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AN EVALUATION OF THE COMPETITIVENESS OF THE SLOVAK AUTOMOTIVE INDUSTRY VIA DIGITALIZATION AND THE ADAPTABILITY OF THE POPULATION TO INDUSTRY 4.0

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Abstract. In this paper, the social effects of rapid digitization in Slovakia are examined. Several data show that the Slovak economy has become less competitive since 2020. Similarly, Slovakia's preparedness for transformation into a modern and resilient economy is a matter of concern. The methodology investigates insolvency models in Slovakia via descriptive statistics of the secondary data. DESI data illustrates population digitization. Study objectives were compared and synthesized using data and visualization techniques. Graphs indicate that the influence of digitization on production and logistics automation surpasses that on product value. The study highlighted the importance of monitoring and predicting digitization's effects. Countries being reviewed must understand this and make changes as quickly as possible.

Keywords: digitization, Industry 4.0, employment, financial analysis, automation, corporate performance.

JEL Classification: A11, C10, O32.

1. Introduction

The changes in manufacturing and associated business activities brought about by digitization are referred to as "Industry 4.0" and "the fourth industrial revolution" (Durana et al., 2021). Industry 4.0 is a topic of discussion among both experts and the public as a result of the gradual incorporation of digitization into daily life (Kliestik et al., 2018). To increase industrial output, the Germans developed Industry 4.0. As a result of this decline, manufacturing establishments were relocated to countries that offered more favorable economic conditions than Germany. Undergone substantial transformations since the onset of the first industrial revolution is the industrial sector (Nikulin et al., 2021). This revolutionary industrial era witnessed the invention of the steam engine, which propelled the industry forward. Electrical energy consumption increased, manufacturing processes were electrified, and the internal combustion engine was invented during the second industrial revolution (Wong & Ngai, 2021). Productivity increased as robotics and ICT were progressively integrated into manufacturing processes during the third industrial revolution. Industry and production underwent substantial expansion and innovation during the preceding industrial revolutions (Nagy et al., 2023). The rapid advancement of technology has facilitated the development of artificial intelligence and the Internet of Things via cyber-physical production systems based on digital twins, algorithms for environment mapping, and immersive metaverse technologies (Zhong et al., 2021). The fourth industrial revolution, Industry 4.0, was established by these developments (Nica, 2021). As a result of the increased productivity brought about by the first industrial revolution, businesses were compelled to maximize profits. As a result, employee discontentment ensued (Cheng et al., 2022). During the Second Industrial Revolution, labor conditions were deplorable, and workers' rights were severely restricted (Yumei et al., 2021). The third industrial revolution generated new employment opportunities by substituting computer technology for human labor. As a result of the fourth industrial revolution, particularly the implementation of Industry 4.0 business principles, it is anticipated that the labor market will undergo transformation. The initial segment of this manuscript presents a theoretical framework and defines the terminology associated with

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"Industry 4.0." The paper analyzes the digital era in Slovakia and provides a description of the research methods in the Materials and Methods section. The assumption assesses the competitiveness of the V4 countries and selects the company due to its market position and potential for insolvency. This portion of the analysis is critical for the adoption of Industry 4.0 in these countries, as it is dependent on the operational performance of industrial enterprises. The utilization or feasibility of technological advancements by loss-making companies cannot be ascertained because no company satisfies the minimum financial performance criteria. Then, enterprises classified by sector and scale by the DESI index are analyzed. It generalizes the digitization of these nations by quantifying the digitization of a subset of corporations. A comprehensive evaluation of the level of digitization in the Slovak Republic and graphical case studies from the automotive industry follow the results of the analysis. Evaluating the analyses and their worth concludes the undertaking. Such analyses are uncommon, and their direct correlation is the final one; this section describes the potential benefits and implications of the research.

