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Supply Chain Interconnectedness in Times of Crises: A Gravity Model with DiD Analysis of COVID-19 Effects on Central and Eastern European Trade

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Abstract: This paper explores the impact of COVID-19-induced disruptions on supply chains, specifically focusing on the interconnectedness of supply chains and the transmission effects they cause. The gravity model framework, together with difference-in-differences analysis, is employed to analyze monthly trade patterns among Central and Eastern European (CEE) countries, Western European countries, and other trading partner countries. The model presented accounts for the country's roles in global value chains (GVCs) by incorporating data related to exports, imports of intermediate and capital goods, and imports of final consumption goods. CEE countries have demonstrated a certain resilience during the COVID-19 pandemic. Yet, they were not immune to adverse consequences due to disrupted supply chains, primarily in the imports of intermediate and capital goods. We find that the countries that suffered from the COVID-19 pandemic the least demonstrated remarkable resilience against disrupted GVCs. The findings of our study enrich the literature on the effects of the COVID-19 pandemic, specifically for the CEE region, by providing a framework for understanding the pandemic's impact on international trade. The results show that supply shock might be greater than demand shocks on production and trade dynamics. Furthermore, our results suggest that policymakers seek adaptability to changing supply and demand patterns, while enterprises should consider broader diversification both within the region and locally.

Keywords: global value chains; disruption; gravity model; DiD; COVID-19; Central and Eastern Europe; international trade

1. Introduction

The global economy faced unprecedented challenges in 2020 as the COVID-19 pandemic triggered widespread disruptions in supply chains, causing a sharp contraction in economic activities. Multiple lockdowns, travel restrictions, and reduced consumer activity led to a disruption in supply and demand worldwide, a collapse in trade, and a shift in purchasing patterns, resulting in sharp declines in gross domestic product (GDP) during the pandemic's early stages. The intricate interconnections within supply chains became a focal point, leading to a cascade of effects across countries. Therefore, this paper delves into the specific impact of COVID-19-induced disruptions on supply chains, primarily focusing on understanding the interconnectedness of these chains and the ensuing transmission effects.

To achieve this, we employ a robust analytical framework that combines the gravity model and difference-in-differences analysis (DiD) to scrutinize annual trade patterns among Central and Eastern European (CEE) countries, Western European (WE) countries, China, and other trading partners. The model considers countries' roles in global value

chains (GVCs), accounting for exports, imports of intermediate and capital goods, and imports of final consumption goods. We aim to unravel how the CEE region responded to the challenges posed by the pandemic, shedding light on the dynamics of supply and demand shocks.

Our analytical framework accounts for well-known facts about the magnitude of this economic disturbance, as the world's GDP[1] collectively fell by 3.4% in 2020. To put this number in perspective, the global GDP[2] reached USD 84.54 trillion in 2020; thus, a 3.4% drop in economic growth resulted in a significant loss of over USD 2 trillion in economic output. A substantial number of publications discuss the potential and recorded impact associated with the spread of the pandemic (Büchel et al. 2020; Meier and Pinto 2020; Bonadio et al. 2021; Espitia et al. 2022; Hayakawa and Mukunoki 2021; Liu et al. 2022; Seuring et al. 2022; Smith and Fatorachian 2023; Yudha and Roche 2023). A common finding is that the pandemic has forced an unprecedented economic shock (Gorynia and Trąpczyński 2022; Rostan and Rostan 2022; Jurado and Kuo 2023) and challenged the trade flows worldwide (Cao et al. 2021; Barbero et al. 2021; Petrylė 2022; Davidescu et al. 2022; Yudha and Roche 2023; Enns et al. 2023). These issues require multidimensional responses (Karuppiah et al. 2022; Chen et al. 2023; Smith and Fatorachian 2023) and adaptation for international trade, including GVC-related trade. Even though governments have implemented extraordinary interventions to tackle the severe economic downturn and protect businesses and workers, the impact has varied (Suskind and Vines 2020).

