Impact of ICT on regional supply chains in CEECs

Mance, Davor; Vilke, Siniša; Debelić, Borna

Davor Mance
University of Rijeka
Faculty of Economics
51000 Rijeka, Croatia
davor.mance@efri.hr

Siniša Vilke
University of Rijeka
Faculty of Maritime Studies
51000 Rijeka, Croatia
sinisa.vilke@pfri.uniri.hr

Borna Debelić
University of Rijeka
Faculty of Maritime Studies
51000 Rijeka, Croatia
borna.debelic@pfri.uniri.hr

JEL: R40, O32, F40, C23
Original scientific article
https://doi.org/10.51680/ev.36.2.12

Received: August 29, 2023
Revision received: September 11, 2023
Accepted for publishing: September 12, 2023

IMPACT OF ICT ON REGIONAL SUPPLY CHAINS IN CEECs

Abstract

Purpose: This paper aims to examine the impact of information and communication technologies and their availability in the Central and Eastern European countries that are members of the EU on regional value chains and regional supply chain management and logistics in CEECs in the context of the growing e-commerce industry.

Methodology: We used a balanced data panel of 11 countries over 9 years (2011-2019) to examine the impact of ICT indicators on regional supply chains. The analysis included the ordinal Spearman rank correlation coefficient and the panel GMM method, which accounts for endogeneity. We implemented the Arellano-Bond estimator within the GMM framework, considering the ordinal nature of the dependent variable. This approach allowed for an effective analysis of the complex relationships in the data, considering the panel structure and the individual country observations.

Results: The findings indicate that the hypothesis claiming that the integration of digital technologies in supply chains in CEEs leads to statistically significant improvements in efficiency, controllability, and cost-effectiveness, cannot be rejected. Enhanced communication, collaboration, and overall logistics performance have led to increased customer satisfaction. Additionally, the study shows a positive correlation between ICT infrastructure and logistics performance, emphasizing the crucial role of digital innovations in shaping supply chain dynamics.

Conclusion: The study supports the hypothesis that integrating digital technologies into supply chain management in Central and Eastern Europe is associated with enhanced efficiency, resilience, and economic integration through value-added export. These insights offer pathways to foster economic integration in the region.

Keywords: ICT, e-commerce, digital technologies, supply chains, RVCs

1. *Introduction*

The e-commerce sector has experienced remarkable growth, and the COVID-19 pandemic has accelerated this trend. This rapid expansion has brought new supply chain management (SCM) challenges. Dealing with fluctuating demand, shorter delivery times and higher customer demands requires innovative solutions. To overcome these hurdles, supply chain professionals are increasingly turning to digital tools such as Big Data analytics, the Internet of Things (IoT) and artificial intelligence (AI).

This paper explores the profound impact of digital advancements on SCM and e-commerce logistics in Central and Eastern European countries (CEECs). These countries include EU member states such as Bulgaria, Croatia, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia. Digital technologies bring numerous benefits, including increased supply chain visibility, improved predictive accuracy and an enhanced customer experience. They enable businesses to tailor their offers, promotions and customer service to individual preferences. IoT tools, such as RFID tags and GPS trackers, provide real-time inventory updates and streamline order fulfilment workflow.

In this context, our hypothesis is that the integration of digital technologies into CEEs supply chain management will lead to increased economic integration through the integration of value-added elements.

Nevertheless, the process of integrating digital technologies into e-commerce supply chains is not without its challenges. These include the need for robust IT infrastructure and expertise, and the looming spectre of data breaches. Channel innovations characterised by omnichannel methods optimise inventory management by seamlessly linking online, retail and app-based channels. While these strategies reduce reliance on warehousing, they require significant investment in IT, logistics and organisational adjustments.

Digital technologies are also transforming e-commerce transfers and inventory monitoring. The synergy of Big Data and IoT increases transport efficiency and transparency, especially in omnichannel strategies. This synergy simultaneously improves inventory management and order fulfilment processes. Emerging models such as direct-to-consumer (DTC) and drop-shipping are gaining traction and promise to reduce costs and improve inventory. However, they require careful management to ensure a satisfactory customer experience.

In summary, digital technologies have immense potential for improving the resilience, efficiency and environmental sustainability of e-commerce supply chains. Our hypothesis assumes their impact on economic integration through value chain integration into CEEs. Yet, their integration comes with numerous challenges, such as the need for specialised skills and the looming spectre of data security breaches. The purpose of this paper is to provide a comprehensive examination of these dynamics.

