Politická ekonomie
2024, Volume 72, Issue 1
https://doi.org/10.18267/j.polek.1422
Open Access

VŠE / PRAGUE UNIVERSITY OF ECONOMICS AND BUSINESS

Innovation and New Technologies as Determinants of Logistics 4.0

Filip Ž. Bugarčić, Veljko M. Mijušković, Slobodan Aćimović

Filip Ž. Bugarčić (corresponding author, e-mail: f.bugarcic@kg.ac.rs): University of Kragujevac, Faculty of Economics, Liceja Kneževine Srbije 3, Kragujevac, Republic of Serbia

Veljko M. Mijušković (e-mail: veljko.mijuskovic@ekof.bg.ac.rs): University of Belgrade, Faculty of Economics and Business, Kamenička 6, 11000 Belgrade, Republic of Serbia

Slobodan Aćimović (e-mail: asloba@ekof.bg.ac.rs): University of Belgrade, Faculty of Economics and Business, Kamenička 6, 11000 Belgrade, Republic of Serbia,

Abstract

Continuous technological changes in various industries are necessary for achieving economic development goals. Logistics, as an integral part of the supply chain, is gaining an increasingly significant role for national economies. To encourage its further development, especially in the era of intensive digitization and the context of Industry 4.0, innovations and new technologies are seen as important drivers. The paper examines the impact of capacity for innovation and availability of latest technologies on countries' overall logistics performance, as well as individual components of international logistics. Additionally, the role of export and import as moderators of this relationship are analysed, to see the patterns of its influence in open economies. The empirical results provide evidence of a positive direct impact of selected technological variables on the elements of international logistics, as well as a positive effect of export and import on the Logistics Performance Index (LPI), while the introduction of moderators into the analysis, using the Baron & Kenny model, points out that the impact of technological components is weaker in economies with a higher volume of exports.

Keywords: Logistics Performance Index, LPI, innovation, new technologies, Logistics 4.0

JEL Classification: F40, O30, O36

Citation: Bugarčić, F. Ž., Mijušković, V. M., Aćimović , S.: Innovation and New Technologies as Determinants of Logistics 4.0. Politická ekonomie, 2024, 72 (1), 102–121, https://doi.org/10.18267/j.polek.1422

1. Introduction

The Fourth Industrial Revolution (Industry 4.0) refers to the intensive application of solutions aimed at raising the level of technological equipment, capacity for innovation and new generations of digital technologies. The exponential development of modern technologies is stimulated by the growing need for continuous industrial development and constant changes to improve economic performance and industrial production. For this reason, Industry 4.0 represents an important factor in structural changes, economic growth and improving competitiveness (Mićić, 2020). What distinguishes this industrial revolution from the previous ones is the interaction between digital technology and the physical world through the intensive application of innovations (Schwab, 2017). Innovations themselves provide numerous benefits in different areas (Akram *et al*., 2023). Digitization of production processes requires the connection of all economic functions, in order to efficiently ensure the creation of added value (Alibekova *et al*., 2020). Intensive technological changes are aimed at increasing the efficiency and productivity of production processes, while the increasingly intense international character of industrial production imposes the need to improve the system of global supply chains (GSC) and global value chains (GVC).

Digital reality, as the basis of Industry 4.0, implies connecting the concept of digital technologies and physical things in the real world ("internet of things, IoT"), which provides the basis for further development of numerous economic activities, such as logistics. Logistics represents a part of the supply chain that plans, implements and controls the efficiency of the movement of goods, services and information, from the point of origin to the point of consumption (Marti *et al*., 2014), and plays an important role in economic and industrial development. The primary role of logistics is in connecting production, distribution and consumption in order to increase the efficiency and intensity of exchange. Bugarčić *et al*. (2020) pointed out that improvement of logistics performance contributes to increases in bilateral trade and intensification of international economic cooperation. Additionally, the negative impact of the distance between individual markets, as equivalent to trade costs, can be mitigated by continuous improvement to the logistics system at the macroeconomic level. The development of logistics through modern technological solutions (Logistics 4.0) is an indispensable part of Industry 4.0. Delfmann *et al*. (2018) emphasized that the digital transformation of economy and society cannot be achieved without adequate logistics support. The goals of Industry 4.0 can only be achieved if the logistics system of an economy is capable of supplying production processes with the necessary inputs while respecting the requirements of timeliness, quality and place of delivery (Hofmann and Rüsch, 2017).

In this context, the concept of Logistics 4.0 stands out as "smart logistics", which implies acknowledgement of modern technological solutions to improve the functioning of this system according to the requirements of Industry 4.0. Logistics 4.0 refers to the optimization of logistics

activities supported by artificial intelligence systems and appropriate software based on which it is possible to use relevant information and establish an optimum degree of automation of all logistics operations (Barreto *et al*., 2017). Timm and Lorig (2015) define the concept of Logistics 4.0 as a transition from hardware-oriented logistics to software-oriented logistics. Existing technological solutions that support Logistics 4.0 are the internet of things, cyber-physical systems, big data, cloud computing, mobile-based systems, social media-based systems and other technologies (Winkelhaus and Grosse, 2020). Based on these characteristics, it can be assumed that the development of logistics is dominantly dependent on availability and efficiency of use of modern technologies and innovations. Digital solutions in this area can provide numerous advantages for individual companies, industries as well as the entire economy by improving business productivity and gaining competitive advantages.