2. Literature review

Organizations, investors, regulatory bodies, and scholars can discern practices that contribute to profit management and gain insight into its incentives and repercussions by employing a multi-pronged examination of the competitiveness of nations and their corporations. This is particularly true considering the ongoing transformations taking place within organizations. The integration of exponential technologies and continuous digitization, which form the foundation of Industry 4.0, are currently being integrated into the business strategies of every significant economic sector (Argawal & Chaterjee, 2015). The evaluation of the financial health of a company is an essential component throughout the business life cycle. A significant indicator of the organization's present state is its financial health (Belas et al., 2021). Organizations are obliged to adjust to prevailing market conditions due to perpetual competitive pressure and dynamic market shifts. Business managers are able to make decisions that may impact the company's future trajectory, such as identifying trends and future directions to attract investors and improve competitiveness, based on an analysis of the finance department's operations. Due to Mergel et al. (2019), the competitiveness of economies and businesses is a crucial economic indicator. Entrepreneurs who operate rationally do so with the ultimate goal of attaining success. As per the established life cycles, the organization experiences a critical juncture that necessitates adaptations to ensure its continued existence amidst the fiercely competitive business landscape. An instance of such adaptation involves the application of earnings management strategies. A rise in revenue signifies an augmentation in the value of the organization, whereas a decline in revenue signifies a reduction in value. Profit management is of general interest to the organization's leadership (Elkington, 1994; Beneish et al., 2012; Gray & Kovacova, 2021). Therefore, it is critical that administrators understand the ramifications of their accounting decisions and can make the most advantageous choices for the business (Cantele & Cassia, 2020; Du et al., 2017). The imperative for financial stability and competitiveness forces organizations to effectively oversee their financial outcomes (Grimaldi et al., 2020). A multitude of studies substantiate the correlation between earnings management and the level of competitiveness. In pursuit of enhanced earnings management, corporations may choose to disclose favorable returns as evidence of their favorable market valuation (Evangelista et al., 2014; Grofcikova, 2020; Jacoby et al., 2019). It is imperative to not only oversee the correlation between profit management and its influence on the financial well-being of the organization, but also to closely monitor its internal operations. As a consequence of the emergence of digitization, which imposes novel obligations on the trajectory and framework of business operations, management methods and approaches are profoundly transformed, existing business models are influenced to evolve, new professions emerge and existing ones are modified, the education, capabilities, and skills of the human workforce undergo a substantial transformation and expansion, the economy undergoes a transformation, and digitization may even function as a multiplier effect (Ionescu, 2021; Clayton & Kral, 2021). The main area of investigation is Industry 4.0, an organization that utilizes sensing networks and sensors, the Internet of Things, computer-based physical systems in manufacturing, intelligent planning processes based on deep learning, and cognitive automation (Durana et al., 2020). To achieve a comprehensive understanding of this subject matter, it is imperative to establish the foundational theoretical framework. Self-configuring, Internet-based networks that operate entirely autonomously are the driving force behind Industry 4.0 (Koderova, 2016; Gajanova et al., 2020). Furthermore, it comprises Internet technologies that have been integrated into a multitude of sectors of industrial production. Kliestik et al. (2018) underscore the importance of establishing connections via both tangible and digital information. Industry 4.0 is predicated on the application of the notion of digitization to horizontally integrated processes whose values and flow are specified. This correlation implies the concept of "digitization."