2. Literature review

2.1 Global and regional value chains

A value chain is a series of steps that companies take to turn an idea into a consumed product, including post-use aspects. The concept of the global value chain (GVC) emerged in the early 2000s and shows how production processes are distributed across countries and interconnected in industries. GVC analysis provides insights into the dynamics of trade, production and economic linkages. It focuses on efficient inputs, foreign linkages and evolving specialisation. It also sheds light on networks, global buyers and economic governance.

De Backer and Miroudot (2014) examine how global trade is organised through GVCs, focusing on country integration. They introduce indicators for an accurate representation and analyse value chains in different industries.

Mance et al. (2023) examine Croatian regional value chains (RVCs) using value added data. They find linkages between Croatian exports and partners' value added, indicating a strategic organisation of regional value chains. The study emphasises the resilience, efficiency and EU integration of RVCs.

It builds on the work of Mance et al. (2021), which highlights the role of RVCs in trade and development. Using UNCTAD Eora data, they derive the RVC indicator - domestic value-added in exports. The study covers Croatia and neighbouring countries and shows how developed countries affect less developed countries in RVCs.

2.2 The role of ICT in supply chain management

In recent years, there has been significant growth in the integration of digital technologies into SCM. These technologies include electronic devices, tools and resources that generate, process, store, transmit and receive data, information and knowledge. Their application has the potential to improve supply chain efficiency by increasing transparency, reducing costs, fostering collaboration, and enhancing customer satisfaction.

Supply chain visibility is a key aspect of efficient SCM. Digital innovations such as radio frequency identification (RFID), bar coding, and global positioning systems (GPS) enable companies to track the path of goods from supplier to customer. These technologies provide real-time data on the whereabouts of goods and enable flexible responses to supply chain disruptions and improved inventory management.

Industry giants such as Best Buy, Wal-Mart, Tesco, Target and Metro AG have effectively harnessed these technologies. Numerous studies (Wamba et al., 2008, Twist, 2005) on a three-tier retail supply chain address scenarios where RFID and the EPC network are merged. Preliminary results of an "open-loop" deployment are promising as these technologies synergise with business process management (BPM) and optimise the synchronisation of information and product flows. This harmony improves data integration between supply chain stakeholders and highlights the potential of these technologies to enable seamless end-to-end information flows within supply chains.

In addition, digital technologies are able to reduce supply chain costs by automating processes, minimising manual labour and improving efficiency. For example, the use of automated guided vehicles and drones can reduce labour costs and increase warehouse productivity (Basaldúa and Di Palma, 2023). The use of machine learning algorithms and artificial intelligence can optimise supply chain operations, reduce costs and increase efficiency.

Another benefit of digital technologies is that they improve collaboration between supply chain partners. They enable real-time communication and information sharing. Cloud computing and social media facilitate interaction between suppliers, manufacturers, retailers and customers. Digital technologies can also support collaborative planning, forecasting and replenishment (CPFR), enabling data sharing and collaborative supply chain planning, especially in healthcare supply chains (Friday et al., 2021).

In addition, digital technologies improve the customer experience by enabling real-time tracking, personalised recommendations and better customer service.

2.3 Logistics performance

The Logistics Performance Index (LPI) shows the ability to track and trace consignments (from 1=low to 5=high). It is an ordinal Likert scale variable indicating the degree of tracking ability as expressed by the parties involved in the logistics and transportation process. The LPI is produced by the World Bank, and it is an important tool for quantifying logistics efficiency and trade facilitation effectiveness. The LPI is based on industry experts' assessments of various aspects such as customs procedures, infrastructure, the quality of logistics services and labour skills, and calculates a score between 1 and 5 to determine the level of logistics capability. Higher scores correspond to higher efficiency and a competitive advantage. This makes the LPI an important tool for policymakers, researchers and businesses to recognise trade landscapes, identify areas in need of improvement and allocate resources for logistics infrastructure development – in line with the World Bank's goal to promote efficiency and facilitation of global trade. This nuanced assessment of logistics capacity underpins the informed promotion of trade-related decisions and policy formulation.

Alnıpak et al. (2023) examine the LPI determinants in the context of the European region. Emphasising the central role of logistics in global trade, the study examines data from 32 European countries from 2010 to 2018. Using static panel data models, the authors find that GDP per capita, the percentage of commercial services imports and the linear shipping connectivity index have a significant impact on LPI scores at the country level, outperforming other factors. In particular, the study uncovers a previously under-researched negative correlation between the LPI and the share of imports of commercial transport services. By applying a comprehensive panel data approach, the study improves the understanding of factors influencing logistics performance in the European region.