Existing literature provides ample evidence of the importance of logistics for improving competitiveness and stimulating economic growth (D'Aleo and Sergi, 2017; Sergi *et al*., 2021), increasing the intensity of international trade (Hausman *et al*., 2013; Puertas *et al*., 2014; Marti *et al*., 2014; Gani, 2017; Bugarčić *et al*., 2020; Zaninović *et al*., 2020) and attracting investments (Luttermann *et al*., 2020; Bugarčić and Skvarciany, 2023). The importance of logistics is especially emphasized in crisis conditions, such as during the COVID-19 pandemic (Richey Jr. and Davis-Sramek, 2020), and as a factor of business development (Aćimović *et al*., 2022). The gap in the existing literature consists in a lack of empirical research and concrete proposals for improving logistics performance at the national level. Such solutions would lead to continuous improvement of various areas within the economy. Bearing in mind the current global business situation and importance of the Logistics 4.0 concept, the determinants of technological development can be singled out as potential factors for the improvement of logistics, especially capacity for innovation and availability of latest technologies, components of the Global Competitiveness Index (GCI). These indicators as elements of the GCI represent key indicators of the level of innovative capacity and the availability of modern technology in different economies. Logistics performance at the level of countries can be monitored through the Logistics Performance Index (LPI), created by the World Bank, which contains six key components of logistics quality, namely: customs, infrastructure, logistics services, timeliness, quality of international shipments and ability to track.

In accordance with the previously stated, as well as the fact that the existing literature provides scarce empirical evidence on Logistics 4.0 and on ways to improve logistics performance, the main subject of this paper is to look at the potential for development of logistics through increasing the capacity for innovation and availability of modern technology. The paper aims to examine the degree of influence of selected GCI components on the LPI and to determine the intermediary role of export and import in this relationship. In this regard, the following hypotheses are formulated:

H_1: Capacity for innovation has a positive impact on logistics performance.

H_2: Availability of latest technologies has a positive impact on logistics performance.

H_3: Export/import moderates the relationship between (a) capacity for innovation (b) availability of latest technologies, and logistics performance.

The contribution of the research consists in finding patterns for improving logistics performance and examining the concrete role of innovations and modern technologies within Industry/Logistics 4.0. Our empirical findings confirm the effects of modern technological solutions in this area, which provides valuable insights for companies as well as policymakers focused on development of the logistics sector. Additionally, the evidence presented on the moderating role of exports and imports points out that the implementation of modern technologies is more significant in small open economies with a lower total volume of foreign trade activity. Large open economies, with a higher absolute value of export, feel the effects to a lesser extent. Also, importers could benefit more. We provide an explanation for those results.

The paper is structured as follows: after the introduction, a literature review is given in Section 2, followed by the research methodology in Section 3 and a discussion of the obtained results in Section 4. Finally, Section 5 presents concluding considerations and recommendations for further research.

2. Literature Review

The development of Industry 4.0 and digital transformation creates new opportunities in various economic sectors and stages along the value chain. According to the World Economic Forum report (WEF, 2017), it is expected that the development of innovation, greater openness of economies and companies' aspirations to include other market participants in innovation and development processes will play a major role in future development patterns. Innovations have already provided many positive effects in different areas (Ullah *et al*., 2023). Modern technology significantly affects production through comprehensive decentralization, strengthening the role of distribution flows and removal of conventional industrial paradigms. Strange and Zucchella (2017) pointed out that new digital technologies have a significant impact on the organization of activities within the GSC. The application of the Industry 4.0 concept creates added value within GVC and is an important element in gaining competitive advantages in many industries. Adeitan *et al*. (2019) stated that logistics operations should be based on the application of modern technology such as the implementation of barcoded, electronic data interchange (EDI), geographical positioning systems (GPS), enterprise resource planning (ERP), distribution requirement planning (DRP), very small aperture terminals (VSAT), geographical information systems (GIS), automated guided vehicle systems (AGVS) and automated inventory tracking systems (AITS). These systems are

based on innovations and modern technologies, which enable business improvement, raise the level of efficiency of logistics operations and contribute to the development of Logistics 4.0. The key advantages of applying modern technological solutions in logistics activities can be seen in business decentralization, self-regulation of processes and increased efficiency (Hofmann and Rüsch, 2017).

Improving logistics performance requires technological changes such as increasing the transparency and efficiency of supply chains and improving process integrity control. These requirements represent the backbone of the Logistics 4.0 concept (Barreto *et al*., 2017). Ślusarczyk *et al*. (2020) agreed that the determinants of Industry 4.0 can positively influence logistics performance, especially in an international context. The application of modern technology enables continuous growth of productivity (Kayikci, 2018), while the application of innovation is reflected in all segments of the supply chain processes (Abdirad and Krishnan, 2020). Digital transformation enables achieving a higher level of flexibility and automation of supply chains (Núñez-Merino *et al*., 2020), which consequently leads to a more efficient logistics system and further contributes to the improvement of the economic environment and creates additional potential for economic growth and development. In this way, the adoption of innovative technologies generates benefits for all actors in the supply chain (Dallasega *et al*., 2018). Here, we can restate the earlier confirmation from individual companies' point of view that the application of new technological solutions leads to better business results in the field of logistics (Lai *et al*., 2010). Improving the technological base and business logistics could provide benefits for all processes and business activities within the supply chain, including procurement, production and delivery. Positive results can be seen through the reduction of logistics costs, optimization of work and reduction of delivery times (Kayikci, 2018), which directly affect the competitive position and the level of participation in GSC.