The motivation for our research stems from the fact that the impact of the pandemic on economies varied depending on their structure and composition. In addition, the economic impact has been heterogeneous within the European Union (EU). There were significant differences in changes to primary macroeconomic aggregates, including consumption, investment, and government fiscal policies. For instance, in some OECD (the Organization for Economic Cooperation and Development) nations, sectors such as recreational and personal services, accommodation, and food services experienced declines exceeding 20% between February and September 2020. In comparison, the manufacturing and construction sectors reported more modest drops of 5% to 8%. Some sectors, notably wholesale and retail trade, recorded favorable growth rates during this period (Arriola et al. 2022). According to Del Rio-Chanona et al. (2020), certain sectors, such as transportation, were hit more by demand shocks, while others, like manufacturing, were primarily affected by supply shocks. Moreover, some sectors, such as tourism and entertainment, experienced a combination of both shocks. Manufacturers encountered difficulties obtaining supplies and components, compounded by a significant decline in production demand, resulting in a severe disruption in international trade flows. Considering the vulnerabilities within the GVCs exposed by the pandemic, it became apparent that disruptions in one part of the value chain can precipitate ripple effects across countries and industries. Thus, the disruption of GVCs became the central theme, affecting industries that heavily rely on imports and exports.

While extensive research exists on the widespread impact of the COVID-19 pandemic, research regarding the experience of CEE countries is lacking. In light of this gap, this study aims to comprehensively examine the impact of COVID-19-induced disruptions on GVCs and international trade. Additionally, it seeks to answer how CEE countries have responded to the evolving trade patterns caused by the pandemic, particularly those concerning their trade connections with WE countries. By addressing this gap, our study contributes to understanding the impact of the pandemic on GVCs for CEE countries.

The remainder of this paper is organized as follows: Section 2 reviews the most relevant literature on the economic impact of the disruptions caused by the COVID-19 pandemic on supply chains. Section 3 describes the research methodology and data utilized in the study. The capabilities provided by BEC rev. 5 (the classification by Broad Economic Categories, Rev. 5) to distinguish between countries' trade in homogeneous and differentiated intermediate and final consumption and capital goods have been applied

to tackle the challenges. Unlike other studies, this approach enables us to examine the direct impact of shocks related to intermediate products and capital goods originating from exporting countries on CEE countries' trade and how the export demand for its final consumption goods affects its exporting partners. Section 4 presents the results of our empirical analysis and robustness check. Section 5 offers a discussion of our results in the context of existing research. Finally, Section 6 presents the conclusions of our research, offering practical implications and suggestions for future research.

2. Theoretical Framework

In recent years, the concept of regional resilience has gained significant popularity in the field of social science. This issue primarily pertains to escalating economic shocks and disruptions in global economies. As the level of uncertainty grows, it becomes more important to consider regional resilience. In the academic literature, the concept of regional resilience within the global supply chain is often linked to a region's capacity to effectively respond to unforeseen shocks, quickly recover from disruptions, and mitigate risks associated with such disruptions (Hassink 2010; Ivanov 2021; Karuppiah et al. 2022; Meng et al. 2022; Sawik 2022). Regional resilience is particularly relevant in understanding the experience of CEE countries in the face of disruptions caused by the COVID-19 pandemic.

The global outbreak of the COVID-19 pandemic and the subsequent disruptions have profoundly impacted international trade, supply chains, demand, and logistics on a global scale (Sawik 2022). Disruptions caused by the COVID-19 pandemic can be observed as a typical cycle of consequential events, as Sawik (2022) suggests. The emergence of a pandemic within a particular geographical area gives rise to various consequences and disruptions in the supply chain. Initially, the region where the outbreak originates undergoes a lockdown, leading to the closure of facilities and the temporary halt of production and shipment of goods. This scenario increases the demand for essential products while non-essential products suffer a decline in demand. A systematic review made by Chen et al. (2023) emphasizes the main sources of uncertainty in supply chains worldwide: (1) uncertainty in demand due to factors such as fierce market competition and variable consumer demand makes it difficult for supply chain companies to obtain complete information about the market demand, (2) supply-side uncertainty due to uncertainty supply quality, quantity, and extended delivery time, and (3) operating cost uncertainty, risk uncertainty, and disruption uncertainty are caused by various internal and external environmental factors.

The disruptions in the supply chain and the spread of a pandemic to other regions result in the implementation of lockdowns, closure of facilities, and suspension of production in those areas. Furthermore, transportation between different regions is impacted. As the lockdown period in the initial outbreak area comes to an end, facilities reopen and production and shipment of products resume. Consequently, there is an increase in the demand for non-essential products. Similarly, as the lockdowns in the other regions are lifted, facilities reopen, production resumes, and transportation between regions resumes. The gradual recovery process eventually leads to a restoration of the entire supply chain.

