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ORIGINAL RESEARCH PAPER

The importance of digitalization and robotization in vehicle production in the European Union

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ABSTRACT

Vehicle manufacturing is an industry in which the technologies used by Industry 4.0 and their evolution can best be traced. Digitalization-robotization is paramount to the technical methods used in the Fourth Industrial Revolution. The question is how close a correlation between productivity and digitalization robotics in vehicle production is in the Member States of the European Union. I perform the relationship between the two variables by correlation calculation. Then I classify the member states according to the closeness of the relationship between the two variables using the method of hierarchical cluster analysis. Empirical results show a robust relationship, with the highest per capita production value in those Member States with the highest degree of digitalization-robotization in vehicle production. In conclusion, the countries in Central and Eastern Europe and the end of the productivity rankings need to increase the degree of digitalization of their vehicle production to increase their productivity and competitiveness.

KEYWORDS

Industry 4.0, European Union, vehicle manufacturing, digitalization-robotization, correlation, cluster analysis

1. INTRODUCTION

Industry 4.0 is the fourth industrial revolution, which is not just a technological issue, but a fundamental paradigm shift in the manufacturing strategy of industrial companies. Former production systems are no longer sustainable. They lead to lasting environmental damage (climate change, pollution, etc.) and digest too many non-renewable energy sources. They require a reduction in the workforce due to aging societies [1].

Industry 4.0 is based on technologies that include CPS (Cyber-Physical Systems), IoT (Internet of Things), and IoS (Internet of Services) [2]. These digitalization technologies enable continuous communication over the internet, thus ensuring a constant interaction and flow of information. The flow of information is not only between human-to-consumer (C2C) but also between human-to-machine (C2M) to machine-to-machine (M2M: machine to machine) [3]. Therefore, the fourth industrial revolution is a phenomenon that affects production systems and society.

Industry 4.0 and "smart" factories aim to create the most flexible production model possible that can meet consumers' high level of personalized expectations. While meeting expectations, a "smart" factory can facilitate real-time interaction between people, products, and devices at any stage of production [4]. Further statements on the significance and essence of Industry 4.0 are made by [5, 6].

Another important factor in gaining a competitive advantage is selecting relevant information from the resulting data to support decision-making [7–9].

According to [10], Industry 4.0 requires new business models and structures, a transformation process that is the digital transformation itself. The basis of the fourth industrial revolution is digitalization and data. The computer is just a means to connect them. Advances in the internet and technology create a continuous network of people, machines, and

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companies and share data about value-creating processes. By sharing the data, the production of competitive products becomes available. Therefore, the source of competitive advantage for companies will be coordinated or completely new production (for example, additive manufacturing) and digital services for products.

This study aims to establish a link between the productivity of the vehicle manufacturing industry in the European Union and the degree of digitalization-robotization. The study will examine the significant relationship between digitalization-robotization (as an independent variable) and vehicle production productivity (as a dependent variable) in the EU Member States with the empirical data used.

1.1. Literature on the relationship between vehicle manufacturing, industry 4.0 and digitalization-robotization

One of the main reasons for developing the world economy is digitalization-robotization, the most critical manufacturing process in Industry 4.0. The positive impact of the two factors on economic growth is evident. However, these factors are not expected to have an explosive effect on economic growth [11].

The achievements and procedures of the fourth industrial revolution make it possible to speed up production processes, increase capacity utilization, and optimize technical, human, and natural resources [12].

Digitalization and technological advances have brought new opportunities, but they also require adaptation from all economic actors. Exploiting the Fourth Industrial Revolution (such as digitalization) can provide a competitive advantage that can lead to lasting productivity gains and thus sustainably increase social welfare.

However, the growth of digitalization alone is not enough to increase social well-being. It must be accompanied by developing new employee competencies, virtual reality, and cooperation networks. It is also relevant that Industry 4.0 is combined into a "system" because this is the only way to become a thriving market practice [13]. Several international surveys have confirmed this expectation described earlier, see [14, 15].

The technological innovations in today's vehicle manufacturing are driven by digitalization and robotics. The development of digitalization and robotics is most noticeable in vehicle manufacturing. Digitalization is a self-catalyzing process that assigns a virtual projection to every aspect of life.

And the concept of robotization means replacing human employees with vending machines in the production value chain process. So far, the development of the vehicle manufacturing industry would not have been possible without the applications of robotics and digitalization [16].