3. Materials and methods

Environmental policy, education, technology, and innovation are all areas that Industry 4.0 seeks to enhance. This was brought about by the Internet's exponential expansion and technological developments. Fundamental knowledge of Industry 4.0 consists of: Horizontal integration comprises extensive production networks, client and business partner networks, and advanced business models; technological implementation encompasses the entire product life cycle; and market exponential technology expedites the reduction of operational expenses; vertical integration comprises innovative production systems, logistics, production, and marketing. By utilizing spatial data visualization techniques, digital twins, autonomous systems, and virtual reality modeling tools, Industry 4.0 can be implemented in the automotive product development sector. Two categories of Industry 4.0 technologies exist, according to their intended purpose. The framework will prioritize front-end technologies associated with Industry 4.0, which offer commodities as intelligent products and transform production into intelligent production (Nagy & Lazaroiu, 2022). The delivery method (smart supply chain) and processing (smart labor) are also incorporated. To attain a comprehensive understanding and sound analysis, it is imperative to initially scrutinize and assess the financially active companies in the specified nations. The degree of digitization among corporations, countries categorized by business sector, and the magnitude of these corporations will be disclosed subsequent to an assessment of their digital adaptability. Authors have determined the most significant technologies in terms of practical outcomes and operational efficiency, namely computer vision algorithms, remote sensing data fusion techniques, and mapping and navigation tools, by analyzing the most recent data and literature on Industry 4.0. Book articles, websites, government publications, internal records, and official documents constituted the principal information sources for this research. The automotive industry contributes as much as thirteen percent to the gross domestic product (GDP) of the Slovak Republic. The latest developments in traffic flow prediction tools, artificial intelligence-based decision-making algorithms, and collision avoidance technologies are closely linked to the establishment of Volvo, a Swedish automotive manufacturer, in the eastern region of Slovakia in 2025. Volvo will specialize in the production of electric vehicles. The Slovak automobile industry's export composition is predominantly composed of passenger vehicles (HS 8703), their respective components (HS 8708), and their bodies (HS 8707) (Federal Ministry for Economic [FMFE], 2017). The automotive sector provides a contribution ranging from 10% to 8% of the gross domestic product (Hungary: 10%; Czech Republic: 7%; Poland: 8.5%). The automotive sector holds considerable importance in the V4 countries, as it generates an estimated 2.7–3 million passenger vehicles and provides employment for nearly 700,000 individuals annually (FMFE, 2017). Sectors and the entire industry that operate within it have a significant influence on production systems based on Industry 4.0. While certain nations may hold a global lead in manufactured units, this dominance does not extend to value-added exports. Due to the exclusive focus on production processes rather than conducting comprehensive research and development, the added value of SR in the automotive industry has fallen short of its potential. Significant developments in the automotive sector pertaining to electromobility and other transformations commonly linked to Industry 4.0 have surfaced within the last five years. The integration of deep learning object detection technology, trajectory planning algorithms, and geospatial data visualization tools has been observed to enhance connectivity and technology-driven services, added value, comfort, and safety within the automotive industry in Slovakia (Figure 1).

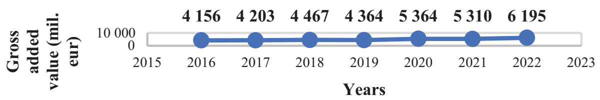

Figure 1. Gross added value of the Slovak manufacturing industry from 2016 to 2022 (mil. €) (source: own elaboration)

Based on data from the Statistical Office of the Slovak Republic, industrial output contributes substantially to the creation of gross added value in the national economy. The data presented in Figure 1 exhibits a straight-lined increase from 2016 to 2022. The gross added value of industrial output peaked at approximately 6,195,000 euros in 2022. The value-added position of the Slovak Republic is approximately 22nd (16.8%) among the member states of the European Union, with the V4 countries trailing it marginally. As mentioned earlier, the Slovak Republic fails to fully exploit its capabilities; consequently, it has resorted to functioning as a nation primarily engaged in assembly operations, devoid of any significant research and development initiatives. The primary reason the Czech Republic has the highest added value (around 21 percent) among the V4 nations is Skoda Auto, which is the largest initiator of passenger car research and development in Mlada Boleslav. A considerable number of analysts and automakers perceive the prevailing megatrends in the industry as a transition towards the ACES model (autonomous driving, connectivity, electromobility, and shared mobility services) through the integration of mapping and navigation tools, obstacle avoidance algorithms, remote sensing technologies, and obstacle avoidance algorithms (Zhong et al., 2021). Prominent original equipment manufacturers (OEMs) predict that the advancement of autonomous vehicles will impact the future expansion of the industry via algorithms for environment mapping, intelligent traffic planning and analysis, and network connectivity. This is corroborated by the European Union's resolution to discontinue manufacturing of vehicles powered by internal combustion engines subsequent to 2035.

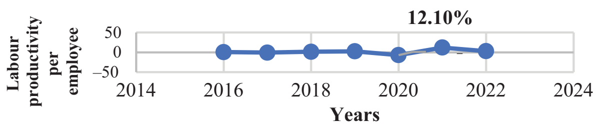

Figure 2. Labor productivity per worker (industrial production enterprises, 2016–2022 (%)) (source: own elaboration)

