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Original research

THE GRANGER CAUSALITY OF DIGITAL CONNECTIVITY AND TRADE GLOBALIZATION IN THE HEALTH CRISIS

Ivana Petkovski [1*], Aleksandra Fedajev [2], Isidora Milošević [2]

[1] *Mathematical Institute of the Serbian Academy of Sciences and Arts, Belgrade, Serbia*
[2] *University of Belgrade, Technical faculty in Bor, Serbia*

Abstract: The widespread adoption of digital technology in the last decade has caused global changes, leading to the belief that technology is altering the global connectivity of economies. This is especially emphasized in light of the global health crisis in 2020. To efficiently monitor this process, it is vital to assess the anticipatory potential of this type of digital connectivity and the growth of globalization in trade. An effective analysis of this issue necessitates looking into the causative relationship between digital technology connections and trade globalization. This is performed by applying the statistical approach of Granger causality to a data set consisting of 35 European countries from 2010 to 2022. A Granger causality study was performed using the lag value estimated based on the Akaike information criterion, which equals 2. The findings suggested that there is a unidirectional causal relationship between active mobile-broadband subscriptions and imports, with the former influencing the latter. However, this causal relationship fails to be valid in the opposite direction. The examination revealed a reciprocal relationship between fixed-telephone subscriptions and exports, as well as a reciprocal relationship between fixed-telephone subscriptions and imports. The results reveal the bidirectional value of the number of fixed telephone subscriptions as a measure of digital connectivity.

Keywords: digital technology, import, export, crisis, causality.

1. INTRODUCTION

The globalization boom began in the 1980s, with developing countries opening to Western markets and expanding foreign direct investment (FDI) (Ari, 2020). Globalization is based on global trade openness and significant financial integration, which is why highly globalized economies are more vulnerable to global market changes than closed countries (Candelon et al., 2020).

[*] *Corresponding author: ivana993@turing.mi.sanu.ac.rs*

Ivana Petkovski, ORCID: 0000-0001-7692-8436
Aleksandra Fedajev, ORCID: 0000-0002-6974-6631
Isidora Milošević, ORCID: 0000-0001-5539-8253

Digital technology, as an important factor in global economic integration, can be considered the driver of globalization development in the 21st century (Baldwin, 2018). Its role in developing society and the economy during the previous decade was critical. This primarily refers to the importance of digital technology, which was highlighted during the period of the global health crisis that began in Europe in 2020 and whose economic consequences are still present and manifest some common features like uncertainty, economic recession, and monetary and fiscal responses (Jebabli et al., 2021).

One of the visible social and economic consequences of the world health crisis was the stagnation of the flow of people, goods, and services beyond national borders. This stagnation resulted in a serious economic slowdown due to the collapse of economic activities, slowed globalization, and reduced the level of international trade activities (Galindo-Martín et al., 2021). Various prohibitions and rules individually adopted by the countries further complicated trade in goods (Liu et al., 2021). The pandemic has imposed restrictions on global trade and the global value chain, particularly for countries that rely on exports (Naseer et al., 2023). Economies have suffered serious fluctuations on the supply and demand sides, and those kinds of market irregularities threaten the speed of recovery after the crisis (Naseer et al., 2023).

Authors Paul et al. (2021) identified the major challenges in the supply chain that can occur during a pandemic, and among the top five challenges they cite are a lack of either financial or other resources, the global recession, a demand decline, a reduction in sourcing options; and an increase in the price of raw materials. Authors Eichengreen et al. (2021) present recent comprehensive research about previous crises and COVID-19, providing a good review of past crisis experiences and attempting to illustrate it with the example of the current crisis. Their study's empirical evidence recalls past crises' challenges and recovery patterns from the 1950s until the current pandemic. However, the main difference between COVID-19 and previous crises is that financial crises start in the financial sector and spread to other sectors. In contrast, health crises emerge in the health sector, hitting other sectors like transport and industry and consequently destroying the financial sector (Jebabli et al., 2021).

Considering the effect of the global health crisis on the scale of worldwide trade as well as the demonstrated value of digital technology during that period, it is vital to investigate the source of these relationships. This study's value lies in exploring the causal relationship between digitalization and globalization, viewed as a share of countries' trade in gross domestic product (GDP). This analysis will enhance the accuracy in predicting the evolution of these phenomena, especially in the dynamic context of the health crisis. The lack of literature on the causal relationship between these two variables throughout the period, including the years before and after the health crisis, motivates this investigation. We applied the Granger-Causality analysis in this research to investigate the causal relationship between digitalization and globalization in trade. The paper's findings should support policymakers, managers, and trade professionals in making rational choices regarding formulating and implementing strategies that would accelerate economic recovery and reinforce global trade.