The emergence and spread of digitalization-robotization technologies, which form the basis of Industry 4.0, has fundamentally changed enterprises' leading and supporting activities, thus the operation of individual industries and entire national economies.

The benefits of digitalization are also evident at the macroeconomic and microeconomic levels. Governments expect incentives to join the digitalization trend to see significant macroeconomic and radical micro-level performance improvements. At the macro level, the contribution to GDP growth or the net positive effect on the labor force in Western European economies can be highlighted [17].

At the micro-level, a wide range of financial and operational indicators can be improved with the transition to industry 4.0 as part of its digitalization [18].

Digitalization provides process and organizational development opportunities for stakeholders from an economic perspective and enables the continuous exchange of data between people and devices from a social perspective. The basis for data exchange is provided by the info-communication infrastructure and the Internet [19, 20].

Digitalization is shaping a socio-economic environment today in which smart devices are constantly communicating with each other and with consumers, touching the material and virtual worlds in parallel [21–23].

Robotization means that networked autonomous industrial robots, which are becoming more and more suitable for tasks, perform tasks instead of humans [24]. Industrial robots are automatically controlled, reprogrammable, multi-purpose devices with varying degrees of freedom for industrial operations. These devices can be fixed or mobile [25].

One major industry trend today is that vehicle manufacturer and suppliers are increasingly turning to collaborative robots, the so-called "COBOT" (CollaBorative Robot). Such devices are smaller, smarter, and safer than traditional manufacturing devices that have been common for decades. Robots are faster, more precise, and more predictable than the human workforce because they do what they are programmed for. The precision and predictability expected of robots are of great importance if the end product (the vehicle) results from thousands of different components and sub-processes [26].

Robots and automation have long existed to replace the human workforce. [27] presents the application possibilities and characteristics of industrial robots and describes the applications of industrial robots in the intelligent production line of cars. Industrial robots are capable of a high division of labor. The technical advantage of robots is their small footprint and high availability, which improve the work efficiency of the automotive industry. On the other hand, the internet revolutionizes manufacturing processes by networking robots [28].

[29] describes the use of robots in the manufacture of vehicle surfaces. The study describes robots with stationary, rotating, and injection tools. The experiments used an IRb60 robot with a modernized computer control system.

The above literature references prove that technical complexity may be why the most "robotic" industry in the global economy today is vehicle manufacturing. Today, the world's vehicle industry is undergoing a complete transformation: grid-connected electric and self-driving cars are gaining ground. The focus of vehicle factory developments is to transform and modernize their manufacturing processes in the spirit of Industry 4.0 and, if necessary, change their business models rapidly [30].

In contrast to the radical socio-economic processes generated by digitalization-robotization, the most important expectation is that these processes take place with sustainability in mind. [31] provide a comprehensive and practical assessment of digitalization's social and environmental opportunities, challenges, and sustainability.

2. MATERIALS AND METHOD

The study will show the significance of digitalization-robotization in the Member States of the European Union and how this level affects the productivity of vehicle production. Of the two variables, the independent variable is the occupation of the member state based on the degree of digitalization-robotization, the dependent variable is the production value per capita. The relationship between two variables could theoretically be functional, stochastic, or completely independent. We assume that this relationship will be stochastic before analyzing the relationship between dependent and independent variables, since functional and complete independence can be ruled out. The appropriate procedure for examining the stochastic relationship is correlation calculation. I use correlation calculation to measure the closeness of the relationship between the two variables.

Correlation answers whether there is a relationship between two or more quantitative variables and, if so, how close it is. Pearson's correlation coefficient characterizes the combined change of the variables. The sign of the correlation coefficient, retaining the character of the covariance, indicates the direction of the relationship. The role of the variables in the correlation study is interchangeable; none of them has a prominent role.

Of the EU member states, only those with significant vehicle production are examined in the study. It is hypothesized that those Member States with a higher ranking in European digitalization and robotics will have the highest production value per primary vehicle manufacturing worker.

Table 1 shows the production value, the number of employees, the production values per capita, and the country's ranking.