The COVID-19 pandemic exposed vulnerabilities within GVCs, as disruptions in one part of the chain could spread downstream, causing a ripple effect of further disruption in the structural configuration of the supply chain and detrimentally impacting its overall performance across countries and industries (Smorodinskaya et al. 2021). The onset of the COVID-19 pandemic allowed Baldwin and Freeman (2020); Baldwin and Tomiura (2020); and Friedt and Zhang (2020) to observe that the impact of a global pandemic on international trade manifests in three distinct ways:

1. First, through direct supply disruptions hindering production, the contagion of GVCs occurs.

2.   Second, disruptions in demand can occur due to a decrease in aggregate demand and delays in consumer purchases.

3.   Third, there are delays in investment by investors.

The existing literature offers a comprehensive analysis of the impact of COVID-19-induced disruptions on GVCs and international trade within EU countries. The economic impact of the COVID-19 pandemic has been heterogeneous across the member countries of the EU. Although the steepest economic decline was recorded in 2020, the overall real GDP level in the first quarter of 2021 remained well below its pre-crisis level in all countries except for Estonia (3.4%), Ireland (13.2%), Lithuania (1.1%), and Luxembourg (3.2%), as illustrated in Figure 1. In contrast, Spain, Italy, Malta, Austria, and Portugal saw the most significant drops in real GDP. Portugal and Spain experienced the most significant setbacks at 9.1% and 9.3%, respectively (Muggenthaler et al. 2021). The economic contraction varied among countries, particularly due to the disruption of GVCs caused by the pandemic. This disruption had an especially profound impact on industries that heavily rely on both imports and exports. While manufacturers worldwide encountered challenges in sourcing materials and components, they also underwent a significant drop in production demand (Kejžar et al. 2022).International trade flows decreased by 13% in 2020 before quickly rebounding, resulting in a significant increase in transportation costs[3] and disruptions in GVCs (Brenton et al. 2022, Cao et al. 2021, Espitia et al. 2022).
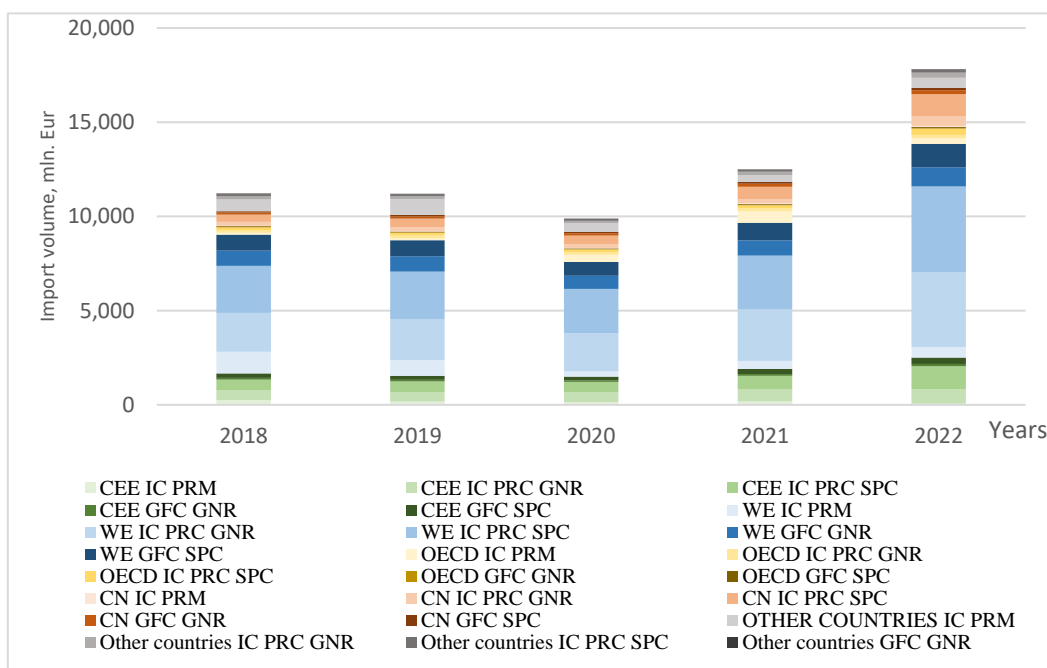

Figure 1. Yearly imports of intermediate goods (IC) (primary (PRM), generic (GNR), and processed special (PRC SPC)) and gross formation capital goods (generic (GFC GNR) and special (GFC SPC)) of Central and Eastern EU (CEE) countries (Bulgaria, Cyprus, Czech, Croatia, Estonia, Hungary, Lithuania, Latvia, Malta, Poland, Romania, Slovakia, and Slovenia). Source: authors' calculations based on the Comext database (Eurostat 2023).