The paper has five sections. The first section offers an introduction, while the second section discusses the findings from recent literature. The third section provides an overview of secondary data used for analysis and describes the approach that was applied. The fourth section covers the essential study findings and their further evaluation. The final section represents the conclusion. This section summarizes the results, describes the limitations of the research, and offers a brief summary of potential future studies.

2. LITERATURE REVIEW

The study by Skare and Soriano (2021) demonstrates the complex dynamics of the relationship between the adoption of digital technology and globalization. Through Granger causality analysis, it is proven that the growth of globalization directly influences the rising use and acceptance of digital technology, which in turn impacts the further advancement of globalization. Empirical research evaluating digitalization's effects on participation in international distribution chains due to globalization has validated previous results (Gopalan et al., 2022). The research confirms that website accessibility and high-speed Internet availability stimulate business involvement in global supply chains (Gopalan et al., 2022). Applying digital technologies, such as the Internet, helps export growth while minimizing expenditures related to transactions and interactions with partners abroad (Visser, 2019).

Early research performed on panel data from 151 countries in the period from 1990 to 2006 suggests that the use of the Internet as a proxy for digitalization has effects on foreign service trade volume and, therefore promotes the expansion of globalization (Choi, 2010). According to Kere and Zongo (2023), the increasing adoption of ICT in sub-Saharan Africa causes modifications in the import and export rates of goods and services. The researchers discuss that the digitalization of information and processes in the international customs system, along with the development of digital infrastructure through greater penetration of optical fibre, will improve trade turnover while cutting the costs related to foreign trade transactions (Kere & Zongo, 2023). Bunje et al. (2022) study tackles the question of digital technology use in the economy and its effects on trade, which is expressed as the ratio of imports and exports as a share of gross domestic product (GDP). The study confirms that digital technology significantly impacts international trade in both long-term and short-term economic contexts (Bunje et al., 2022). The authors suggest prioritizing the construction of broadband infrastructure and the creation of digital platforms for e-trade (Bunje et al., 2022). Using machine learning methods on a sample of 30 Chinese provinces from 2000 to 2018, another study proved internet use's positive impact on the value of export activities (Shetewy et al., 2022). Another study, which appeared in 2023, examines the effect of internet connectivity on international trade from the perspective of the gravity model (Herman & Oliver, 2023). This research confirms the presence of a correlation between internet usage and international trade, indicating that the Internet supports foreign trade activities (Herman & Oliver, 2023).

A literature review provides evidence about the reverse causality between trade globalization and the adoption of digital technology. In a causal analysis conducted by Grossman & Helpman (1995), the bidirectional causality between digital technology and international trade has been verified. An early study conducted in 2011 confirms the causality between export activities and technology adoption (Bustos, 2011). However, the results of the latest research studies show the bidirectional relationship between digital technology broadband and connectivity and trade openness has been confirmed in a sample of G20 economies (Arvin et al., 2021). The study verifies a bidirectional causal relationship between the number of mobile phone subscriptions, individuals using the Internet, secure Internet servers, fixed broadband subscriptions, and the constructed ICT index as proxies for digital development and, on the other side, trade openness (Arvin et al., 2021). In addition, the study confirms a unidirectional causal relationship between trade openness and the number of fixed telephone subscriptions (Arvin et al., 2021). The authors suggest that promoting the use of digital platforms in foreign trade business can foster transparent and fair trade (Arvin et al., 2021). Research examining the

reciprocal relationship suggests that engaging in a worldwide supply chain affects the integration of digital technologies (Delera et al., 2022). Another empirical study presented in 2022 discusses the Granger causality test results between trade openness, ICT index, and economic growth on a sample of 14 industrial sectors in Tunisia acquired from 1995 to 2018 (Dahmani et al., 2022). The research provides evidence of the bidirectional relationship between the ICT index and trade openness. The authors suggest developing digital infrastructure and sharpening digital skills (Dahmani et al., 2022).