Seen from a macroeconomic perspective, where there is insufficient research in the existing literature, innovation and technological readiness can favourably influence the development of logistics (Moldabekova *et al*., 2021). Their research first provided evidence of the positive impact of innovation factors and modern technology on all elements of countries' logistics performance (measured using the LPI), thus establishing one of the ways to stimulate the development of Logistics 4.0. The results of the study are in line with Çemberci *et al*. (2015), who emphasized that if a country strives to improve its competitive advantage in the international environment, it must improve the quality of logistics services, especially international transportation, tracking and tracing and timeliness. Their analysis of potential factors for improving the logistics performance of countries by examining the relationship between the economy's global competitiveness and logistics system gave certain results. Ekici *et al*. (2016) analysed the relationship between the pillars of the GCI and LPI to find the most adequate development strategy to improve the LPI. Among the many factors related to logistics performance, they concluded that the wide availability of the internet represents the most important determinant of sustainable development of logistics. A later addition to that research (Ekici *et al*., 2019) shows that governments should focus

on technological readiness, higher education and training, innovation, market size and infrastructure to achieve improvements in their countries' logistics performance.

When it comes to the mediating role of economic openness factors, the existing literature provides different evidence on the part of export and import as moderators. The role of export in the relationship between the LPI and GDP does not give statistically significant results (D'Aleo and Sergi, 2017), while support of export as a moderator is present in the relationship between the market orientation of companies and financial performance (Mostafiz *et al*., 2021). Regarding the impact of technological innovations on export, it has been proven that process innovations, unlike products, have a positive effect on export performance (Edeh *et al*., 2020), which unequivocally indicates the importance of modern technologies and the capacity of innovations for export competitiveness (Bıçakcıoğlu-Peynirci *et al*., 2020). In addition to direct impact examination, these findings provide a basis for the inclusion of economic openness components as moderators in looking at the relationship between innovation and modern technology on the one hand, and logistics performance on the other. This approach would lead to the creation of a broader picture in understanding the scope of Logistics 4.0 and would supplement the previous research that has indicated the possibilities of applying this system in different areas, such as in specific industries (Jagtap *et al*., 2020), from the aspect of sustainability (Facchini *et al*., 2019; Torbacki and Kijewska, 2019) or the perspective of individual companies (Bag *et al*., 2020; Ardolino *et al*., 2022).

Previous literature has provided indications regarding the importance of modern technologies and the potential of various determinants of Industry 4.0, where the concept of Logistics 4.0 arises. Also, the necessity of implementing these concepts in different industries has been emphasized. However, there is a noticeable lack of empirical studies and scientific confirmations regarding the contribution of innovations and new technologies in the improvement of logistics performance at the level of countries. Additionally, we find a motive in the lack of evidence that considers the role of countries' export and import as key components of economic growth and development that can determine the success of the Logistics 4.0 concept within the research framework.

3. Methodology and Data

To test the moderating effect, several regression models were created. A moderator is a qualitative or quantitative variable that affects the direction and/or strength of the relationship between the independent or predictor variable and the dependent or criterion variable (Baron and Kenny, 1986). In this study, export and import are used as moderators, and it is assumed that they influence the relationship between GCI components (capacity for innovation and availability of latest technologies) and the LPI. The LPI includes aggregate and individual ratings for quality of customs procedures, physical infrastructure, opportunities and ease of arranging international shipments, quality of logistics services, the ability to track shipments and timeliness. This index represents

the most relevant assessment of the level of development for trade logistics (Arvis *et al*., 2018), which is why it was chosen as the dependent variable. The independent variables used represent benchmarks within global competitiveness of economies, quantifying segments of innovation and success of application of modern technologies from reliable sources. Also, the LPI represents the most comprehensive measure of logistics performance at the country level, developed by the World Bank. This index provides an assessment of national logistics systems, including components on the policy regulations side (inputs) and outcomes of service delivery performance. Potential biases and limitations may arise due to the use of indices that provide only one dimension of secondary data and the limited years of observation. The LPI has been published biannually since 2007. Also, the analysis includes selected variables within the Industry 4.0 concept, while other elements of the framework are neglected due to data availability at the national level.

According to the procedure developed by Baron and Kenny (1986), regression models could answer whether there is a moderator effect of selected variables. This is particularly important for our research objective since we want to see how innovation and new technology behave in different economies depending on their degree of openness, measured by our moderators: volumes of exports and imports. This model enables us to make the assessment according to existing data. The first model indicates the results of the multiple regression analysis, which determines the influence of the independent and moderating variable on the dependent variable. The second model involves testing the influence of the interaction variable (independent × moderator variable) on the dependent variable, while the third model presents the results of the moderator analysis. To eliminate the problem of multicollinearity between the independent and moderator variables, individual variables were centred (mean-centring), which participate in the formation of the interaction variable (Aiken and West, 1991). The analysis used secondary data from 31 European countries (including the EU and Western Balkans countries), for the period from 2007 to 2018, which was defined based on the availability of the LPI, whose assessment was published biannually during the observed period.

4. Empirical Findings and Discussion

The results of the empirical analysis indicate that the variance growth value (VIF) is less than 10, based on which it is concluded that multicollinearity is not a problem, while the F-statistic is significant at the $p < 0.001$ level. The presented values indicate that there is a significant direct influence of GCI components on the LPI and its dimensions, as well as a direct influence of export/import on the LPI (Table 1). Also, the results of the regression analysis and the applied methodology state that there is a moderating effect of export and import on the relationship between capacity for innovation and availability of latest technologies, and the LPI. These results were also confirmed for individual LPI components (presented in the Appendix).