Martí et al. (2014) conducted an empirical analysis of developing countries and used the gravity model to assess the role of logistics in export in the regions such as Africa, South America and Eastern Europe. The results indicate positive correlations between the LPI coefficients and its components, reflecting a commitment to improving logistics. The need for competitive freight services is evident, especially as developing countries seek integration into global trade networks.

Wong and Tang (2018) find that nations with lower corruption and a stable political climate have a higher LPI, and that improvements in resource provision, such as infrastructure, technology, labour, and education, also have a significant and positive impact on LP. As a result, making institutional reforms and boosting resources are effective options for accelerating LP.

2.4 ICT-enhanced supplier selection in green supply chains

The need for sustainable supplier selection highlights the importance of a multi-criteria decision-making model (MCDM) in green supply chains. Amin-Tahmasbia and Alfi (2018) address this complexity by using ICT to manage uncertainty and optimise supplier capacity in line with customer demand. Their model refines supplier ranking through interconnected criteria and uses fuzzy linguistic relationships for more precision. By integrating the utility index, their MCDM approach systematically selects suppliers and awards contracts, improving the sustainability and success of the green supply chain. Fuzzy logic accounts for uncertainties in capacity and demand and provides an accurate overview of the supply chain. Evaluation of criteria such as cost, quality, delivery, technology and environmental factors is enabled. Merging incomplete fuzzy linguistic relationships refines comparisons and rankings. Optimisation of cost and purchase value functions balances financial and environmental considerations. This innovative blend of sustainability and operational efficiency enables informed decision-making in line with green supply chain goals.

2.5 Big Data analytics in supply chain management

The rise of data in the supply chain is both a challenge and an opportunity for managers. Big Data analytics involves processing huge data sets to gain insights and make informed decisions that provide real-time visibility and a rapid response to issues. Studies highlight the SCM potential of Big Data. For example, it optimises transportation, shortens lead times and improves customer service. Similarly, Gupta and Kohli (2006) find that real-time insights improve responsiveness. However, there are some challenges in implementing Big Data analytics in SCM. Due to disparate data sources, there is a lack of a standard framework for integration, making meaningful insights difficult. In addition, the required investment in technology and expertise can be prohibitive for some companies.

2.6 Internet of Things in supply chain management

The Internet of Things (IoT) refers to the networking of physical devices, vehicles and objects with embedded sensors, software and network connectivity. IoT technology has the potential to revolutionise supply chain functions by enabling real-time tracking of products and assets, providing instant insight into supply chain operations and facilitating proactive decision-making.

Numerous studies highlight the potential benefits of IoT technology for sustainable SCM. For example, Saqib and Zhang (2021) found that IoT technology can improve supply chain visibility, reduce lead times and increase supply chain flexibility without compromising sustainability. Mathaba et al. (2017) also found that IoT technology can improve inventory management by providing real-time inventory data and enabling automatic replenishment. They explored the fusion of RFID and Web 2.0 technologies to improve inventory management. Their research shows the synergy between object communication of RFID in IoT and data transmission in Web 2.0.

2.7. Blockchain in regional supply chain management

Blockchain, a distributed ledger technology, improves supply chain transparency and product authenticity. It limits fraud and improves traceability to solve transparency issues, especially related to product provenance (Cole et al., 2019). Furthermore, automation, e.g. in order tracking and payment processing, optimises SCM efficiency (Moosavi et al., 2021).

This technology is reshaping SCM with transparency, security and efficiency. Its decentralised, immutable ledger provides tamper-proof records in the supply chain. It empowers stakeholders to verify authenticity, quality and compliance, while minimising fraud and errors through streamlined processes. Smart contract integration increases efficiency. As companies use blockchain for collaborative supply chain optimisation, its transformative potential becomes increasingly clear.

As part of the global and regional value chain assessment, the UNCTAD-Eora GVC database covers 189 countries and provides a time series from 1990 to 2018 with indicators for foreign value added (FVA), domestic value added (DVA) and indirect value added (DVX). The GVC, which is based on value added (VA), quantifies production inputs net of input costs and captures the value of labour, capital and production elements. Incorporation of blockchain increases the precision of value creation through transparent, traceable data throughout the supply chain, increasing accuracy and reducing errors. Traceability mechanisms and smart contracts improve value allocation and speed up transactions. Blockchain's versatility improves data reliability and collaboration.

Amid fragmented global value chains (GVCs), blockchain provides accessible records that manage the complexity of sustainability. Nikolakis et al. (2018) present an evidence, verifiability and enforceability framework (EVE) that uses blockchain for sustainability. Tan et al. (2023) illustrate how SCI mediates the visibility of blockchain and SCP. In the context of global trade, the emphasis on GVCs, driven by technology, cost dynamics and policy changes, increases efficiency and competitiveness. Given the policy implications of GVCs, empirical evidence remains essential. This study provides GVC indicators, dissects industries and examines supply chain functions. A comprehensive understanding of the role of GVCs is central to discussions of trade, competitiveness, growth and development.