When discussing the effects of the global health crisis, economies that base their development on demand-led growth are the most vulnerable during a crisis, and this state results in an economic recession, which is followed by additional financial constraints such as borrowing restrictions and decreasing purchasing power (Lacerda, 2019). After the global health crisis, the worldwide supply chain can be improved through the expansion of digital technology adoption and trade partnerships, especially between capital-intensive industrialized economies (Liu et al., 2024). Peng et al. (2024) studied the causal relationship between the global health crisis and trade in the form of equity. The authors propose a set of fiscal and economic measures to stabilize the market, including reducing the tax burden, implementing social security programs, and cutting the interest rate on loans (Peng et al., 2024).

3. DATA AND METHODOLOGY

In order to test the causal relationship between the type of digital connectivity and trade globalization, the research study included annual panel data for 35 European countries that were available in the selected data repository. The full list of countries, including EU and non-EU member states, is documented in Table 1. The period covered in the research is 2010 to 2022.

Table 1. List of countries

Austria	Denmark	Iceland	Montenegro	Serbia
Belarus	Estonia	Ireland	Netherlands	Slovak Republic
Belgium	Finland	Italy	North Macedonia	Slovenia
Bulgaria	France	Latvia	Norway	Spain
Croatia	Germany	Lithuania	Poland	Sweden
Cyprus	Greece	Luxembourg	Portugal	Switzerland
Czech Republic	Hungary	Malta	Romania	United Kingdom

Regarding the set research objective, the data were distributed into two groups that illustrate the types of digitalization and trade globalization. The data gathered for the first four variables represents the type of digitalization, and the following two variables were selected for the presentation of trade globalization. The list of variables is reported in Table 2, with appropriate abbreviations and sources.

Table 2. Variable information.

Group	Variable	Abbreviation	Source
Digital connectivity	Active mobile-broadband subscriptions per 100 inhabitants	*AMBS*	World Bank open data (2023)
	Fixed broadband subscriptions per 100 inhabitants	*FBS*	
	Mobile-cellular subscriptions per 100 inhabitants	*MCS*	
	Fixed-telephone subscriptions per 100 inhabitants	*FTS*	
Trade globalization	Import of goods and services as % of GDP	*IMP*	
	Export of goods and services as % of GDP	*EXP*	

The research's analytical component contains the application of econometric analysis using the Granger causality test. Author Clive Granger first described the theoretical broadness of the Granger causality analysis and introduced the technique (Granger, 1969). The Granger causality analysis method analyzes the causal relationship between variables in time series data (Shojaie & Fox, 2022). This analysis suggests that if the past value of the first variable provides a better prediction of the second variable than the past values of the second variable, it is Granger-caused (Granger, 1969). The nature of this relationship might be either unidirectional or bidirectional, depending on the causal directions between the variables. If the values of the first variable are used in predicting the values of the second variable, but there is no realization of reverse causality, then it can be described as a unidirectional causal relationship (Granger, 1969). If a causal relationship can be established between two variables in both directions, then the relationship is considered to be bidirectional causal (Granger, 1969).

When conducting a time series analysis, it is crucial to ascertain the presence of a trend in the data by assessing the stationarity of the data (Shojaie & Fox, 2022). The unit root test assesses the stationarity of panel data (Kónya, 2004). Several tests are available for measuring the unit root, including the Im, et al., (2003), test the Fisher ADF test (Dickey & Fuller, 1979), and the Fisher PP test (Phillips & Perron, 1988). The mathematical calculation of stationarity is performed for data at the level as well as for the first and second differences. Within the test structure, it is possible to include intercept values as well as intercepts with a trend. The lag length is selected according to the available information criteria when doing the unit root test. Practitioners commonly use the following criteria: (1) the Akaike Information Criterion; (2) Schwarz Information Criterion; and (3) the Hannah Quinn Criterion (Bierens, 2004). The null hypothesis for testing stationarity suggests that variable *X* exhibits the presence of a unit root (Kwiatkowski et al., 1992).

Differentiation is performed if the null hypothesis is rejected (Kónya, 2004). The following criteria guide the selection of the lag length value before conducting the Granger causality test (Bierens, 2004; Clarke & Mirza, 2006; Hatemi-J & Hacker, 2009):

1. *LR*: The sequential modified LR test statistic is used at a 5% significance level for each test.
2. *FPE*: Final prediction error is a measure used for prediction accuracy.
3. *AIC*: The Akaike information criterion is a statistical measure used for model selection.
4. *SC*: The Schwarz information criterion is another statistical measure used for model selection.
5. *HQ*: The Hannan-Quinn information criterion is another statistical measure used for model selection.