Table 1: Moderating effect of export/import (dependent variable: LPI)

Variables	Model 1	Model 2[1]	Model 3[2]
A. Effect of export on "capacity for innovation – LPI" linkage			
Capacity for innovation (*X*)	0.830***	0.727***	0.517***
Export (*W*)		0.193***	0.736***
X* × *W			−0.530***
***F*-statistic**	404.534***	228.439***	211.455***
R^2	0.689	0.715	0.778
B. Effect of import on "capacity for innovation – LPI" linkage			
Capacity for innovation (*X*)	0.830***	0.711***	0.550***
Import (*W*)		0.222***	0.620***
X* × *W			−0.410***
***F*-statistic**	404.534***	238.064***	208.859***
R^2	0.689	0.723	0.776
C. Effect of export on "availability of latest technologies – LPI" linkage			
Availability of latest technologies (*X*)	0.824***	0.704***	0.545***
Export (*W*)		0.298***	0.616***
X* × *W			−0.356***
***F*-statistic**	387.053***	277.969***	232.468***
R^2	0.679	0.753	0.794
D. Effect of import on "availability of latest technologies – LPI" linkage			
Availability of latest technologies (*X*)	0.824***	0.692***	0.547***
Import (*W*)		0.311***	0.590***
X* × *W			0.323***
***F*-statistic**	387.053***	285.474***	238.567***
R^2	0.679	0.758	0.798

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, ns – not significant

Source: Authors' own calculations

1 VIFs < 5

2 VIFs < 10

The first model confirms hypotheses H_1 and H_2 by proving a direct positive impact of innovation and the application of modern technologies on overall logistics performance. This relationship is also confirmed in individual components of the national logistics system, which further justifies the application of innovation and modern technologies as determinants of logistics improvement and indicates the importance and contribution of the Logistics 4.0 concept. The implications of these empirical results point to the justification of directing the strategy towards raising modern technological capacities, in order to enable further development of all elements of the logistics system through a greater degree of digitization, application of modern technical and technological solutions in logistics activities and development of innovations in this sector. The ultimate goal, which is reflected in an increased level of logistics system efficiency and improvement of its elements, enables further realization of its role as a factor of trade and industrial development.

The second model presents the results of impact of the interaction variable on the LPI, where there is also a positive statistically significant influence that provides the basis for applying the selected method of moderator analysis in the case of export and import as moderators. Based on that, the results of the third model indicate a statistically significant role and the existence of a moderating influence of both export and import, which confirms the third hypothesis (H_3). The results, however, indicate that the positive effects of direct influence, presented in Model 1, will decrease with an increase in countries' exports and imports. The impact of capacity for innovation on the LPI will thus be smaller if it is a country with a higher volume of foreign trade activity. Analogously, the impact of availability of latest technologies on the LPI will also be lower if export is higher, while on the contrary, an increase in countries' import will contribute to a greater degree of this impact.

As an explanation of the presented results, we can point out the assumption that initial development of modern technologies and innovation capacity gives direct positive effects on the development of logistics. However, this impact is more significant in smaller economies with a lower total volume of foreign trade activity. Large open economies, with a higher absolute value of export, will feel the effects of the Logistics 4.0 concept to a lesser extent. On the other hand, the positive role of import as a moderator of the relationship between availability of latest technologies and the LPI can be attributed to the import of modern technologies, which would contribute to strengthening the positive effects of this relationship for those countries with a suitable import structure. The explanation for the presented results could also be connected to some negative sides of economic openness, such as evidence of asymmetric effects in the short and long term in the impact of the openness of the economy on economic growth (Udeagha and Ngepah, 2021). The lack of positive influence of export as a moderator of selected variables can also be attributed to the fact that countries with high participation in GSC already possess a high level of logistics system development.

5. Conclusion

The aspiration to intensify further development of logistics, to achieve the goals of economic policy aimed primarily at encouraging international trade, improving competitiveness and attracting foreign investments, requires determination of factors that contribute to raising the quality of the logistics system in a national economy. With intensive digitization and the imperative of applying modern technologies, as well as continuous innovations in various fields, there is a need to examine the role of these elements in improving logistics performance. This concept is recognized in the literature as Logistics 4.0, within which the potential for further development of this sector is presented. The stated assumptions concern the application of modern technologies and innovations to further develop the overall logistics system and its components. Our empirical analysis with secondary data confirmed the set hypotheses through direct and moderating influence, where the elements of the openness of the economy that are closely related to the realization of international logistics activities were selected as moderators.

Fulfilling the assumption about the positive influence of innovation and modern technologies on logistics performances implies the importance of Logistics 4.0 and provides empirical validation of this concept. In this way, we can state that capacity for innovation and availability of latest technologies make a direct contribution to the development of the overall and individual elements of the logistics system. Additionally, the role of export and import as moderators of this relationship was examined using the Baron & Kenny model. It was shown that export reduces the contribution of modern technologies to the development of logistics, while there is a positive contribution of import as a moderator of this relationship. The presented evidence can serve in further understanding of the Logistics 4.0 concept and guide economic policymakers towards improvements in logistics performance at the national level. The small time interval of the analysis due to the LPI availability can be singled out as a limitation of the research. It would be interesting to see what the outcomes will be in the coming years due to the increasingly rapid development of innovations and new technologies. Will it provide an even greater stimulus for the improvement of logistics, or will there be saturation? In addition, the paper tested the impact of two selected indicators of the level of technological readiness, while future studies may consider other determinants of the Fourth Industrial Revolution to test their contribution to the development of the logistics system. Also, other sources of selected variables could be used to compare results. Regarding moderators, an additional angle may be constructed by the implementation of new moderators. In this way, the understanding of the environment in which logistics performance can be further developed would be expanded.