Table 1. Production value of motor vehicles in Europe in 2018 (in a million euros), direct automotive manufacturing jobs in the EU (head) by country, value per capita (in euros), and rank

Country	Production value	Number of employees	Value per person	Rank among 16 countries
Germany	401,872	919,002	437,292	4.
France	102,479	238,666	429,382	5.
Spain	67,221	161,722	415,658	6.
Italy	65,142	177,908	366,156	9.
Czechia	50,093	181,487	276,014	10.
Sweden	37,227	92,576	402,124	7.
Poland	36,652	214,642	170,759	14.
Slovakia	29,892	80,963	369,206	8.
Hungary	26,498	101,908	260,002	11.
Romania	21,340	194,787	109,556	15.
Austria	17,771	38,873	457,155	2.
Netherlands	15,506	25,162	616,247	1.
Belgium	13,194	29,749	443,511	3.
Portugal	10,365	43,553	237,986	12.
Slovenia	3,780	15,889	237,900	13.
Bulgaria	1,122	23,556	47,631	16.

Source: [32, 33], own calculation.

3. RESULTS

3.1. Results of production value data analysis

In the study, I carry out the normality test of the data on the production value per capita of vehicle production in the European Union member states and the classification of the countries into clusters. To examine the normal distribution of the data, I performed a Shapiro-Wilk test, the results of which are as follows: *P*-value: 0.6985, W: 0.962, Sample size (n):16, Average ($\bar{x}$): 329.8125, Median: 367.5, Sample Standard Deviation (S): 147.3129, Sum of Squares: 325,516.4375, b: 559.5995, Skewness: –0.2082 (Figs 1–4).

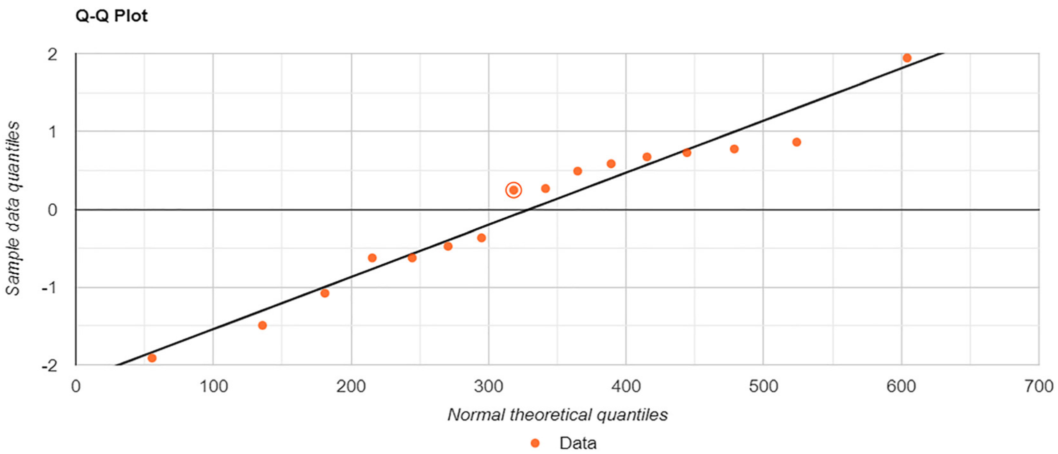

Fig. 1. Normality testing of per capita output value data in vehicle manufacturing

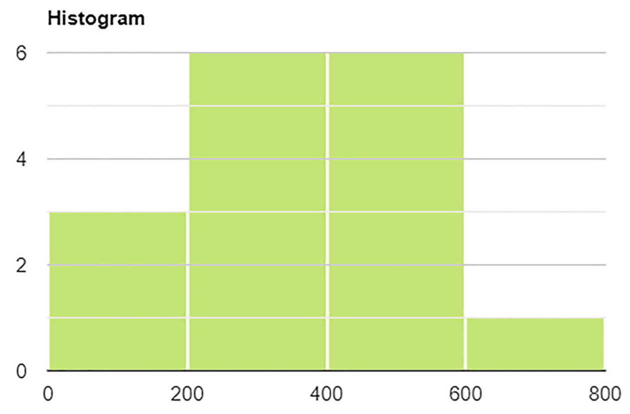

Fig. 2. Clusters based on per capita production value.
Note: *y*-axis: frequency of occurrence of countries in the production value cluster, *x*-axis: value range of the clusters based on per capita production value

The per capita production value data follow a normal distribution based on the test results. It follows from the previous finding that the 16 EU Member States examined can be classified into clusters. The histogram in Fig. 2 illustrates the clusters.

The first cluster includes Poland, Romania, and Bulgaria. Of the clusters based on per capita production value, only the Netherlands was in the fourth, with the highest per capita production value. The third cluster included Austria, Belgium, Germany, France, Spain, and Sweden, followed by Slovakia, Italy, the Czech Republic, Hungary, Portugal, and Slovenia. These countries have the lowest per capita production value in the automotive industry.