3. Data and methods

We used a balanced data panel of 11 countries (Bulgaria, Croatia, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia) during 9 years spanning the period from 2011 to 2019, with the goal to grasp the dynamic effects of changes in the growth of ICT indicators on the changes in the growth of regional supply chains in terms of value added. It is not our intention to imply causation, just statistical association. The dataset was carefully structured to facilitate the identification of unique country observations.

Since one of our dependent variables is ordinal, we should focus on statistical methods that are appropriate for analysing ordinal outcomes. In this context, ordinal Spearman's rank correlation coefficient measures the strength and direction of the monotonic relationship between two variables, even if the relationship is not linear.

The regression equation was carefully formulated to include the ordinal outcome variable, continuous predictors, indices and additional covariates. To mitigate endogeneity problems arising from the potential bidirectional relationship between certain predictors and the ordinal outcome, the generalised panel method of moments (panel GMM) was applied. This approach allows the inclusion of appropriate instruments, such as lagged variables and exogenous predictors, to correct for possible bias due to endogeneity. The panel GMM framework was implemented using the Arellano-Bond estimator, which is tailored to the panel structure. The subsequent interpretation of the coefficients considered the ordinal nature of the dependent variable and accounted for the endogeneity addressed. The use of the GMM offers distinct advantages in modelling scenarios, where the dependent variable is a Likert scale and the independent variables include an index and a continuous variable. The efficiency of the GMM lies in its ability to accommodate different types of data. Following the seminal contributions of Arellano-Bond (1991) and Wooldridge (2001), the ability of the GMM to incorporate moment conditions based on underlying theoretical relationships allows for effective mitigation of non-linearities inherent in Likert-scale data, while accounting for potential endogeneity issues. The fusion of an index and a continuous variable within the GMM framework enhances its analytical capabilities and facilitates the detection of complicated relationships and plausible interactions. Moreover, the GMM is more resistant to model misspecification due to its emphasis on moment conditions rather than strict distributional assumptions. Thus, the generalised method of moments proves to be indispensable for estimating complicated relationships between Likert-scale variables and different independent variables. In an Arellano-Bond GMM procedure, lagged differences of endogenous variables are used as tools to mitigate endogeneity problems in dynamic panels. This involves a two-step procedure. First, a generalised least squares model is estimated using the first differences and then the lagged values are integrated as instruments.

4. Results

Table 1 shows the results of a comprehensive Spearman rank-order cross-correlation analysis between the logistics performance index (LPI), information and technology infrastructure (ICTINFR), information and technology access ICTACC, and gross domestic product per capita corrected for purchase parity (GDPPCPPP).

Table 1 Spearman rank-order cross-correlation analysis

		LPI	ICTINFR	ICTACC	GDPPCPPP
LPI	Correlation	1.000000			
	Probability	–			
ICTINFR	Correlation	0.164040	1.000000		
	Probability	0.1047	–		
ICTACC	Correlation	0.203438	0.789287	1.000000	
	Probability	0.0434	0.0000	–	
GDPPCPPP	Correlation	0.378926	0.679438	0.719825	1.000000
	Probability	0.0001	0.0000	0.0000	–

Calculation: Eviews 13. Sample: 2011 2019. Periods included: 9. Cross-sections included: 11. Included observations: 99.
Source: World Bank

The correlation values, which range from -1 to 1, provide information about the degree and direction of linear relationships. The correlation coefficient of 0.79 between ICTINFR and ICTACC shows a high level of multicollinearity between the two variables. Thus, we needed to eliminate one of them for further analysis. We kept ICTINFR.

The Levin-Lin-Chu (LLC) test shown in Table 2 is a robust panel unit root test. In particular, it takes into account both cross-sectional and time-series dimensions by adjusting for potential cross-sectional dependence through a correction to the group mean, and along with its ability to adjust for bias and efficiency, it makes the test suitable for panels with heterogeneous characteristics. The null hypothesis of the Levin-Lin-Chu (LLC) test is that the series under consideration have a unit root.

