innovation is a product, it has the chance to create a new product or to change an existing product in the innovation market by modifying it, improving it and changing its quality characteristics. By digitising business processes and applying the latest technologies, a digital enterprise can expand production with the same number of resources. In Figure 5 there is a movement, from point A_3 to point C_3. Among the successful examples, which in the practical activity of DE, so to speak, "move" the curve in Figure 5, can be mentioned GPS trackers in precision agriculture; ER planning in IT system resource planning; CAPP, Timeline in the design of commercial and technological operations.

Digitalisation is gradually changing business practices, especially in sales and digital marketing, and efforts are being made to identify the relationship between demographics and entrepreneurial motivation. Demographic factors do not significantly affect the implementation of digital technologies in sales strategy, and the greatest motivation for entrepreneurship based on digital technologies is the desire to change the world (Plecko, 2023).

It is quite obvious that the drivers of the formation of Industry 5.0 based on DE, which is formed in the 21st century under the influence of technical and technological changes, are hyperintelligence, hyperknowledge, hyperinformation and hyper-communication, which are constantly updated under the influence of economic growth factors (Hypothesis 2).

Technological improvement, digitalisation and innovation make it possible to increase the volume of production and improve the quality of innovative products and digital services with the same number of factors used factors of DE. Technical and technological perfection is a component of the development of



where, R is the total number of different types of resources; Q is the total volume of innovative products and digital services; T_1, T_2 are the curves demonstrating technical and technological changes, the emergence of new types of technologies.

Figure 5. Graphical interpretation of the change in the position of the production function curve under the influence of technical progress and technological improvement on the way to the formation of Industry 5.0

Source: built on the basis of (Samuelson & Nordhaus, 1998; McConnell, 2009) and the authors' own observations

DE, which is exposed to the effects of challenges and sensitive to changes. This is due to the fact that technology can be considered as a public good that is extremely difficult to produce, but that does not pose particular difficulties to reproduce an existing one or to create a similar one (Samuelson & Nordhaus, 1998). That is why the governments of countries that want to become innovative with digitalised business processes should pay due attention to the formation of a new quality of institutionalisation of intellectual property and guarantee the protection of rights for authors of ideas, innovators, researchers and developers of new techniques and technologies.

The present study considers the ranking of countries by the "Business Sophistication" index to be a subject of interest for analysis, as part of the "Knowledge Assimilation" sub-index presented in Fig. 6. Switzerland is the leader in paying for intellectual property, with Sweden, Thailand, Brazil, the USA and China also maintaining high ratings in 2023. According to this indicator, Ukraine attained 45th position, a noteworthy achievement given the prevailing internal socio-economic challenges and financial reliance on partner countries.

Irrespective of high-tech imports, Switzerland can be regarded as a leader according to the indicators in Figure 6. The leading countries according to this indicator are Vietnam, China, the USA and Thailand. Ukraine is dependent on high-tech imports, which explains its 48th place. In pursuit of the goal of innovation and digitalisation, every country in the world should create appropriate institutional and structural conditions to become less dependent on the import of high technology. It is worth stimulating the development of institutes of science, education, technology and innovation by supporting institutes of innovative and digital development whose activities are aimed at increasing innovative and digital activity using the latest high-order technologies.

Switzerland is the world's leading exporter of high technology, and it goes without saying (Figure 7). That it receives the highest income from intellectual property. The United States, Sweden and China rank high in terms of income from intellectual property. China, Vietnam, Thailand, the US and Sweden will continue to focus on high technology exports.

Most of the advanced countries of the world with an innovative economy are striving to accelerate technological progress, and there is a growing realisation that we are on the threshold of impressive discoveries, because the basis of the VIIth technical and technological system is being formed, and its main production factor is not innovation, but creative intelligence. In accordance with this technical and technological structure, technological changes are not confined to a mechanical procedure of identifying superior products or high-quality services and digitising production business processes. The objective of enhancement and utilisation in DE and in the course of the digital identification of a person, cognitive drugs, cognitive assistants, neuroimaging, the formation of artificial sense organs, and applications of Brain-Machine Interfaces is being pursued.