A significant trend in labor productivity per employee among industrial production enterprises with a workforce exceeding 20 individuals between 2016 and 2022 is depicted in Figure 2. During the period under investigation, labor productivity experienced an initial decline, succeeded by a subsequent increase. From a historical perspective, real labor productivity per employed individual in Slovakia increased substantially, peaking at 12.10% year-over-year in June 2021 and falling to an all-time low of –7.20% in June 2020. Several methodologies were employed to conduct a more comprehensive analysis of the added value and potential of digitization, as well as the Industry 4.0 trends that influence the added value in the economies of the V4 countries (mainly in Slovak republic). These methodologies utilized current secondary data from the companies of the V4 countries, including fundamental financial indicators and other company characteristics. Additionally, an automotive industry case study was presented, which offered a more comprehensive evaluation of the organization's digital agility. Furthermore, the research incorporates a comprehensive synthesis and analysis of subsequent findings. Given that the examination of added value is currently underway within the automotive sector, the findings of this case study will essentially apply to the entire industrial domain of the V4 nations, with a specific emphasis on the automotive industry. After conducting an analysis of secondary data that unveiled the progression of Industry 4.0 in the V4 countries, the subsequent methodological procedures were implemented in order to accomplish the principal aim of the study: 1) This research examines secondary sources pertaining to the growth of the automotive sector in the V4 countries, with a limited discussion of other sectors as classified by the SK NACE division. Organizations eligible for digital transformation are identified through the analysis of their financial analytics, which disclose details such as their rate of success and susceptibility to insolvency. Emerging markets were analyzed in this study utilizing Altman's Z-Score and Taffler's models (Sario, economy.gov.sk, datacube, Statistical Office of the Slovak Republic). From the available data (The ORBIS Database), information on 16,689 businesses from the V4 countries was extracted. The analysis utilized these two fundamental models due to their ability to depict the financial condition of companies faithfully and unambiguously, despite their advanced age. Moreover, these models are applicable to developing markets, including those in the V4 countries. 2) Analyze the application of the digital-economic-social index (DESI) in order to decipher the extent of digital transformation demonstrated by V4 firms, with firms classified according to industry and company size. 3) A visual depiction of a case study within the automotive sector, focusing on automotive companies in particular, that emphasizes the automation of production and the areas of the organization that are most heavily automated through digital means. Following this, an application of these results to the automotive industry in the V4 nations is presented. An analysis of the automotive industries in the V4 nations, concentrating on the development and expansion of value-added via the implementation of Industry 4.0, digitization, and innovation.

4. Results and discussion

Determining the degree to which businesses in Slovakia (V4 nations) have embraced digitization and adaptability is the principal aim of this research. Given the prevailing conditions in the Slovak Republic, it is critical to realign efforts towards endeavors linked to the generation of substantial added value, as the country is falling behind its V4 counterparts in this aspect. This comprehensive segment is comprised of an ample number of subsections. Although they each focus on a unique objective, they ultimately achieve the same result. The sequence of stages (Figure 3) of the analysis, which evaluates the financial health of the company using the Altman Z-Score model for developing countries and the Taffler model, comprises the results section. Subsequently, the aforementioned EU digital index will be analyzed to obtain a comprehensive overview of the most digitally prepared enterprises in the V4 countries. This analysis aims to ascertain the nation that is most adequately equipped to embrace digitization. The third assignment is to perform graphic processing on the case study of the automotive industry. The aim is to identify the processes within automotive companies that are most vulnerable to digitization and to conduct a thorough assessment of the latest Industry 4.0 trend and its implications for various domains. By doing so, the assignment clarifies the trend's fundamental function and the responsibility of the general public to comprehend it. The series of events is depicted in Figure 3.

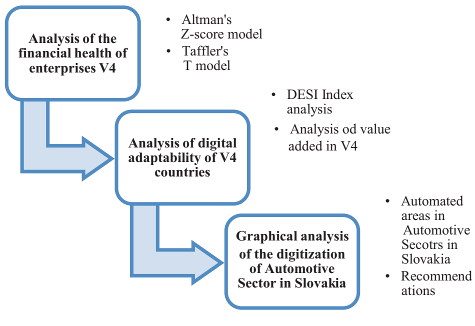

Figure 3. The order of research procedures
(source: own elaboration)

4.1. Analysis of the financial health of enterprises V4

This segment provides a description of a subset of the corporations from the ORBIS database that were utilised in the study – descriptive statistics of the secondary data. Companies were initially categorised based on their industry of operation, and subsequently assessed on their financial well-being. The analysis focused exclusively on sound companies, as it was rationalised that insolvent organisations would not engage in digitization efforts.