Note: If an EU Member State is placed in a higher number of clusters than in the cluster, the output value of vehicle production in that country is higher than in the countries in the previous clusters.

3.2. Results of data analysis of digitalization-robotization

In the study, I test the normality of the degree of development of digitalization-robotization in the European Union member states and classify the countries into clusters. To examine the normal distribution of the data, a Shapiro-Wilk test was performed, the results of which are as follows: *P*-value: 0.3699, W: 0.9417, Sample size (n): 16, Average ($\bar{x}$): 13.9081, Median: 12.75, Sample Standard Deviation (S): 7.2819, Sum of Squares: 795.3904, b: 27.3677, Skewness: 0.1707 (Fig. 3).

Based on the test results, the digitalization-robotization data follow a normal distribution. It follows from the previous finding that the 16 countries examined can be classified into clusters (Fig. 4).

The histogram in Fig. 4 illustrates the clusters.

Belgium, the Netherlands, and Sweden are the first clusters formed based on digitalization and robotization. This ranking means that these three countries have the highest level of development of digitalization-robotization. Slovenia and France are in the second cluster, Portugal, Germany, Austria, and Spain in the third, Italy, the Czech Republic, Poland in the fourth, Slovakia, Hungary, Bulgaria in the fifth, and Romania alone in the sixth cluster. Romania's last ranking means that this country has the lowest level of digitalization-robotization.

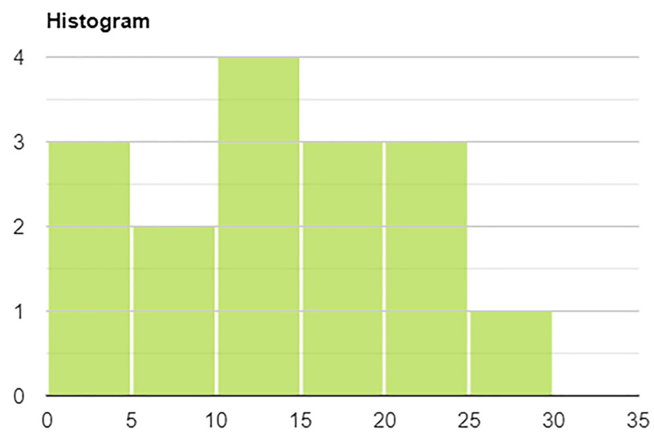

Fig. 4. Clusters based on the development of digitalization and robotization.
Note: *y*-axis: frequency of occurrence of countries in the given cluster, *x*-axis: value range of clusters based on the degree of digitalization-robotization

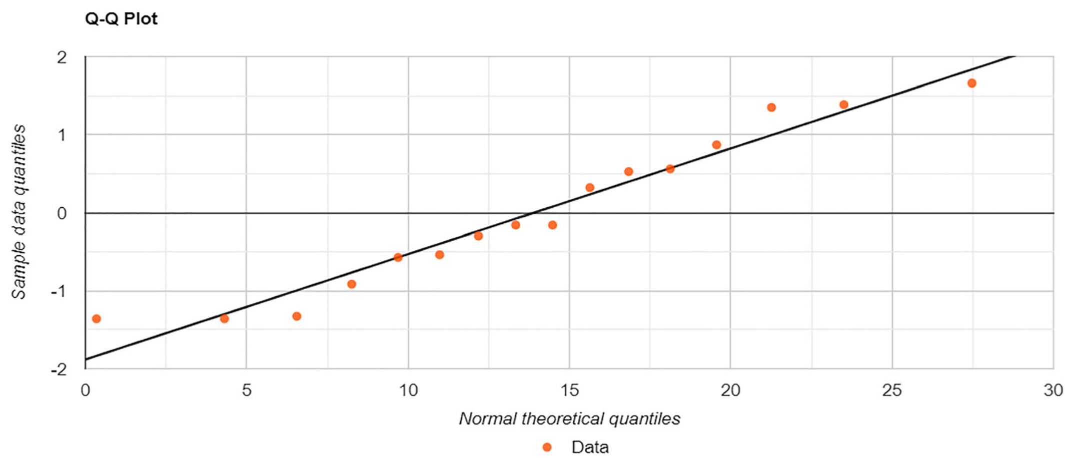

Fig. 3. Normality test of digitalization and robotization data

Table 2. Digitalization of enterprises in EU countries – level and ranking of robotization without financial sector, by size, 2018