Table 2 Common unit root test table – Levin-Lin-Chu (LLC) test

At Level		LPI	ICTINFR	GDPPCPPP
With Constant	t-Statistic	0.5673	3.1414	8.2742
	Prob.	0.9936	0.9992	1.0000
With Constant and Trend	t-Statistic	0.8774	0.6161	-2.8135
	Prob.	0.9997	0.0001	0.0025
At First Difference		d(LPI)	d(ICTINFR)	d(GDPPCPPP)
With Constant	t-Statistic	0.2884	0.0421	-2.1055
	Prob.	1.0000	0.0005	0.0176
With Constant and Trend	t-Statistic	0.1121	0.0031	-10.9165
	Prob.	0.9999	0.0031	0.0000

Calculation: Eviews 13. Sample: 2011 2019. Periods included: 9. Cross-sections included: 11. Included observations: 99.
Source: World Bank

Across variables (LPI, ICTINFR, and GDPPCPPP), the test statistics indicate the presence of unit roots, implying non-stationarity, except for ICTINFR when considering both constant and trend. After taking the first differences, ICTINFR and GDPPCPPP, our main independent variables become stationary. Thus, we decided to use dynamic panel analysis in the form of the Arellano-Bond GMM procedure.

Table 3 Panel GMM of the LPI as a dependent and ICT infrastructure as an independent variable

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LPI(-1)	0.272840	0.033570	8.127575	0.0000
ICTINFR	0.003684	0.001654	2.227616	0.0500
Mean dependent var	0.041429	S.D. dependent var		0.206070
S.E. of regression	0.217686	Sum squared resid		3.554052
J-statistic	8.788123	Instrument rank		11
Prob(J-statistic)	0.457058			

Calculation: Eviews 13. Transformation: First Differences. Sample (adjusted): 2013 2019. Periods included: 7. Cross-sections included: 11. Total panel (balanced) observations: 77. Instrument specification: @DYN (LPI, -2).

Source: World Bank

We performed a GMM panel regression analysis using the first differences approach. With a panel structure spanning seven periods and including eleven cross-sectional units, we examined the relationship between the logistics performance index (LPI) and the information infrastructure index (ICTINFR). Our results show that the lagged value of the dependent variable, LPI (-1), has a significant and positive impact on the current logistics performance index. Specifically, a one unit increase in the lagged value of the logistics performance index is associated with an average 0.272840 unit increase in the current value, highlighting its persistent influence. At the same time, we found that the Information Infrastructure Index (ICTINFR) is positively and statistically significantly associated with logistics performance. A one unit increase in the information infrastructure index is associated with an average increase of 0.003684 units in the current logistics performance index. While this relationship is statistically significant with a p-value of 0.05, it suggests a nuanced interaction between information infrastructure and logistics performance. The specification of the model with cross-sectional fixed effects combined with a comprehensive assessment of summary statistics and J-statistics underscores the importance of information infrastructure in shaping modern logistics and its impact on optimised global trading systems. Table 4 shows the results of the Arellano-Bond post-hoc test.

Table 4 Arellano-Bond serial correlation test

Test order	m-Statistic	rho	SE (rho)	Prob.
AR (1)	1.297311	0.182239	0.140475	0.1945
AR (2)	-1.772997	-0.569836	0.321397	0.0762

Sample: 2011 2019. Included observations: 77.

Source: World Bank

The null hypothesis of the Arellano-Bond serial correlation test is that there is no serial correlation in the residuals of the dynamic panel data regression model. In other words, the null hypothesis states that the error terms of the model are uncorrelated over time, homoscedastic and have no serial dependence or autocorrelation. The associated p-values of 0.19 for AR (1) and 0.08 for AR (2) indicate that there is no strong evidence to reject the null hypothesis of no first-order serial correlation. By adding the GDP p.c. corrected for PPP to the model, we see increases in the strain on the logistics performance in Table 4.

Table 5 Panel GMM of the LPI and ICT infrastructure indices and GDPPCPPP

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LPI(-1)	0.162320	0.036674	4.426072	0.0013
ICTINFR	0.013276	0.002142	6.198077	0.0001
GDPPCPPP	$-2.93 \cdot 10^{-5}$	$5.21 \cdot 10^{-6}$	-5.616948	0.0002
Mean dependent var	0.041429	S.D. dependent var		0.206070
S.E. of regression	0.225338	Sum squared resid		3.757518
J-statistic	8.859688	Instrument rank		11
Prob(J-statistic)	0.354271			

Calculation: Eviews 13. Transformation: First Differences. Sample (adjusted): 2013 2019. Periods included: 7. Cross-sections included: 11. Total panel (balanced) observations: 77. Instrument specification: @DYN (LPI, -2).

Source: World Bank

The results of the Arellano-Bond test for serial correlation with the associated probabilities (Prob.) of 0.4298 and 0.1299 for AR (1) and AR (2) indicate that there is no significant autocorrelation at the first and second lag.