As it comprised employees from various departments, the quantity of whom varied according to the respective organisations, the inquiry in the questionnaire survey can be described as a random selection. In order to conduct this analysis, a subset of firms was classified into five fundamental sectors based on the concentration of their primary production as denoted by the SK NACE code: manufacturing (C); electricity and gas (D); construction (F); wholesale and retail trade (G); and transportation (H). The sectors in question were selected for the analysis due to their most substantial representation in the V4 countries. It is feasible to discuss critical sectors that constitute the economic foundation of the countries in question. For the investigation, every legal business structure that was accessible was chosen. Prominent industries, including automotive manufacturers, are trailblazers in the adoption of digital technologies and drive economic growth; thus, eliminating outliers from the sample would invalidate the analysis. In this study, three business sizes – large, medium, and small – were analyzed. The enterprises were categorized based on their size for the purpose of analysis, under the premise that larger organizations utilize the I4 foundations more frequently than smaller organizations with fewer employees. Additionally, it is customary in financial analysis to categorize entities into three tiers based on their magnitude. The analysis mentioned above occurs during the period from 2016 to 2021. Therefore, this time frame can be partitioned into two distinct periods: the pre-COVID-19 period (2016–2019) and the COVID-19 period (2020–2021). Out of the total cohort, 16,689 enterprises are represented by the V4 nations. The analysis utilized the foundational frameworks of financial analysis of enterprise health developed by Altman and Taffler (Taffler & Harvey-Cook, 1988):

$$Altman\ Z\text{"}\ Score\ model\ for\ EM = 3.25 + \left(A \times 6.72\right) + \left(C \times 1.05\right) + \left(D \times 6.5\right) + \left(E \times 3.26\right), \quad (1)$$

where:

$$A = {EBIT}\!\left/\!{Total\ assets}\right.;$$

$$C = {Book\ value\ of\ equity}\!\left/\!{Total\ liabilities}\right.;$$

$$D = {Working\ capital}\!\left/\!{Total\ assets}\right.;$$

$$E = {Retained\ earnings}\!\left/\!{Total\ assets}\right..$$

$$Taffler\ T\ Score\ model\ for\ EM = 0.53 \times X1 + 0.13 \times X2 + 0.18 \times X3 + 0.16 \times X4, \quad (2)$$

where,

$$X1 = {EBT}\!\left/\!{Current\ liabilities}\right.;$$

$$X2 = {Current\ assets}\!\left/\!{Total\ liabilities}\right.;$$

$$X3 = {Current\ assets}\!\left/\!{Total\ assets}\right.;$$

$$X4 = {Revenue}\!\left/\!{Total\ assets}\right..$$

The comparison of the Altman model's outcomes is as follows: A Z model value exceeding 2.6 signifies that the environment in which the organization operates is stable, competitive, and sustainable. When Z falls within the range of 2.6 to 1.1, the organization finds itself in an ambiguous position where it does not incur losses but also lacks a more secure market position. The company should exit the market without delay if its profitability and competitiveness diminish to a level below 1.1 on the model.

Table 1. Altman's Z-score model for emerging markets (period 2016–2019) (source: own elaboration)

Altman's Z-score model for emerging markets				
Before COVID-19 (2016–2019)				
Company size	Number of companies	Green zone (Z > 2.6)	Grey zone (Z = 1.1–2.6)	Red zone (Z < 1.1)
Large sized companies	1,933	1,687	133	113
Medium sized companies	8,043	7,648	283	112
Small sized companies	6,713	6,255	316	142

Table 1 presents the interpretation of the Altman Z-Score model analysis for emerging businesses in the V4 countries from 2016 to 2019, prior to the COVID-19 pandemic. The analysis is based on the data mentioned earlier. The table unequivocally depicts the categorization of enterprises based to scale. The objective of this table is to categorize the businesses of the V4 countries based to their stage of development prior to and subsequent to

Table 2. Altman's Z-score model for emerging markets (period 2020–2021) (source: own elaboration)

Altman's Z-score model for emerging markets				
After COVID-19 (2020–2021)				
Company size	Number of companies	Green zone (Z > 2.6)	Grey zone (Z = 1.1–2.6)	Red zone (Z < 1.1)
Large sized companies	1,933	1,682	146	105
Medium sized companies	8,043	7,612	296	135
Small sized companies	6,713	6,278	297	138

the COVID-19 era. Evidently, a significant proportion of enterprises are situated in the green zone, signifying their competitive stability and a strong inclination towards future endeavors involving the widespread adoption of digital solutions, thereby facilitating their progression towards financial stability. 367 organizations are located in the red zone, while 732 are located in the gray zone.