Country	All enterprises (10 persons employed or more)	Small enterprises (10–49 persons employed)	Medium enterprises (50–249 persons employed)	Large enterprises (250 persons employed or more)	Average company size placements	Unweighted ranking among 16 countries
Germany	10	14	13	10	11.75	7
France	8	13	10	8	9.75	5
Spain	14	12	11	14	12.75	9
Italy	17	15	16	17	6.25	10
Czechia	16	21	18	16	17.75	11
Sweden	4	5	4	4	4.25	3
Poland	15	21	21	15	18.00	12
Slovakia	20	19	22	20	20.25	13
Hungary	21	27	26	21	23.75	14
Romania	27	23	27	27	26.00	15
Austria	9	18	15	9	12.75	8
Netherlands	5	3	3	5	4.00	1
Belgium	3	4	5	4	3.75	2
Portugal	11	9	9	11	10.00	6
Slovenia	6	10	7	6	7.25	4
Bulgaria	23	25	25	23	24.00	16

Source: [34], own calculation.
Note: the table only includes data for the 16 EU Member States with a significant value-added vehicle industry. The TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) linear ranking method was used to determine the ranking of EU countries at the level of digitalization-robotization, based on the size of enterprises. All diagnostic variables used in the study are stimulants. During the analysis, weights of equal value are assigned to each indicator.

Note: If an EU Member State is placed in a higher number of clusters when it is clustered, the degree of digitalization-robotization in that country is low.

3.3. Correlation between the productivity of vehicle production and the degree of digitalization-robotization

A correlation calculation between the per capita production value showing the productivity of vehicle production and the degree of digitization-robotization was performed. The preliminary hypothesis was that there would be a solid but negative correlation between the two variables. The correlation can be presumed because the degree of digitalization-robotization must impact the productivity of vehicle production. The negative correlation can be assumed because which EU Member State has a high per capita production value in vehicle production. The same country is likely to rank lower according to digitalization-robotization. For the correlation calculation, I used the data in column 4 of Table 1 and column 6 of Table 2. The Pearson coefficient was highly significant at –0.69884.

This high coefficient value confirms the hypothesis, so the high degree of digitalization-robotization contributes robustly to the high level of productivity in the automotive industry.

4. DISCUSSION

The results of several studies have confirmed the productivity gains achieved using digitalization-robotization, e.g. [35–37]. However, some studies have not demonstrated such a strong correlation as the close correlation presented in this study. According to a [38] survey, firms struggle to improve their productivity despite all efforts to digitize corporate operations. For example, in the United States, labor productivity growth grew at an annual average of only 1.06 percent between 2010 and 2018, compared with a yearly average of 2.73 percent from 2000 to 2010. A similar trend can be observed in other developed industrial countries. Productivity in OECD member countries grew by an average of 0.98 percent per year from 2010 to 2017 and 1.4 percent between 2001 and 2010. This so-called 'modern productivity paradox' shows that while companies are steadily increasing their investment in digital and robotics technologies, they are not achieving the expected productivity gains overall.

The results of the study are also indicative for practitioners in vehicle manufacturing. The results show that the digitization and robotization of vehicle manufacturing is creating new business opportunities in the manufacturing and service industries. These business opportunities are open to large companies as well as small and medium-sized businesses. Another suggestion for practitioners from the results of this study is that maintaining corporate competitiveness is not possible without Industry 4.0 applications. One such application is digitization-robotization. These applications initially require a lot of capital, but are a quick return on investment.

This study provides the following support for a theoretical and practical survey of European vehicle manufacturing: (1) it provides empirical evidence that the development of digitalization-robotization has a decisive impact on the productivity of vehicle manufacturing; (2) it also provides empirical evidence that the two factors have a positive effect on vehicle production; (3) promote an understanding of the need to increase the level of digitalization-robotization in order to maintain the international competitiveness of vehicle manufacturers.

The limitations of this study are as follows: (1) the data collection process is not optimal because only 2018 data on the level of digitalization-robotization of the economies of the EU member states are available; (2) The results of the study cannot be generalized to all EU Member States, as they are limited to countries with a significant share of vehicle production.

Future research directions may include: (1) using other output data from EU vehicle production for the study; (2) examining the role of other independent variables influencing the productivity of vehicle production, such as CPS (Cyber-Physical Systems), IoT (Internet of Things), IoS (Internet of Services), and so on.