The slope with the lowest value, given by most criteria, is selected. Afterwards, the data points are arranged to undergo Granger analysis. The null hypothesis being examined can be presented in the following form (Granger, 1969):

H0: Previous values of variable X do not offer any additional insight in forecasting future values of variable Y than the past values of Y.

The decision involving causality is made based on the findings of the evaluated assumptions.

4. RESULTS AND DISCUSSION

The descriptive statistical measures presented in Table 3 provide insight into the characteristics of the data set. Spanning a total series of 455 observations, it becomes evident from the minimum and maximum values that substantial disparities exist in the attained values

across the observed countries. This variability is particularly pronounced in the variable denoting active mobile broadband subscriptions, wherein data dispersion around the mean is most pronounced, reflecting the high variance.

Table 3. Descriptive statistics.

Variable	Minimum	Maximum	Mean	Std. Deviation	Variance
AMBS	8.00	210.00	80.61	35.1392	1234.76
FBS	10.00	50.00	30.96	8.2011	67.26
MCS	87.00	203.00	123.33	16.5607	274.26
FTS	3.00	96.00	34.51	15.5603	242.12
IMP	26.00	180.00	61.65	29.4363	866.49
EXP	22.00	213.00	64.04	34.8347	1213.46
Valid N = 455					

The basic step in analyzing the times series is related to verifying the stationarity of the data set. The stationarity of the data was checked using the panel unit root analysis based on the test developed by Im et al. (2003). This type of test was selected because it considers the presence of heterogeneity among the data reflected in observing different countries (Antonietti & Franco, 2021). The latency length was assumed to be 2 when conducting this test, as suggested by the Akaike Information Criterion (AIC). This is also the typical value applied when analyzing annual data, as in this example. The results of the unit root test are shown in Table 4.

The stationarity check led to the conclusion that all variables, except for active mobile broadband subscriptions (*AMBS*), lack stationarity. The authors applied the mathematical calculation of the first difference between the values of the provided variables to address this problem and transform all non-stationary variables into stationary ones. The outcomes presented in Table 4 illustrate the Im, Pesaran, and Shin tests after the first difference calculation. Before conducting the Granger causality test, standard vector autoregression estimates (VAR) were used to examine the value of the lag length based on six endogenous variables. Table 5 presents the results of the VAR analysis, encompassing all six information criteria used to measure the lag length.

Table 4. Im, Pesaran and Shin unit root test.

Variable	Level		1st difference	
	Intercept	Intercept and trend	Intercept	Intercept and trend
AMBS	0.0000	0.0055	0.0000	0.0000
FBS	0.9045	0.8897	0.0000	0.0000
MCS	0.2985	0.3815	0.0000	0.0000
FTS	0.2106	0.0000	0.0000	0.0000
IMP	0.9936	0.0035	0.0000	0.0000
EXP	0.8068	0.0014	0.0000	0.0002

Table 5. VAR Lag order selection criteria.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-6284.323	NA	164000000	35.94471	36.01084	35.97103
1	-5768.448	1011.116	10589035	33.20256	33.66551*	33.38683
2	-5699.994	131.8224*	8798154.*	33.01711*	33.87688	33.35933*

* indicates lag order selected by the criterion

LR: sequential modified LR test statistic; FPE: Final prediction error; AIC: Akaike information criterion; SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion.

In most cases, the selected value of the length of the lag is 2, which is the adopted value for further pairwise Granger causality analysis, and the analysis outcome is presented in Table 6.

Table 6. Pairwise Granger Causality Tests, lags: 2.

Null Hypothesis:	Observations	F-Statistic	Probability (*p*-value)
Δ*IMP* does not Granger Cause *AMBS*	350	1.41113	0.2453
AMBS does not Granger Cause Δ*IMP*		4.58984	0.0108
Δ*EXP* does not Granger Cause *AMBS*	350	0.27414	0.7604
AMBS does not Granger Cause Δ*EXP*		2.05075	0.1302
Δ*IMP* does not Granger Cause Δ*FBS*	350	0.89242	0.4106
Δ*FBS* does not Granger Cause Δ*IMP*		0.78035	0.4591
Δ*EXP* does not Granger Cause Δ*FBS*	350	0.78664	0.4562
Δ*FBS* does not Granger Cause Δ*EXP*		1.65447	0.1927
Δ*IMP* does not Granger Cause Δ*MCS*	350	0.92681	0.3968
Δ*MCS* does not Granger Cause Δ*IMP*		1.25544	0.2862
Δ*EXP* does not Granger Cause Δ*MCS*	350	1.99499	0.1376
Δ*MCS* does not Granger Cause Δ*EXP*		0.11339	0.8928
Δ*IMP* does not Granger Cause Δ*FTS*	350	5.08357	0.0067
Δ*FTS* does not Granger Cause Δ*IMP*		5.44011	0.0047
Δ*EXP* does not Granger Cause Δ*FTS*	350	4.67553	0.0099
Δ*FTS* does not Granger Cause Δ*EXP*		3.94448	0.0202