Acknowledgement

Funding: There was no funding, either externally or internally, towards this study.
Conflicts of interest: The authors hereby declare that this article was not submitted nor published elsewhere.
The data that support the findings of this study are available from the corresponding author, [F.Ž.B.], upon reasonable request.

References

Abdirad, M., Krishnan, K. (2020). Industry 4.0 in logistics and supply chain management: A systematic literature review. *Engineering Management Journal*, 33(3), 187–201. https://doi.org/10.1080/10429247.2020.1783935

Aćimović, S., Mijušković, V., Bugarčić, F. Ž. (2022). Logistics system as a factor of business development: the case of the Republic of Serbia. *Ekonomika preduzeća*. 70(5–6), 325–334. https://doi.org/10.5937/EKOPRE2206325A

Adeitan, A. D., Aigbavboa, C., Agbenyeku, E. E. O. (2019). Global Logistics in the Era of Industry 4.0. In: Arai, K., Bhatia, R., Kapoor, S. *Proceedings of the Future Technologies Conference 2019*, 652–660. Cham: Springer. https://doi.org/10.1007/978-3-030-32523-7_48

Aiken, L. S., West, S. G. (1991). *Multiple Regression: Testing and Interpreting Interactions*. Thousand Oaks: Sage.

Akram, R., Ibrahim, R. L., Wang, Z., et al. (2023). Neutralizing the surging emissions amidst natural resource dependence, eco-innovation, and green energy in G7 countries: Insights for global environmental sustainability. *Journal of Environmental Management*, 344, 118560.

Alibekova, G., Medeni, T., Panzabekova, A., et al. (2020). Digital Transformation Enablers and Barriers in the Economy of Kazakhstan. *Journal of Asian Finance, Economics and Business*, 7(7), 565–575. https://doi.org/10.13106/jafeb.2020.vol7.no7.565

Ardolino, M., Bacchetti, A., Perona, M., et al. (2022). An exploratory survey on the impacts of Logistics 4.0 on Italian manufacturing companies. *International Journal of Integrated Supply Management*, 15(2), 121–150. https://doi.org/10.1504/IJISM.2022.121909

Arvis, J. F., Ojala, L., Wiederer, C., et al. (2018). *Connecting to compete 2018: trade logistics in the global economy*. World Bank Working Paper No. 128355.

Bag, S., Gupta, S., Luo, Z. (2020). Examining the role of logistics 4.0 enabled dynamic capabilities on firm performance. *The International Journal of Logistics Management*, 31(3), 607–628. https://doi.org/10.1108/IJLM-11-2019-0311

Baron, R. M., Kenny, D. A. (1986). The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of personality and social psychology*, 51(6), 1173–1182. https://doi.org/10.1037/0022-3514.51.6.1173

Barreto, L., Amaral, A., Pereira, T. (2017). Industry 4.0 implications in logistics: an overview. *Procedia Manufacturing*, 13, 1245–1252. https://doi.org/10.1016/j.promfg.2017.09.045

Bıçakcıoğlu-Peynirci, N., Hizarci-Payne, A. K., Özgen, Ö., et al. (2020). Innovation and export performance: a meta-analytic review and theoretical integration. *European Journal of Innovation Management*, 23(5), 789–812. https://doi.org/10.1108/EJIM-06-2019-0149

Bugarčić, F. Ž., Skvarciany, V. (2024). Logistics Influence on FDI: "hard" versus "soft" Infrastructure Components. *European Journal of International Management*. https://doi.org/10.1504/EJIM.2022.10051618

Bugarčić, F. Ž., Skvarciany, V., Stanišić, N. (2020). Logistics performance index in international trade: case of Central and Eastern European and Western Balkans countries. *Business: Theory and Practice*, 21(2), 452–459. https://doi.org/10.3846/btp.2020.12802

Çemberci, M., Civelek, M. E., Canbolat, N. (2015). The moderator effect of global competitiveness index on dimensions of logistics performance index. *Procedia – Social And Behavioral Sciences*, 195, 1514–1524. https://doi.org/10.1016/j.sbspro.2015.06.453

D'Aleo, V., Sergi, B. S. (2017). Does logistics influence economic growth? The European experience. *Management Decision*, 55(8), 1613–1628. https://doi.org/10.1108/md-10-2016-0670

Dallasega, P., Rauch, E., Linder, C. (2018). Industry 4.0 as an enabler of proximity for construction supply chains: A systematic literature review. *Computers in Industry*, 99, 205–225. https://doi.org/10.1016/j.compind.2018.03.039

Delfmann, W., Ten Hompel, M., Kersten, W., et al. (2018). Logistics as a science: Central research questions in the era of the fourth industrial revolution. *Logistics Research*, 11(9), 1–13. https://doi.org/10.23773/2018_9