6. Drivers of Innovation and Digital Economic Development

There is already in the literature "the concept of collective intelligence (people and their autonomous digital clones) as a joint authority to make decisions, which can be a driver for a sustainable industry focused on collective intelligence 4.0 – a hybrid of Industry 5.0" (Golovianko, 2023). Universities that will "support socially oriented scientific research and

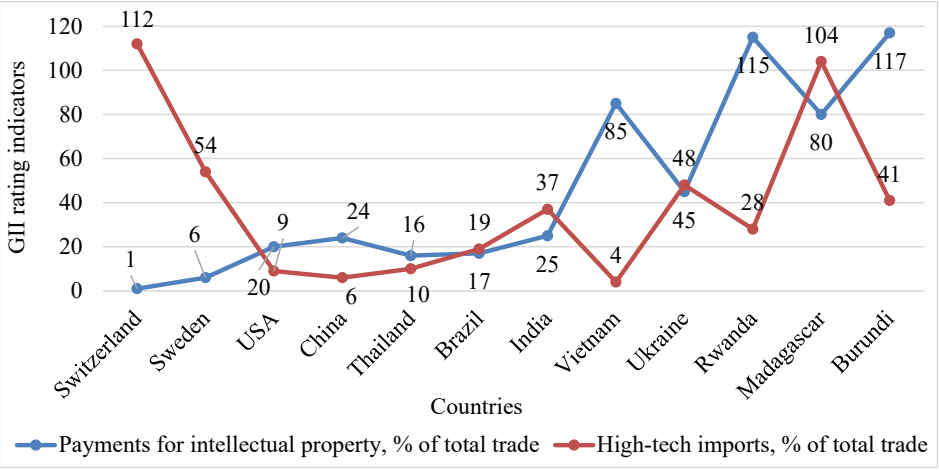


Figure 6. GII 2023 ranking of countries according to the Business Sophistication index within the Knowledge Assimilation sub-index by country group by income level

Source: built on the basis of (Dutta, 2023)

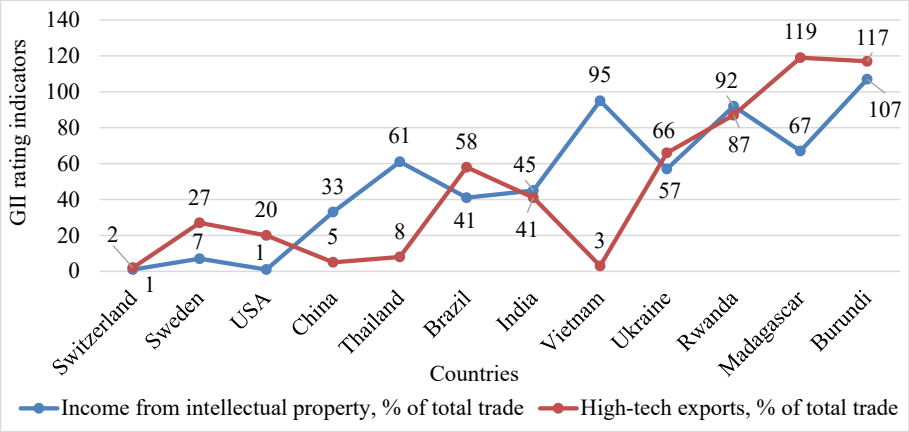


Figure 7. GII 2023 country rankings for the Knowledge and Technology Outputs index within the Knowledge Diffusion sub-index by country group by income level

Source: built on the basis of (Dutta, 2023)

strive for innovation, which creates the basis for social innovation that meets public and private values and needs...; the digital context of innovation can change the way innovation and knowledge are disseminated and created in socio-economic systems. The power of new IT tools and AI can lead to more democratic approaches to the management, transfer, and dissemination of knowledge in society." (Carayannis & Morawska-Jancelewicz, 2022)

It is hypothesised that in countries with innovative digital economies, this is achieved through the functioning of the following type of chain:

"*The spirit of invention and research – the spirit of DE – guarantees of profitability/reward for innovation – protection of intellectual property rights – free institutionalized innovation market and numbers.*"

Working along this chain lays the foundation for the formation of Industry 5.0. The Industry 5.0 ecosystem is so advanced that its 4 drivers have formed and crystallised, as shown in Figure 8.

"Industry 5.0 emphasizes changes from mass automation to the process of increasing the capabilities of workers to achieve personalization," so it is necessary to understand what skills need to be acquired and developed, what the rules of human-machine interaction are, and whether conflicts between humans and AI can arise (Paschek, 2019).

Among the mechanisms that would contribute to the accelerated establishment of Industry 5.0 based on DE, it is worth mentioning financial and institutional support for basic scientific, technical and engineering work, research and development. Not the last "violin" in the process of digitalisation of the Industry 5.0 ecosystem is played by an effective patent system available in the country, and financial and economic incentives, such as tax credits for funds that have a targeted direction for conducting scientific research and search work. Governments of countries that have chosen the path of accelerating the digitalisation of business should stimulate technological progress, the emergence and application of innovative technologies and encourage foreign investors to invest their free funds in economies that show hope for innovation and digitalisation.