Table 2 depicts the same method of analysis, but for the COVID-19 period, where it can be observed and argued that there is not a significant departure from the preceding period. Potentially attributable to the robust position of certain industries, particularly automotive and other industrial firms, which also exhibited commendable performance throughout this time frame. For additional analysis, the Taffler model was utilized, which serves a comparable purpose by expressing the competitiveness stage of the organization. This model's results are interpreted as follows: T > 0.3 – the company is in the green zone, it is advantageous, and it generates a great deal of value. T = 0.2 – 0.3 – the business is in the gray area. T < 0.2 – the company must cease operations; it is in the danger zone.

Table 3. Taffler's model for emerging markets (period 2016–2019) (source: own elaboration)

Taffler's model for emerging markets				
Before COVID-19 (2016–2019)				
Company size	Number of companies	Green zone (T > 0.3)	Grey zone (T = 0.2–0.3)	Red zone (T < 0.2)
Large sized companies	1,933	1,780	108	171
Medium sized companies	8,043	7,648	298	147
Small sized companies	6,713	6,255	327	166

Based on Table 3, it can be concluded that the majority of businesses operate in the green zone and are therefore competitive. There are approximately 700 businesses in the gray zone, 340 in the red zone.

Table 4. Taffler's model for emerging markets (period 2020–2021) (source: own elaboration)

Taffler's Z-score model for emerging markets				
After COVID-19 (2020–2021)				
Company size	Number of companies	Green zone (Z > 2.6)	Grey zone (Z = 1.1–2.6)	Red zone (Z < 1.1)
Large sized companies	1,933	1,732	89	103
Medium sized companies	8,043	7,575	312	156
Small sized companies	6,713	6,213	346	154

Table 4 demonstrates the same concept as Table 3, but for the period following COVID-19. The table confirms that these are not particularly large deviations; thus, the majority of companies in the V4 countries are still in the green zone, i.e., they are stable and competitive. In order to demonstrate which country has the highest level of green competitiveness from a more recent perspective (Figure 4).

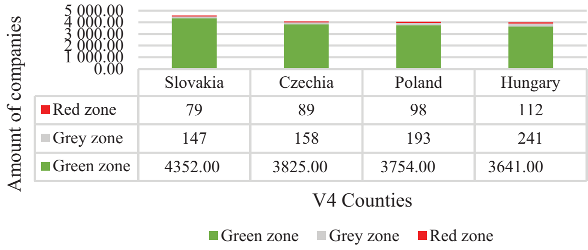

Figure 4. Illustration of the financial stability of the V4 nations (source: own elaboration)

Figure 4 depicts the interpretation of Altman's model in the COVID-19 period, as well as the specific distribution of V4 countries and their comparative competitiveness. As can be seen, the Slovak Republic has the greatest number of green businesses (cca 27.95 %), followed by the Czech Republic (cca 24.56 %), Poland (cca 24.11 %), and Hungary (cca 23.38 %). There are the most gray and red businesses in Hungary. Authors selected the current period 2019–2020 (i.e., after the period of COVID-19) and the Altman model for the analysis; as both models are very similar, it is unnecessary to mention both. It is possible to contend that the V4 nations and their companies are primarily stable and have high market values.

4.2. Analysis of digital adaptability of V4 countries

The Digital-Economic-Social Index (DESI), which evaluates a nation's preparedness for the digital age by considering human capital, connectivity, integration with digital technologies, and digital public services, is employed in this analysis. The authors of this analysis utilized data from the DESI study for 2022 (Nagy et al., 2023), which provides the means to ascertain which EU member state generates the most optimal digital transition assumptions.

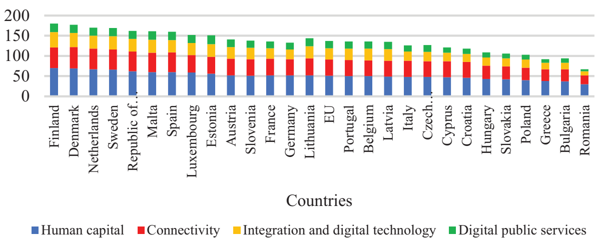

Figure 5. DESI index ranking 2022 (EU countries) (source: own elaboration according to Federal Ministry for Economic, 2017 (accessed on 28 July 2023))

It is possible to deduce, based on the data presented in Figure 5, that Finland exhibits the most elevated degrees of digital readiness, stability, and complexity.