The inclusion of the GDPPCPPP variable in the model shows that a higher GDP per capita corrected for purchasing power parity increases the burden of logistics performance. This phenomenon could be explained by the fact that with each increase in GDP per capita, international trade activities also increase at the same time. This relationship is due to the correlation between economic prosperity, trade dynamics and logistics demands. A more prosperous economy tends to engage more in global trade, leading to increased demand for logistics networks to ensure the efficient movement of goods. The positive correlation between the GDPPCPPP and the logistics burden suggests that economic growth leads to more trade, which exacerbates logistics challenges and highlights the complicated interplay between economic factors and logistics.

Table 6 Panel GMM of the Croatian VA export and ICT infrastructure index

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CROATIA(-1)	1.039696	9.66E-05	10767.68	0.0000
ICTINFR	$1.97 \cdot 10^{9}$	3869068.	508.7500	0.0000
Mean dependent var	$7.77 \cdot 10^{9}$	S.D. dependent var		$9.26 \cdot 10^{10}$
S.E. of regression	$1.32 \cdot 10^{11}$	Sum squared resid		$3.24 \cdot 10^{10}$
J-statistic	18.51260	Instrument rank		17
Prob(J-statistic)	0.236676			

Calculation: Eviews 13. Transformation: First Differences. Sample (adjusted): 2013 2019. Instrument specification: @ DYN (ICTINFR, -2).

Source: World Bank

The probabilities (Prob.) of 0.3124 for AR (1) and 0.3542 for AR (2) indicate that there is no significant autocorrelation at the first and the second lag. We conclude that in the case of Croatia, an increase in ICT infrastructure is statistically positively associated with an increase in the Croatian value-added export. In what follows, we provide the results of the panel GMM test for other CEECs (Table 7).

Table 7 Panel GMM of the VA export and ICT infrastructure index

Dependent var.	Independent var.	Coefficient	Std. Error	Prob.	AR(1)	AR(2)
BULGARIA	BULGARIA (-1)	-0.41206	$3.57 \cdot 10^5$	0.0000	0.3270	0.3444
	ICTINFR	$7.16 \cdot 10^8$	3882133	0.0000		
CZECH REP.	CZECH REP. (-1)	0.205094	0.000275	0.0000	0.2958	0.2720
	ICTINFR	$7.95 \cdot 10^{10}$	$2.03 \cdot 10^{10}$	0.0000		
ESTONIA	ESTONIA (-1)	0.393418	$6.51 \cdot 10^5$	0.0000	0.7466	0.3141
	ICTINFR	$-2.77 \cdot 10^8$	3997688	0.0000		
HUNGARY	HUNGARY (-1)	0.434731	$3.47 \cdot 10^5$	0.0000	0.1811	0.4500
	ICTINFR	$6.32 \cdot 10^{10}$	56262278	0.0000		
LATVIA	LATVIA (-1)	0.322652	0.000275	0.0000	0.2563	0.3087
	ICTINFR	$-1.35 \cdot 10^9$	6576098	0.0000		
LITHUANIA	LITHUANIA (-1)	0.399418	0.000123	0.0000	0.5234	0.3010
	ICTINFR	$-3.37 \cdot 10^9$	28751594	0.0000		
POLAND	POLAND (-1)	0.493702	8.47E-05	0.0000	0.2552	0.3456
	ICTINFR	$6.17 \cdot 10^{10}$	$1.04 \cdot 10^8$	0.0000		
ROMANIA	ROMANIA (-1)	0.405411	0.000142	0.0000	0.2553	0.1348
	ICTINFR	$1.21 \cdot 10^{10}$	62159672	0.0000		
SLOVAKIA	SLOVAKIA (-1)	0.407618	0.000100	0.0000	0.3173	0.3799
	ICTINFR	$2.98 \cdot 10^{10}$	63379591	0.0000		
SLOVENIA	SLOVENIA (-1)	0.403251	0.000154	0.0000	0.2911	0.2786
	ICTINFR	$2.14 \cdot 10^{10}$	48096784	0.0000		

Calculation: Eviews 13. Transformation: First Differences. Sample (adjusted): 2013 2019. Instrument specification: @ DYN (ICTINFR, -2).

Source: World Bank

The results presented in Table 7 shed light on the relationship between value-added (VA) export and the ICT infrastructure index in a number of countries. It is worth noting that there are differences not only in the magnitudes but also in the signs of the ICT infrastructure coefficients (ICTINFR) between these countries. While most countries have positive coefficients for ICTINFR, indicating a positive correlation between ICT infrastructure and VA export, other countries have negative coefficients, indicating an opposite relationship, as is the case with the Baltic States. This is something worth investigating further.