The implementation of an effective macroeconomic policy can contribute to the emergence of new digital technologies. The content of the policy to promote innovation and the digitalisation of the economy consists in low but constant taxes, fees on capital income and the low cost of capital for the digital enterprise. Digital enterprises must focus on a quick return on investment. Provided that the digital enterprise enjoys low interest rates, this condition should be viewed by the digital enterprise as an

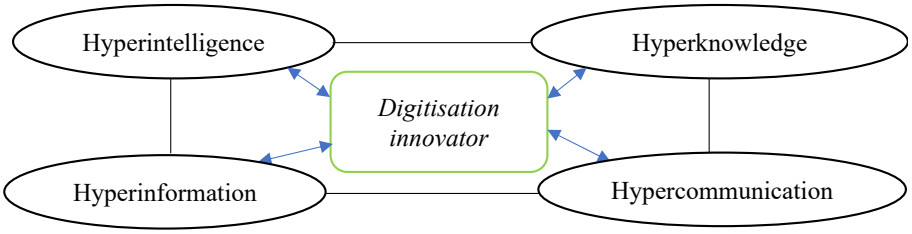


Figure 8. Four driving forces for the progressive development of Industry 5.0

Source: development of the authors

opportunity for long-term capital investment. It is evident that if real interest rates were lower for digital enterprises, then such a direction would provide DE with greater incentives and motivation to engage in long-term, high-risk projects (Samuelson & Nordhaus, 1998). It is evident that the enhancement of digital technologies and the escalation in productivity within digital enterprises can only be attributed to the augmentation of investments in the knowledge of creative individuals who generate innovation in the "world of numbers".

There is an opinion in the academic community that the future focus should be on how humans and machines co-operate in different sectors; how Industry 5.0 can contribute to more sustainable production processes; new cybersecurity solutions to protect Industry 5.0 systems from cyber threats; ethical aspects of Industry 5. 0, in particular the impact on employment and social justice; on developing a better dual transition to Industry 5.0, as well as how the digital transition can contribute to the environmental transition; on exploring new business models that take advantage of Industry 5.0 opportunities, as well as exploring the challenges and opportunities associated with their implementation (Youssef & Mejri, 2023).

7. Conclusions

Scientific and technological progress is an important factor in the long-term digital development of the innovative economy. Under the conditions of complex modernisation of the economy, digital transformation and institutionalisation of innovative development, there are opportunities for rapid and radical innovative changes in the digitalisation of business processes for companies, organisations and enterprises. It is about optimising and digitalising production capacities, increasing the share of the latest technologies in the added and consumer value of the produced innovative product and digital service, and carrying out innovative digital technical and technological modernisation of the production process in DE.

An attempt has already been made to fill the research gap on the institutional changes and incentive structures that influence the ability of universities to engage in (digital) social innovation within the digital and environmental transition. "Rapid transformation..., the complexity and variability of modern challenges (for example, climate change or political and economic disturbances) can lead to further turns that will affect the development of ecosystems and the role of universities in them," (Carayannis & Morawska-Jancelewicz, 2022) and therefore in the future it is worth focusing on twin issues of university digital transitions, new types of digital and social innovation in innovation ecosystems that integrate human-machine relationships and prioritise environmental and sustainable considerations.

Digital technologies and technical-technological changes that accelerate the development of Industry 5.0 have resulted in a shift in the content of the work of innovative ecosystems, with a concomitant emphasis on the development of their digital component. In the 21st century, the basic aspects of creating digital platforms are undergoing rapid change, giving rise to synergistic effects for participants in virtual network businesses. A balance is emerging between spatial and territorial economic development. Technological changes can be regarded as a component of the process of deepening the utilisation of intellectual capital. Economic growth factors, which function as drivers of economic progress, generate a high level of added value in domains such as information technology and implant technology, aerospace and genetic engineering, and microelectronics.

Despite the fact that "digital technologies promote social integration, increase connectivity and promote broader integration of stakeholders", scholars highlight the limitations of implementing digital technologies within the framework of sustainable business models (Fuerst, 2023) and propose a number of policy solutions to overcome such gaps: "further acceleration of the digital economy process; improvement of the institutional environment of the broadband access network and standardisation of the order of construction of the broadband access network; stimulating the entrepreneurial motivation of the workforce, paying attention to the problem of skill bias and optimising the employment structure, balancing efficiency and equity, and contributing to the ultimate sustainable development of developing countries" (Kong, 2023).

The role of STP in increasing productivity, production and industry, and the level and quality of life in society, is indisputable. The effectiveness of the application and use of factors of economic growth is evidenced by the increase in the number of digitised equipment during the formation of DE and innovative technological modernisation of production through the use of mobile and adaptive technologies, big data analytics, cloud computing, e-commerce, and Internet trade.

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