Nevertheless, among the V4 nations, the Czech Republic possesses the most potential, followed by Slovakia and Hungary, and finally Poland. Over an extended period of time, the proactive research policy of the Czech Republic is evident in this case, specifically in the Skoda automobile corporation, which employs the most cutting-edge research methodologies globally. The primary emphasis is placed on exclusive engines, designs, and innovative methodologies. To provide a more comprehensive analysis, this study examines digital adaptability in relation to the sample size and industry (16,689 businesses). Determining the approximate level of business digitalization in the V4 nations is the aim of this study. Additionally, DESI data are employed in this analysis.

Table 5. Digital adaptability analysis (source: own elaboration)

Digital adaptability Analysis					
Size/ Sector	Manu-facturing	Electri-city	Cons-truction	Whole-sale	Trans-porta-tion
Large	50.02%	66.41%	26.23%	63.99%	63.99%
Me-dium	25.01%	46.40%	17.63%	34.76%	34.76%
Small	23.79%	42.40%	9.46%	29.23%	29.23%

For Table 5, a sample of businesses from V4 nations was analyzed. The degree of digitization exhibited by these enterprises is indicative of their industry and size. Large organizations possess indispensably more time, energy, data, and other resources to implement this transition. Automobile manufacturers naturally fall within the classification of large corporations; thus, the analysis unequivocally demonstrates the ramifications of Industry 4.0 in these domains. Considering the Slovak Republic's reliance on the automotive industry, this would substantially boost exports of value-added products. Based on a prior assessment of financial health, the preponderance of green companies situated in Slovakia. This signifies that the Slovak Republic ought to promptly capitalize on this opportunity, as it holds immense potential for establishing leading positions in the realms of research and development and digital expertise.

4.3. Graphical analysis of the digitization of automotive industry in Slovakia

A questionnaire-based graphical representation of the digitalization of the automotive industry in Slovakia constitutes the final analysis of this project. This segment was finalized with the aid of the digitization department of this organization (approximately eighty individuals from various companies). In Slovakia, four automobile manufacturers are operational, followed by a cluster of lesser connected enterprises. The authors successfully contacted the aforementioned subset of employees from these organizations in order to collect the required data via their responses. These individuals held positions in the administrative, production, and management domains. The majority of the queries were open-ended. As shown in Figure 6, approximately 55% of the industrial sector is comprised of automated processes. Robotic processing and laser technology (675 robots) are the principal concerns in this context. Maintenance and services occupy a tie for third place with a 10% share, whereas logistics ranks second with a 20% share. The increasing prevalence of mechanized equipment and product movement further underscores the growing significance of logistics. While the remaining 5% of activities consist of a diverse range of tasks, the vast majority (95%) are core processes that are automated.

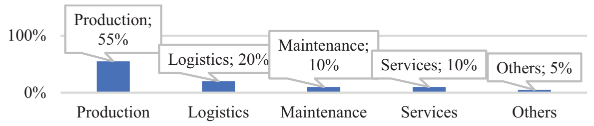

Figure 6. Automated areas of the automotive companies in Slovakia (source: own elaboration)