5. CONCLUSIONS

The clusters formed based on per capita production value, and the degree of digitalization-robotization contain similar countries, only in reverse order. The same countries lead in per capita production value rankings and digitalization-robotization (the Netherlands, Belgium). The same countries are last in the two scales (Romania and Bulgaria). A robust conclusion can be drawn from these facts that the high degree of digitalization-robotization positively affects vehicle production output (production value). The results show a strong correlation in the automotive industry between the development of production output and the growth of digitalization-robotization in the European Union's member states. The value of the correlation coefficient – 0.69884 shows that it is a healthy coexistence of the two variables. The coefficient value means that vehicle per capita production value in the EU Member States (as a dependent variable) is explained by the high degree of digitalization-robotization (as an independent variable).

The negative sign of the correlation coefficient indicates that if the per capita production value of vehicle production is high in one of the studied member states, then the ranking of the same member state in the order of digitalization-robotization is lower (i.e., better). The correlation is also accurate: if vehicle production's per capita production value is deficient in one of the studied member states, then the ranking of the same member state is higher (i.e., worse) in the order of digitalization-robotization.

The research results confirm that among the applications of Industry 4.0, the application of the digitalization-robotization technologies highlighted in the study causes an increase in efficiency and productivity at the enterprise level, which increases the gross added value of the vehicle manufacturing sector. Digitalization-robotization will become mandatory for virtually all automotive manufacturers to stay competitive. In Central and Eastern Europe and the Balkans, at the end of the ranking, it is necessary to increase the degree of digitalization-robotization to increase the productivity of vehicle production.

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REFERENCES

[1] S. Wang, J. Wan, D. Li, and C. Zhang, “Implementing smart factory of industrie 4.0: an outlook,” *Int. J. Distrib. Sens. Netw.*, vol. 12, no. 1, pp. 1–10, 2016. https://doi.org/10.1155/2016/3159805.

[2] H. Lasi, P. Fettke, H.-G. Kemper, T. Feld, and M. Hoffmann, “Industry 4.0,” *Bus. Inf. Syst. Eng.*, vol. 6, no. 4, pp. 239–42, 2014. https://doi.org/10.1007/s12599-014-0334-4.

[3] J. Cooper and A. James, “Challenges for database management in the internet of things,” *IETE Tech. Rev.*, vol. 26, no. 5, pp. 320–9, 2009. https://doi.org/10.4103/0256-4602.55275.

[4] K. Zhou, T. Liu, and L. Zhou, “Industry 4.0: towards future industrial opportunities and challenges,” in *Paper presented at the 2015 12th International Conference on Fuzzy Systems and Knowledge Discovery (FSKD)*, 2015. Available: https://doi.org/10.1109/FSKD.2015.7382284.

[5] E. Hofmann and M. Rüsch, “Industry 4.0 and the current status as well as future prospects on logistics,” *Comput. Ind.*, vol. 89, pp. 23–34, 2017, http://dx.doi.org/10.1016/j.compind.2017.04.002.

[6] J. Müller, V. Dotzauer, and K. I. Voigt “Industry 4.0 and its impact on reshoring decisions of German manufacturing enterprises,” in *Supply Management Research*. Wiesbaden: Springer, Gabler, pp. 165–79, 2017, https//doi.org/10.1007/978-3-658-18632-6_8.

[7] H. V. Heynitz, M. Bremicker, D. M. Amadori, and K. Reschke, *The Factory of the Future*, Germany: KPMG AG, 2017 [online]. Available: https://assets.kpmg/content/dam/kpmg/es/pdf/2017/06/the-factory-of-the-future.pdf. Accessed: Nov. 2, 2021.

[8] Deloitte, *Industry 4.0 – an Introduction*, Deloitte, 2015 [online]. Available: https://www2.deloitte.com/content/dam/Deloitte/be/Documents/Operations/2015_Industry%204%200%20Report%20vFinal.pdf. Accessed: Nov. 2, 2021.

[9] L Török, “Industry 4.0 from a few aspects, in particular in respect of the decision making of the management/Will the new industrial revolution change the traditional management functions?” *Int. Rev. Appl. Sci. Eng.*, vol. 11, no 2, pp. 140–6, 2020, https://doi.org/10.1556/1848.2020.20020.