In our research, we adopt the conceptual framework of the triple pandemic effect on trade by examining trade shocks within CEE countries. This systematic approach directly addresses the research question by offering means to evaluate CEE countries' adaptation to evolving trade patterns caused by the pandemic, particularly in their connections with WE countries. We place particular focus on backward and forward linkages. The former refers to COVID-19-induced disruptions within foreign supplier networks, and the latter relates to demand decline due to government-imposed restrictions. As Figure 1 shows,

CEE countries witnessed a substantial decrease in their imports of intermediate consumption (IC) and gross formation capital (GFC) goods, significantly decreasing during the first year of the COVID-19 pandemic.

The supply of intermediate and capital goods is crucial for the production process, which encountered uneven disruptions. The most significant decrease was observed in the form of imports from countries that had joined the EU before 2004, as well as from China and other global regions. However, imports from other CEE countries performed relatively stably, with minimum level fluctuations.

A similar pattern was observed regarding the demand for final consumption (FC) products manufactured within the CEE region. A decline in demand was witnessed across all regions except for other CEE countries. However, unlike intermediate and capital goods, whose supply had already recovered by 2021, demand recovery extended up to two years, as depicted in Figure 2. The demand for CEE FC goods, both homogeneous (PRM) and differentiated (PRC), fully recovered in 2022, surpassing pre-pandemic levels, particularly within the WE countries.
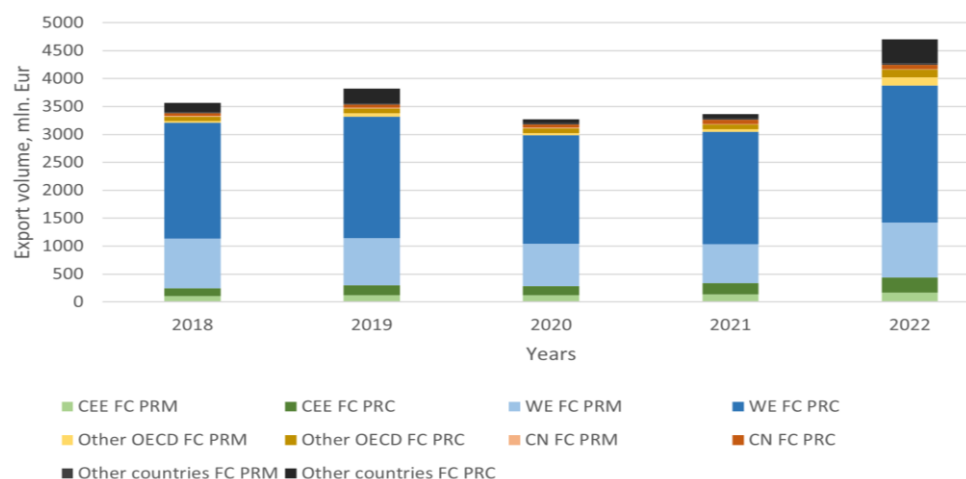

Figure 2. Yearly exports of final consumption goods (FC) (primary (PRM) and processed (PRC)) of Central and Eastern EU (CEE) countries (Bulgaria, Cyprus, Czech, Croatia, Estonia, Hungary, Lithuania, Latvia, Malta, Poland, Romania, Slovakia, and Slovenia). Source: authors' calculations based on the Comext database (Eurostat 2023).

Numerous studies have already stipulated empirical evidence regarding the impact of supply and demand shocks on international trade. However, some research adopts a single-country perspective, not explicitly highlighting the connections between countries in GVCs (Büchel et al. 2020; Liu et al. 2022). Alternatively, certain studies examine specific countries' real economic activity, cross-sectorial effects of labor supply shocks or financial sectors (Meier and Pinto 2020; McCann and Myers 2020; Bonadio et al. 2021; Hacıoğlu-Hoke et al. 2021) or focus on the firm level (Hassan et al. 2020). Others explore bilateral trade just for capital goods flows or examine bilateral trade from a multi-country perspective, with an emphasis on supply chain relationships, although frequently relying on synthetic indices as proxies (Arriola et al. 2022; Kejžar et al. 2022). In the latter case, assessing how effectively these indices reflect actual GVC relationships can present fundamental challenges.

3. Methodology: Model Framework and Data

In this section, we aim to assess the theoretical insights empirically. We examine how CEE countries have adapted to the new patterns of international trade caused by the pandemic in relation to their connections with other European countries. By analyzing linkages, we aim to provide valuable insights into trade shocks within this region.