The applicability of cyber-physical production systems to the vast majority of industries was confirmed by the respondents. The implementation of Industry 4.0 should be undertaken on a national scale, given the considerable variation in viewpoints regarding the intricacy of the fourth industrial revolution (Nikulin et al., 2021; Kliestik et al., 2020). Investing in research and development, enhancing education, fostering the development of young talent, expanding school laboratories, and undertaking similar initiatives are regarded as critical. The analyses provide insight into the considerable adaptability exhibited by populations and businesses in the V4 nations. However, this is a national issue, not just one involving corporations; therefore, state governments and the law are also essential (Cheng et al., 2022; Durana et al., 2020). This suggests that in the absence of adequate state assistance, this trend might not lead to the progress of nations, but rather to their deterioration (Clayton & Kral, 2021). Incorporating cognitive wireless sensor networks, connected vehicle technologies, algorithms for environment mapping and location tracking, mapping and navigation tools, and similar components into intelligent urban mobility systems is not only advantageous but also essential for modern life (Ionescu, 2021). The foundational principles of digitization possess the capacity to significantly enhance the standard of living and safeguard the lives of the inhabitants in each of these countries. IoT sensing networks, spatial data visualization tools, cyber-physical production networks, and cognitive decision-making algorithms comprise the sensing sectors of Industry 4.0 (Nagy et al., 2023). Urban transportation systems integrate digital twin algorithms, machine learning and deep learning technologies, virtual reality modeling tools, and IoT-based production logistics in real time. Intelligent and sustainable urban mobility systems are optimized through the utilization of robotic wireless sensor networks, spatial data visualization techniques, virtual simulation modeling tools, and artificial intelligence cognitive algorithms. These questions were conclusively answered by the analyses: the vast majority of organizations are already implementing digitization on a large scale and are adaptable to the issue; and high-quality technologies can assist organizations in predicting their competitiveness and/or bankruptcy by notifying them of potential downtime or other production gaps (Kliestik et al., 2018). As the European Union pursues digitization, it is critical to remain current and refrain from prematurely abandoning this process. Unambiguously, the organization affirmed that Industry 4.0 is an indispensable component in all departments capable of digital communication; the only remaining factor is a readiness to adopt and integrate such an intricate system; once more, government backing is vital.

5. Conclusions

The research demonstrates the digitization and Industry 4.0 potential of V4 nations. Public safety, numerous industries, and cyber security all rely heavily on digitization. An examination of digitization across various sectors reveals that adaptability increases annually. It is significant whether its growth is contingent on components or growth alone, to what degree its expansion is dependent on exports of added value, and in what way. Based on this study, V4 vehicle Industry 4.0 production systems incorporate computer vision algorithms, integration of remote sensing data, and mapping and navigation functionalities. The proportion of V4 nations with financially stable sectors and industries relative to their size was the subject of this initial of three studies. Assuring organizations had attained this level in order to foster adaptation was crucial. An analysis shows that most businesses in these nations are financially stable, enabling Industry 4.0 adoption. This data showed Slovak companies were most stable. The next section examined nations' and businesses' digital readiness. The V4 DESI digital index placed Slovakia second behind the Czech Republic. Electrical and industrial industries are digitally intensive. Slovakia has the biggest EU automakers. Like the third study, this showed limited added value and suggested allocating significant resources to research and development with government support from specific countries. The majority of companies (primarily automotive) that conducted the research, confirmed the highest level of production automation and predicts that the digitization of logistics will increase by 27% annually. Given the occasional lack of comprehension regarding the concept of digital adaptability, it is imperative that all nations under examination develop into proactive, innovative nations by not only implementing similar digitization recommendations but also taking the initiative to do so. When this research establishes a connection between digital adaptability, Industry 4.0, and business finances, it is at its most beneficial. Although summarizing this intricate matter presents the greatest challenge of this endeavor, it significantly enhances its value. Although the study is relevant to all four countries, its scope is restricted to Poland, the Czech Republic, Slovakia, and Hungary. Industry 4.0 production systems necessitate further investigation in order to comprehend, implement, and realize. The automotive industry, along with other sectors, employs deep learning object detection and collision prevention technology, geospatial data visualization, trajectory planning algorithms, and sensor fusion to analyze autonomous vehicles within intelligent transportation and network connectivity systems. This study contributes theoretically and practically. He theoretically describes Industry 4.0 and digitization's main achievements, emphasising the importance of understanding these concepts in the future. The work may benefit the designated countries' governments with recommendations and assistance. Industry 4.0's foundations offer many benefits that apply to other fields but are limited by national laws. It's important to highlight these issues and propose solutions, as shown in the work. A sample of 17,000 companies from four countries was investigated. Although a constraint, this sample represents the population well. Subsequent investigations may examine the parameters' effects on the entire European Union and the feasibility of using more complex methods to assess corporate financial stability. In the V4 countries (primarily the Slovak Republic), intelligent traffic engineering will require a new scientific and technological dimension beyond mass production to accommodate autonomous production processes, interconnected virtual services, tools for predicting traffic flows, and collision avoidance technologies.

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