[10] G. Prause, “Sustainable business models and structures for Industry 4.0,” *J. Secur. Sustain. Iss.*, vol. 5, no. 2, pp. 159–69, 2015, http://dx.doi.org/10.9770/jssi.2015.5.2(3).

[11] M. Arsic, “Impact of digitalisation on economic growth, productivity and employment,” *Dec. 2020 Econ. Themes*, vol. 58, no. 4, pp. 431–57, 2020, https//doi.org/10.2478/ethemes-2020-0025.

[12] Sogeti, “The fourth industrial revolution. Things to tighten the link between IT and OT,” 2014 [online]. Available: https://www.fr.sogeti.com/globalassets/global/downloads/reports/vint-research-3-the fourth-industrial-revolution. Accessed: Nov. 4, 2021.

[13] A. Adamik, “Creating a competitive advantage in the age of industry 4.0,” *Probl. Zarządzania – Manag.*, nos 2/2019(82), pp. 13–31, 2019, https://doi.org/10.7172/1644-9584.82.1.

[14] J. Qin, Y. Liu, and R. Grosvenor, “A categorical framework of manufacturing for industry 4.0 and beyond,” *Proced. CIRP*, vol. 52, pp. 173–8, 2016, https://doi.org/10.1016/j.procir.2016.08.005.

[15] P. Ajdovec, B. R. Kovacic, and M. Vidmar, “Corporate strategy and Industry 4.0: bibliometric analysis on factors of modernization,”

Dyn. Relatsh. Manag. J., vol. 6, no. 2, pp. 47–59, 2017, https://doi.org/10.17708/DRMJ.2017.v06n02a04.

[16] M. Krzywdzinski, "Automation, digitalization, and changes in occupational structures in the automobile industry in Germany, the United States, and Japan. A brief history from the early 1990s until 2018," in *Conference: GERPISA International Colloquium*, August 2020 [online]. Available: https://doi.org/10.34669/wi.ws/10.

[17] M. Blanchet and T. Rinn, "The industrie 4.0 transition quantified. How the fourth industrial revoluion is reshuffling the economic, social, and industrial model," *Roland Berger Strategy Consultants GmbH., München*, 2016 [online]. Available: https://www.rolandberger.com/publications/publication_pdf/roland_berger_industry_40_20160609.pdf. Accessed: Nov. 10, 2021.

[18] C. López-Gómez, D. McFarlane, E. O'Sullivan, and C. Velu, "The practical impact of digital manufacturing. Results from recent international experience," Interim Report Institute for Manufacturing (IfM), University of Cambridge, Cambridge, 2018 [online]. Available: https://www.ifm. eng.cam.ac.UK/uploads/Content_Images/IfM_IUK_Interim_revised.PD. Accessed: Nov. 14, 2021.

[19] Capgemini, "The challenges of the digital revolution. Digital transformation review," *No. 1. Capgemini Consulting*, 2011 [online]. Available: https://www.capgemini.com/wp-content/uploads/2017/07/Digital_Transformation_Review__No_1__July_2011.pdf. Accessed: Nov. 14, 2021.

[20] S. Krishna, "Enhancing academic outcome through digitalization. Conference paper," *Quality Enrichment and Excellence in Indian Higher Education System in the Era of Globalization*, 2017 [online]. Available: https://www.researchgate.net/publication/314072584_ENHANCING_ACADEMIC_OUTCOME_THROUGH_DIGITALIZATION. Accessed: Nov. 14, 2021.

[21] J. S. Hwang, "The fourth industrial revolution (industry 4.0): intelligent manufacturing," *Researchgate Publications, SMT Prospects Perspectives*, 2016 [online]. Available: http://www.jenniehwang.com/pdfs/industry4.pdf. Accessed: Nov. 14, 2021.

[22] H. Kagermann, R. Anderl, J. Gausemeier, G. Schuh, and W. Wahlster, "Industrie 4.0 in a global context: strategies for cooperating with international partners. Acatech study," *Herbert Utz Verlag, München*, 2016 [online]. Available: https://www.acatech.de/wp-content/uploads/2018/03/acatech_STU_engl_KF_Industry40_Global.pdf. Accessed: Nov. 19, 2021.

[23] H. C. Pfohl, B. Yahsi, and T. Kurnaz, "The impact of industry 4.0 on the supply chain," in *Innovations and Strategies for Logistics and Supply Chains: Technologies, Business Models And Risk Management.* Proceedings of the Hamburg International Conference of Logistics (HICL), W. Kersten, T. Blecker, and C. M. Ringle (Eds), 2015 [online]. Available: https://www.econstor.eu/bitstream/10419/209250/1/hicl-2015-20-031.pdf. Accessed: Nov. 19, 2021.