Edeh, J. N., Obodoechi, D. N., Ramos-Hidalgo, E. (2020). Effects of innovation strategies on export performance: New empirical evidence from developing market firms. *Technological Forecasting and Social Change*, 158, 120167. https://doi.org/10.1016/j.techfore.2020.120167

Ekici, Ş. Ö., Kabak, Ö., Ülengin, F. (2016). Linking to compete: Logistics and global competitiveness interaction. *Transport Policy*, 48, 117–128. https://doi.org/10.1016/j.tranpol.2016.01.015

Ekici, Ş. Ö., Kabak, Ö., Ülengin, F. (2019). Improving logistics performance by reforming the pillars of Global Competitiveness Index. *Transport Policy*, 81, 197–207. https://doi.org/10.1016/j.tranpol.2019.06.014

Facchini, F., Oleśków-Szłapka, J., Ranieri, L., et al. (2019). A maturity model for logistics 4.0: An empirical analysis and a roadmap for future research. *Sustainability*, 12(1), 86. https://doi.org/10.3390/su12010086

Gani, A. (2017). The Logistics Performance Effect in International Trade. *Asian Journal of Shipping and Logistics*, 33(4), 279–288. https://doi.org/10.1016/j.ajsl.2017.12.012

Hausman, W. H., Lee, H. L., Subramanian, U. (2013). The impact of logistics performance on trade. *Production and Operations Management*, 22(2), 236–252. https://doi.org/10.1111/j.1937-5956.2011.01312.x

Hofmann, E., Rüsch, M. (2017). Industry 4.0 and the current status as well as future prospects on logistics. *Computers in Industry*, 89, 23–34. https://doi.org/10.1016/j.compind.2017.04.002

Jagtap, S., Bader, F., Garcia-Garcia, G., et al. (2020). Food logistics 4.0: Opportunities and challenges. *Logistics*, 5(1), 2. https://doi.org/10.3390/logistics5010002

Kayikci, Y. (2018). Sustainability impact of digitization in logistics. *Procedia Manufacturing*, 21, 782–789. https:// doi.org/10.1016/J.PROMFG.2018.02.184

Lai, K. H., Wong, C. W. Y., Cheng, T. C. E. (2010). Bundling digitized logistics activities and its performance implications. *Industrial Marketing Management*, 39(2), 273–286. https://doi.org/10.1016/j.indmarman.2008.08.002

Luttermann, S., Kotzab, H., Halaszovich, T. (2020). The impact of logistics performance on exports, imports and foreign direct investment. *World Review of Intermodal Transportation Research*, 9(1), 27–46. https://doi.org/10.1504/WRITR.2020.106444

Martí, L., Puertas, R., García, L. (2014). The importance of the Logistics Performance Index in international trade. *Applied economics*, 46(24), 2982–2992. https://doi.org/10.1080/00036846.2014.916394

Mićić, V. (2020). Industry 4.0 development conditions in the Republic of Serbia. *FACTA UNIVERSITATIS – Economics and Organization*, 17(2), 97–112.

Moldabekova, A., Philipp, R., Satybaldin, A. A., et al. (2021). Technological readiness and innovation as drivers for logistics 4.0. *The Journal of Asian Finance, Economics, and Business*, 8(1), 145–156. https://doi.org/10.13106/jafeb.2021.vol8.no1.145

Mostafiz, M. I., Sambasivan, M., Goh, S. K. (2021). Antecedents and consequences of market orientation in international B2B market: role of export assistance as a moderator. *Journal of Business & Industrial Marketing*, 36(6), 1058–1075. https://doi.org/10.1108/JBIM-09-2019-0411

Núñez-Merino, M., Maqueira-Marín, J. M., Moyano-Fuentes, J., et al. (2020). Information and digital technologies of Industry 4.0 and Lean supply chain management: a systematic literature review. *International Journal of Production Research*, 58(16), 5034–5061. https://doi.org/10.1080/00207543.2020.1743896

Puertas, R., Martí, L., García, L. (2014). Logistics performance and export competitiveness: European experience. *Empirica*, 41(3), 467–480. https://doi.org/10.1007/s10663-013-9241-z

Richey Jr., R. G., Davis-Sramek, B. (2020). Supply Chain Management and Logistics: An Editorial Approach for a New Era. *Journal of Business Logistics*, 41(2), 90–93. https://doi.org/10.1111/jbl.12251

Schwab, K. (2017). *The fourth industrial revolution*. New York: Currency. ISBN 978-1524758868.

Sergi, B. S., D'Aleo, V., Konecka, S., et al. (2021). Competitiveness and the Logistics Performance Index: The ANOVA method application for Africa, Asia, and the EU regions. *Sustainable Cities and Society*, 69, 102845. https://doi.org/10.1016/j.scs.2021.102845

Ślusarczyk, B., Tvaronavičienė, M., Haque, A. U., et al. (2020). Predictors of Industry 4.0 technologies affecting logistic enterprises' performance: international perspective from economic lens. *Technological and economic development of economy*, 26(6), 1263–1283. https://doi.org/10.3846/tede.2020.13376

Strange, R., Zucchella, A. (2017). Industry 4.0, global value chains and international business. *Multinational Business Review*, 25(3), 174–184. https://doi.org/10.1108/MBR-05-2017-0028

Timm, I. J., Lorig, F. (2015). Logistics 4.0-A challenge for simulation. In: IEEE. *2015 Winter Simulation Conference (WSC)*, 3118–3119. https://doi.org/10.1109/WSC.2015.7408428