Using pairwise Granger causality analysis, researchers found both one-way and two-way links between different aspects of digital connectivity and globalization in trade. A statistically significant unidirectional connection was observed from the variable of active mobile broadband subscribers (*AMBS*) to the import variable (*ΔIMP*) ($p < 0.05$). Specifically, the number of active mobile broadband customers can serve as an indicator for anticipating fluctuations in imports because any change in the number of mobile users leads to a change in import balance. The inverse relationship of this relationship was not validated, indicating that the statistics on imports do not significantly impact the estimation of the number of active mobile broadband customers. The Granger causality test could not detect any statistically significant causal links between the export variables (*ΔEXP*) and active mobile broadband subscribers (*AMBS*). No causal relationship was found between fluctuations in imports (*ΔIMP*) and exports (*ΔEXP*) in connection with variations in the number of fixed broadband subscribers (*ΔFBS*) and mobile cellular subscribers (*ΔMCS*). These findings demonstrate that the data on imports and exports does not impact the number of fixed broadband users or mobile cellular subscribers. As a result, they cannot be utilized to forecast future values in either direction. Conversely, the positive outcomes of the Granger test demonstrated a bidirectional connection between imports (*ΔIMP*) and fixed telephone subscribers (*ΔFTS*), as well as between exports and fixed telephone subscribers (*ΔFTS*), with statistical significance ($p < 0.05$). The results of the study of the Granger causality test suggested that the use of fixed telephones as a form of digitalization has a causal effect on the fluctuations in imports and exports of the countries under investigation and vice-versa. Through that connection, the relationship reflects control and management of the flow of goods and services in international trade. The bidirectional causality results align with the previous research results (Arvin et al., 2021; Delera et al., 2022; Dahmani et al., 2022). By utilizing these indicators, it is possible to develop more accurate predictive models, as variations in the number of fixed telephones might forecast changes in the trade balance and vice-versa. The results have profound implications for decision-making

based on information and knowledge, indicating that intervening in one variable can also impact other variables.

5. CONCLUSION

When developing a forecasting model to understand the relationship mechanism, it is essential to identify the causal relationship between the variables. This study provides an understanding of the causality between different types of digital connectivity and globalization in trade. It analyses the research problem by applying the generally accepted Granger causality analysis to a dataset spanning 35 European countries between 2010 and 2022.

The paper's scholarly value is found in examining the relationship between different kinds of digitalization and trade globalization, both before and shortly after the emergence of the 2020 global health crisis. It provides essential knowledge into the utilization of these variables for developing prediction models, considering that international trading witnessed a substantial decline during the crisis period due to the stagnation of cross-border trade. Furthermore, digital technology plays an integral part in supporting the integration of the global population.

In addition to its scientific significance, the research study also holds practical value. Causal analysis has proven that mobile technology accessibility can impact import volume. Therefore, improving digital mobile technology can influence the globalization of trade flows, aligning with strategies for future trade development. The growing popularity of mobile telephony has the potential to enhance the efficiency of international trade by facilitating the exchange of goods and services across different e-commerce platforms.

The relationship between the number of fixed telephony customers and imports and exports demonstrates the importance of population and economic integration in global trade flows. Modernizing and broadening the digital infrastructure for fixed telecommunications will be extremely helpful for managing worldwide trade flows. Adopting such guidelines may strengthen the effectiveness of global trade operations and lower trade expenses.

The study's limitations pertain to the data collection time frame, which could expand with historical data availability. Furthermore, the limitation is evident in the selection of variables that depict globalization in trade. Therefore, additional research might incorporate a broader range of these indicators. The final identified limitation is the inability to perform a Granger cause analysis on distinct data sets prior to and following the health crisis. This is due to the small data set size after 2020, which consequently delays the completion of the comparative analysis until a future period.

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