[24] M. Rüssmann, M. Lorenz, P. Gerbert, M. Waldner, J. Justus, P. Engel, and M. Harnisch, "Industry 4.0: the future of productivity and growth in manufacturing industries," *The Boston Consulting Group*, 2015 [online]. Available: https://www.bcg.com/publications/2015/engineered_products_project_business_industry_4_future_productivity_growth_manufacturing_industries. Accessed: Nov. 29, 2021.

[25] J. Wallén, "The history of the industrial robot. Technical report from Automatic Control at Linköpings universitet," 2008 [online]. Available: http://liu.diva-portal.org/smash/get/diva2:316930/FULLTEXT01.pdf. Accessed: Nov. 19, 2021.

[26] A. Djuric, R. J. Urbanic, and J. L. A. Rickli, "Framework for collaborative robot (CoBot) integration in advanced manufacturing systems," *April 2016 SAE Int. J. Mater. Manuf.*, 2016, vol. 9, no. 2, https://doi.org/10.4271/2016-01-0337.

[27] W. Wang, "Applied research of industrial robots in automotive intelligent manufacturing production line," *May 2020 J. Phys. Conf. Ser.*, vol. 1550, no. 4, 2020, Paper no. 042061, https://doi.org/10.1088/1742-6596/1550/4/042061.

[28] E. Holodny, "A key player in China and the EU's "third Industrial Revolution" describes the economy of tomorrow," *Business Insider*, 2017 [online]. Available: http://www.businessinsider.com/jeremy-rifkin-interview-2017-6. Accessed: Nov. 19, 2021.

[29] T. Mikolajczyk, "Manufacturing using robot," *March 2012 Adv. Mater. Res.*, vol. 463–464, pp.1643–6, 2012, https://doi.org/10.4028/www.scientific.net/AMR.463-464.1643.

[30] D. Ibarra, J. Ganzarain, and J. I. Igartua- Lopez, "Business model innovation through Industry 4.0: a review," *January 2018 Proced. Manuf.*, vol. 22, pp. 4–10, 2018, https://doi.org/10.1016/j.promfg.2018.03.002.

[31] S. Lange and T. Santarius, "Smart green world? making digitalisation work for sustainability," ISBN 9780367467579, Published May 20, 2020 by Routledge.

[32] Statista, "Production value of motor vehicles in European countries 2018," 2021 [online]. Available: https://www.statista.com/statistics/1192686/production-value-of-motor-vehicles-and-trailers-in-europe/. Accessed: Dec. 1, 2021.

[33] ACEA, "Direct automotive manufacturing jobs in the EU, by country," 2021 [online]. Available: https://www.acea.auto/figure/direct-automotive-manufacturing-jobs-in-the-eu-by-country/. Accessed: Dec. 11, 2021.

[34] J. Brodny and M. Tutak, "Assessing the level of digitalization and robotization in the enterprises of the European Union Member States," *Plos One*, Published: July 22, 2021, https://doi.org/10.1371/journal.pone.0254993.

[35] S. Ribeiro-Navarrete, D. Botella-Carrubi, D. Palacios-Marqués, and M. Orero-Blat, "The effect of digitalization on business performance: an applied study of KIBS," *J. Business Res.*, vol. 126, March 2021, pp. 319–26, 2021, https://doi.org/10.1016/j.jbusres.2020.12.065.

[36] D. L. Traşcă, G. Stefan, D. N. Sahlia, S. O. Raz van Honirau, and G. Laurentiu, "Digitalization and business activity. The struggle to catch up in CEE countries," *Sustainability*, vol. 11, no. 8, p. 2204, 2019, https://doi.org/10.3390/su11082204.

[37] G. Cette, S. Cette, and L. Nevoux, "The impact of ICTs and digitalization on productivity and labor share: evidence from French firms," *January 2021 Econ. Innov. New Technol.*, 2021, https://doi.org/10.1080/10438599.2020.1849967.

[38] S. Schweikl and R. Obermaier, "Lessons from three decades of IT productivity research: towards a better understanding of IT-induced productivity effects," *Manag. Rev. Q.*, vol. 70, pp. 461–507, 2020, https://doi.org/10.1007/s11301-019-00173-6.