Torbacki, W., Kijewska, K. (2019). Identifying Key Performance Indicators to be used in Logistics 4.0 and Industry 4.0 for the needs of sustainable municipal logistics by means of the DEMATEL method. *Transportation Research Procedia*, 39, 534–543. https://doi.org/10.1016/j.trpro.2019.06.055

Udeagha, M. C., Ngepah, N. (2021). The asymmetric effect of trade openness on economic growth in South Africa: a nonlinear ARDL approach. *Economic Change and Restructuring*, 54(2), 491–540. https://doi.org/10.1007/s10644-020-09285-6

Ullah, S., Adebayo, T. S., Irfan, M., et al. (2023). Environmental quality and energy transition prospects for G-7 economies: The prominence of environment-related ICT innovations, financial and human development. *Journal of Environmental Management*, 342, 118120. https://doi.org/10.1016/j.jenvman.2023.118120

WEF (2017). *Impact of the Fourth Industrial Revolution on Supply Chains*. Genève: World Economic Forum.

Winkelhaus, S., Grosse, E. H. (2020). Logistics 4.0: a systematic review towards a new logistics system. *International Journal of Production Research*, 58(1), 18–43. https://doi.org/10.1080/00207543.2019.1612964

Zaninović, P. A., Zaninović, V., Skender, H. P. 2020. The effects of logistics performance on international trade: EU15 vs CEMS. *Economic Research – Ekonomska Istraživanja*, 1–17. https://doi.org/10.1080/1331677X.2020.1844582

Appendix

Table 2: Moderating effect of export/import (dependent variable: customs)

Variables	Model 1	Model 2[3]	Model 3[4]
A. Effect of export on "capacity for innovation – customs" linkage			
Capacity for innovation (*X*)	0.847***	0.771***	0.600***
Export (*W*)		0.144***	0.585***
X* × *W			−0.430***
***F*-statistic**	466.207***	249.713***	207.116***
R^2	0.718	0.733	0.774
B. Effect of import on "capacity for innovation – customs" linkage			
Capacity for innovation (*X*)	0.847***	0.759***	0.628***
Import (*W*)		0.164***	0.490***
X* × *W			−0.336***
***F*-statistic**	466.207***	255.179***	204.638***
R^2	0.718	0.737	0.772
C. Effect of export on "availability of latest technologies – customs" linkage			
Availability of latest technologies (*X*)	0.840***	0.736***	0.617***
Export (*W*)		0.260***	0.496***
X* × *W			−0.265***
***F*-statistic**	438.714***	291.609***	219.848***
R^2	0.706	0.762	0.785
D. Effect of import on "availability of latest technologies – customs" linkage			
Availability of latest technologies (*X*)	0.840***	0.728***	0.620***
Import (*W*)		0.264***	0.471***
X* × *W			−0.240***
***F*-statistic**	438.714***	292.599***	220.028***
R^2	0.706	0.763	0.785

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, ns – not significant.

Source: Authors' own calculations

3 VIFs < 5.

4 VIFs < 10.

Table 3: Moderating effect of export/import (dependent variable: infrastructure)

Variables	Model 1	Model 2[5]	Model 3[6]
A. Effect of export on "capacity for innovation – infrastructure" linkage			
Capacity for innovation (*X*)	0.833***	0.291**	0.521***
Export (*W*)		0.305**	0.719**
X* × *W			−0.473***
***F*-statistic**	416.296***	11.226***	218.911***
***R*²**	0.695	0.230	0.784
B. Effect of import on "capacity for innovation – infrastructure" linkage			
Capacity for innovation (*X*)	0.833***	0.692***	0.554***
Import (*W*)		0.264***	0.606***
X* × *W			−0.352***
***F*-statistic**	416.296***	264.560***	217.269***
***R*²**	0.695	0.744	0.783
C. Effect of export on "availability of latest technologies – infrastructure" linkage			
Availability of latest technologies (*X*)	0.835***	0.702***	0.576***
Export (*W*)		0.330***	0.582***
X* × *W			−0.281***
***F*-statistic**	419.915***	338.394***	262.847***
***R*²**	0.696	0.788	0.813
D. Effect of import on "availability of latest technologies – infrastructure" linkage			
Availability of latest technologies (*X*)	0.835***	0.689***	0.575***
Import (*W*)		0.344***	0.562***
X* × *W			−0.252***
***F*-statistic**	419.915***	350.124***	271.257***
***R*²**	0.696	0.794	0.818

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, ns – not significant.

Source: Authors' own calculations

5 VIFs < 5.

6 VIFs < 10.

Table 4: Moderating effect of export/import (dependent variable: international shipment)

Variables	Model 1	Model 2[7]	Model 3[8]
A. Effect of export on "capacity for innovation – international shipment" linkage			
Capacity for innovation (*X*)	0.744***	0.660***	0.458***
Export (*W*)		0.157***	0.679***
X* × *W			−0.509***
***F*-statistic**	226.530***	121.035***	102.239***
R^2	0.553	0.571	0.629
B. Effect of import on "capacity for innovation – international shipment" linkage			
Capacity for innovation (*X*)	0.744***	0.646***	0.494***
Import (*W*)		0.181***	0.562***
X* × *W			−0.391***
***F*-statistic**	226.530***	123.904***	100.197***
R^2	0.553	0.577	0.624
C. Effect of export on "availability of latest technologies – international shipment" linkage			
Availability of latest technologies (*X*)	0.703**	0.595***	0.420***
Export (*W*)		0.271***	0.618***
X* × *W			−0.389***
***F*-statistic**	178.966***	113.874***	92.142***
R^2	0.494	0.556	0.604
D. Effect of import on "availability of latest technologies – international shipment" linkage			
Availability of latest technologies (*X*)	0.703**	0.584***	0.427***
Import (*W*)		0.282***	0.581***
X* × *W			−0.346***
***F*-statistic**	178.966***	115.669***	92.588***
R^2	0.494	0.560	0.605

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, ns – not significant.