5. Discussion

In this study, we examine the dynamic interplay between information and communication technology indicators and regional supply chain growth in Central and Eastern European countries over the period from 2011 to 2019. Our Spearman cross-correlation analysis reveals complex relationships between logistics performance, information and communication infrastructure and access and gross domestic product per capita adjusted for purchasing power parity. The stationarity tests revealed unit roots in the data, prompting us to perform a dynamic panel analysis. The subsequent General Method of Moments panel regression reveals a positive persistent impact of lagged logistics performance and a nuanced association between information infrastructure and current logistics performance. Moreover, the introduction of gross domestic product per capita valued in constant purchasing parity highlights the correlation between economic growth and logistics challenges. Extending our investigation to specific Central and Eastern European countries, we find different relationships between value-added export and information and communication infrastructure. In summary, our study highlights the transformative potential of digital technologies for supply chain management and e-commerce logistics. It highlights the benefits and challenges while using advanced statistical techniques to decipher the intricate relationships between key variables in this evolving landscape.

The impact of digital advances on supply chain management is unmistakable. These digital innovations promise to revolutionise supply chain management, leading to greater efficiency, resilience and sustainability. Yet integrating these digital marvels is not without its challenges. Supply chain professionals must be prepared to allocate resources to new technologies and revise their operational frameworks to take advantage of digital technologies. In addition, the implementation of these technologies raises legitimate privacy and data security concerns that require careful consideration.

Digital technologies offer improved supply chain transparency. Real-time insights into the movement of goods can improve delivery speed, accuracy and customer satisfaction. These technologies also increase supply chain flexibility. AI and Big Data quickly detect shifts in demand and help with adjustments. Challenges include data security, privacy, ownership and accessibility, which require careful management for a seamless digital transition.

Another challenge is the investment required. Many digital technologies require significant investment in hardware procurement, software implementation and extensive training. At the same time, supply chain professionals may need to reconfigure their processes to realise the full potential of digital technologies, a transition that requires additional investment in terms of time and resources. This complex interplay of challenges and opportunities underscores the transformative yet complex landscape that digital technologies offer to supply chain management.

Finally, this paper looks at the transformative impact of digital technologies on SCM and e-commerce logistics, with a focus on Central and Eastern European countries. With the rapid growth of the e-commerce industry, accelerated by the COVID-19 pandemic, supply chain professionals face both opportunities and challenges in their quest for efficient, agile and customer-centric operations. The integration of digital technologies, including Big Data, IoT and AI, is emerging as a key strategy to improve visibility, forecasting accuracy and customer experience in the evolving landscape. The study identifies notable factors such as GDP per capita, imports of trade services and the linear shipping connectivity index as influential factors in assessing the logistics performance index at the country level. The adoption of omnichannel strategies and innovative distribution channels, along with technological advances, is proving to be a promising approach to supply chain optimisation. Despite the promising benefits, the adoption of digital technologies comes with privacy, security, investment cost and workforce qualification considerations.

The empirical results presented in the study, supported by advanced statistical methods such as Spearman rank order covariance, cross-correlation analysis and the generalised method of moments, provide a comprehensive insight into the nuanced relationships between key variables and fail to reject the research hypothesis that information and communication technology is positively associated with economic integration at the regional level in terms of rising dynamic values of value-added present in multilateral commerce.

6. Conclusion

In conclusion, our research hypothesis that the integration of digital technologies into Central and Eastern European (CEE) supply chain management is a catalyst for greater efficiency and resilience, together with its potential impact on economic integration through imported value-added export, finds empirical support in our comprehensive analysis. The evidence presented in this study shows that digital innovations, particularly in information infrastructure, play a central role in shaping logistics performance. Our results show a positive relationship between logistics performance and ICT infrastructure, suggesting that the adoption of digital technologies contributes to more efficient supply chains. Moreover, the complex dynamics uncovered between value-added export and ICT infrastructure in specific countries CEE underscores the nuanced nature of this relationship.

Overall, our study contributes to a deeper understanding of the transformative impact of digital technologies on CEE supply chains and highlights their potential to drive economic integration in the region.