Source: Authors' own calculations

7 VIFs < 5.

8 VIFs < 10.

Table 5: Moderating effect of export/import (dependent variable: logistics competence)

Variables	Model 1	Model 2[9]	Model 3[10]
A. Effect of export on "capacity for innovation – logistics competence" linkage			
Capacity for innovation (*X*)	0.834***	0.719***	0.511***
Export (*W*)		0.215***	0.752***
X* × *W			−0.524***
***F*-statistic**	416.995***	243.486***	226.194***
R^2	0.695	0.728	0.789
B. Effect of import on "capacity for innovation – logistics competence" linkage			
Capacity for innovation (*X*)	0.834***	0.704***	0.549***
Import (*W*)		0.241***	0.628***
X* × *W			−0.399***
***F*-statistic**	416.995***	252.970***	221.224***
R^2	0.695	0.736	0.786
C. Effect of export on "availability of latest technologies – logistics competence" linkage			
Availability of latest technologies (*X*)	0.818***	0.688***	0.536***
Export (*W*)		0.322***	0.626***
X* × *W			−0.340***
***F*-statistic**	369.230***	281.210***	230.621***
R^2	0.669	0.756	0.793
D. Effect of import on "availability of latest technologies – logistics competence" linkage			
Availability of latest technologies (*X*)	0.818***	0.677***	0.537***
Import (*W*)		0.333***	0.600***
X* × *W			−0.309***
***F*-statistic**	369.230***	287.752***	235.765***
R^2	0.669	0.760	0.796

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, ns – not significant.

Source: Authors' own calculations

9 VIFs < 5.

10 VIFs < 10.

Table 6: Moderating effect of export/import (dependent variable: tracking and tracing)

Variables	Model 1	Model 2[11]	Model 3[12]
A. Effect of export on "capacity for innovation – tracking and tracing" linkage			
Capacity for innovation (*X*)	0.786***	0.685***	0.458***
Export (*W*)		0.191***	0.777***
X* × *W			−0.571***
***F*-statistic**	296.641***	164.226***	153.309***
R^2	0.618	0.645	0.718
B. Effect of import on "capacity for innovation – tracking and tracing" linkage			
Capacity for innovation (*X*)	0.786***	0.664***	0.489***
Import (*W*)		0.227***	0.665***
X* × *W			−0.450***
***F*-statistic**	296.641***	172.858***	153.753***
R^2	0.618	0.655	0.718
C. Effect of export on "availability of latest technologies – tracking and tracing" linkage			
Availability of latest technologies (*X*)	0.798***	0.685***	0.511***
Export (*W*)		0.281***	0.627***
X* × *W			−0.387***
***F*-statistic**	320.819***	215.408***	182.056***
R^2	0.637	0.703	0.751
D. Effect of import on "availability of latest technologies – tracking and tracing" linkage			
Availability of latest technologies (*X*)	0.798***	0.671***	0.511***
Import (*W*)		0.301***	0.606***
X* × *W			−0.355***
***F*-statistic**	320.819***	223.774***	189.904***
R^2	0.637	0.711	0.759

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, ns – not significant.

Source: Authors' own calculations

11 VIFs < 5.

12 VIFs < 10.

Table 7: Moderating effect of export/import (dependent variable: timeliness)

Variables	Model 1	Model 2[13]	Model 3[14]
A. Effect of export on "capacity for innovation – timeliness" linkage			
Capacity for innovation (*X*)	0.715**	0.629***	0.410***
Export (*W*)		0.162***	0.728***
X* × *W			−0.552***
***F*-statistic**	191.451***	102.645***	89.862***
R^2	0.511	0.530	0.598
B. Effect of import on "capacity for innovation – timeliness" linkage			
Capacity for innovation (*X*)	0.715**	0.611***	0.438***
Import (*W*)		0.193***	0.626***
X* × *W			−0.445***
***F*-statistic**	191.451***	105.890***	90.282***
R^2	0.511	0.538	0.599
C. Effect of export on "availability of latest technologies – timeliness" linkage			
Availability of latest technologies (*X*)	0.724***	0.625***	0.445***
Export (*W*)		0.246***	0.605***
X* × *W			−0.401***
***F*-statistic**	201.753***	123.264***	101.370***
R^2	0.524	0.575***	0.627
D. Effect of import on "availability of latest technologies – timeliness" linkage			
Availability of latest technologies (*X*)	0.724***	0.613***	0.444***
Import (*W*)		0.262***	0.584***
X* × *W			−0.373***
***F*-statistic**	201.753***	126.142***	104.563***
R^2	0.524	0.581	0.634

Note: *** $p < 0.001$, ns – not significant.

Source: Authors' own calculations

Table 8: List of commonly used abbreviations

GCI	Global Competitiveness Index
GSC	Global supply chain
GVC	Global value chain
LPI	Logistics Performance Index

13 VIFs < 5.

14 VIFs < 10.