References

1. Alnıpak, S., Isikli, E. & Apak, S. (2023). The propellants of the Logistics Performance Index: an empirical panel investigation of the European region. *International Journal of Logistics Research and Applications*, *26*(7), 894-916. https://doi.org/10.1080/13675567.2021.1998397
2. Arellano, M. & Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *The Review of Economic Studies*, *58*(2), 277-297. https://doi.org/10.5267/j.dsl.2017.11.002
3. Amin-Tahmasbi, H. & Alfi, S. (2018). A fuzzy multi-criteria decision model for integrated suppliers' selection and optimal order allocation in the green supply chain. *Decision Science Letters*, *7*(4), 549-566. doi:10.5267/j.dsl.2017.11.002
4. Basaldúa, M. S. & Cruz Di Palma, R. J. (2023). Production, Supply, Logistics, and Distribution. In Nof, S. Y. (Ed.), *Springer Handbook of Automation* (pp. 893-907). Springer International Publishing. https://doi.org/10.1007/978-3-030-96729-1_40
5. Cole, R., Stevenson, M. & Aitken, J. (2019). Blockchain technology: implications for operations and supply chain management. *Supply Chain Management: An International Journal*, *24*(4), 469-483. https://doi.org/10.1108/SCM-09-2018-0309
6. De Backer, K. & Miroudot, S. (2014). *Mapping Global Value Chains* (ECB Working Paper No. 1677). Frankfurt am Main: European Central Bank. http://dx.doi.org/10.2139/ssrn.2436411
7. Friday, D., Savage, D. A., Melnyk, S. A., Harrison, N., Ryan, S. & Wechtler, H. (2021). A collaborative approach to maintaining optimal inventory and mitigating stockout risks during a pandemic: capabilities for enabling health-care supply chain resilience. *Journal of Humanitarian Logistics and Supply Chain Management*, *11*(2), 248-271. https://doi.org/10.1108/JHLSCM-07-2020-0061
8. Gupta, M. & Kohli, A. (2006) Enterprise resource planning systems and its implications for operations function. *Technovation*, *26*(5-6), 687-696. https://doi.org/10.1016/j.technovation.2004.10.005
9. Mance, D., Debelić, D. & Vilke, S. (2023). Croatian Regional Export Value-Added Chains. *Economies*, *11*(8), 202. http://dx.doi.org/10.3390/economies11080202
10. Mance, D., Debelić, B. & Vilke, S. (2021). Regional value chains in Croatia's neighboring countries as economic drivers. In Dujak, D. (Ed.). *Proceedings of the 21st International Scientific Conference Business Logistics in Modern Management* (pp. 233-244). Osijek: Faculty of Economics in Osijek.
11. 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
12. Mathaba, S., Adigun, M., Oladosu, J. & Oki, O. (2017). On the use of the Internet of Things and Web 2.0 in inventory management. *Journal of Intelligent and Fuzzy Systems*, *32*(4), 3091-3101. https://doi.org/10.3233/JIFS-169252.
13. Moosavi, J., Naeni, L. M., Fathollahi-Fard, A. M. & Fiore, U. (2021). Blockchain in SCM: A review, bibliometric, and network analysis. *Environmental Science and Pollution Research*, 1-15. https://doi.org/10.1007/s11356-021-13094-3
14. Nikolakis, W., John, J. & Krishnan, H. (2018). How blockchain can shape sustainable global value chains: An evidence, verifiability, and enforceability (EVE) framework. *Sustainability*, *10*(11), 3926. https://doi.org/10.3390/su10113926
15. Saqib, Z. A. & Zhang, Q. (2021). Impact of sustainable practices on sustainable performance: the moderating role of supply chain visibility. *Journal of Manufacturing Technology Management*, *32*(7), 1421-1443.
16. Tan, C. L., Tei, Z., Yeo, S. F., Lai, K. H., Kumar, A. & Chung, L. (2023). Nexus among blockchain visibility, supply chain integration and supply chain performance in the digital transformation era. *Industrial Management and Data Systems*, *123*(1), 229-252. https://doi.org/10.1108/IMDS-12-2021-0784
17. Twist, D. C. (2005). The impact of radio frequency identification on supply chain facilities. *Journal of Facilities Management*, *3*(3), 226-239. https://doi.org/10.1108/14725960510808491

18. Wamba, S. F. & Boeck, H. (2008). Enhancing Information Flow in a Retail Supply Chain Using RFID and the EPC Network: A Proof-of-Concept Approach. *Journal of Theoretical and Applied Electronic Commerce Research*, *3*(1), 92-105. https://doi.org/10.3390/jtaer3010010
19. Wong, W. P. & Tang, C. F. (2018). The major determinants of logistic performance in a global perspective: evidence from panel data analysis. *International Journal of Logistics Research and Applications*, *21*(4), 431-443.
https://doi.org/10.1080/13675567.2018.1438377
20. Wooldridge, J. M. (2001). Applications of Generalized Method of Moments Estimation. *Journal of Economic Perspectives*, *15*(4), 87-100. https://doi.org/10.1257/jep.15.4.87