In this study, we test different trade-related pandemic-induced shock transmission mechanisms that affect CEE. For this purpose, we use data on intermediate, capital, and final consumption goods in CEE bilateral trade involving Western Europe, China, other OECD countries, and other significant CEE trade partners. The research data cover five years, from 2018 to 2022. We employ the international trade gravity model to annual data to assess the impact of short-term trade shocks with the DiD approach. As shown in Figures 1 and 2 above, trade shocks triggered by the COVID-19 pandemic emerged, persisted, and subsided relatively quickly (like the policies implemented by the affected countries). To account for pandemic-induced shock transmission mechanisms in bilateral trade, we test for supply and demand shocks coming from domestic and foreign trade partners.

3.1. Gravity Model Framework with DiD

To assess the impact of the COVID-19 pandemic on international trade, we employ the DiD method based on the gravity model, which is commonly used to test trade relationships among countries and the impact of economic policies on these relationships. The main idea of the model is that the volumes of international trade between countries are directly proportional to the size of their respective markets (e.g., GDP) and inversely proportional to the geographical distance between them (Tinbergen 1962). Although various model variations have been developed and adopted over time, it is necessary to distinguish Anderson and van Wincoop's (2003) research. They introduce the concept of the "border puzzle", which illuminates the phenomenon of trade volumes across international border control points, particularly those between neighboring countries, being lower than what conventional gravity models would predict. They emphasize the dominance of larger economies, often representing major global economies, in shaping global trade patterns and underscore constraints this dominance places on trade flows, specifically for small countries. Hence, in line with the approach established by Anderson and van Wincoop (2003), the framework of the gravity model we employ can be defined as follows:

$$X_{ijt} = \frac{Y_{it}Y_{jt}}{Y_t} \left(\frac{t_{ijt}}{\Pi_{it}P_{jt}}\right)^{1-\sigma} \tag{1}$$

where X_{ijt} denotes trade flows of CEE countries, Y_t represents the world GDP, and Y_{it} and Y_{jt} represent the GDP of countries *i* and *j*, respectively. t_{ijt} (one plus the tariff equivalent of overall trade costs) is the cost in *j* of importing a good from *i*, $\sigma > 1$ is the elasticity of substitution, and Π_{it} and P_{jt} represent exporter and importer ease of market access (or country *i*'s outward and country *j*'s inward multilateral resistance terms).

Considering the multiplicative nature of the gravity equation, we employ the standard procedure for estimating a gravity model (1) by simply taking the natural logarithms of all variables and obtaining a log-linear equation that can be estimated by ordinary least squares regression. Following up on Anderson and van Wincoop's (2004) conceptual framework for controlling the multilateral resistance terms, we use the following trade costs specification:

$$t_{ijt} = dst_{ijt}^{\delta_1} + \delta_2 cont_{ij} + \delta_4 lang_{ij} + \delta_4 RTA_{ij} + \delta_4 CEE_{ij} + \delta_4 WE_{ij} + \delta_4 CN_{ij} + \delta_4 OECD_{ij} \tag{2}$$

where dst_{ijt} is adjusted bilateral distance, and $cont_{ij}$, $lang_{ij}$, and RTA_{ij} are dummy variables denoting, respectively, whether the two countries have a common border, common language, and whether the two countries are members of a regional trade agreement (RTA). We also control cost terms indirectly by introducing different country-specific dummies separately for old EU and new EU member states (those that joined the EU in 2004 (WE countries) and those that joined afterward (CEE countries)) and other

OECD countries (OECD). In this respect, we distinguish China (CN) for its economy's magnitude.

By employing this gravity model framework, we follow up on Chen et al.'s (2018) methodology, under which we incorporate the DiD method into the gravity model to assess the impact of COVID-19 on the CEE countries' exports (EX) and imports of intermediate goods (IG), capital goods (CG), and final consumption goods (FCG).

Thus, our augmented gravity equations are as follows:

$$EX_{ijt} = \beta_0 + \beta_1 AFC_i + \beta_2 d_2 + \beta_3 d_3 + \beta_4 d_2 AFC_i + \beta_5 d_3 AFC_i + \beta_6 AF'_{ijt} + \beta_7 X'_{ijt} + \varepsilon_{ijt} \tag{3}$$

$$IG_{ijt} = \beta_0 + \beta_1 AFC_i + \beta_2 d_2 + \beta_3 d_3 + \beta_4 d_2 AFC_i + \beta_5 d_3 AFC_i + \beta_6 AF'_{ijt} + \beta_7 X'_{ijt} + \varepsilon_{ijt} \tag{4}$$

$$CG_{ijt} = \beta_0 + \beta_1 AFC_i + \beta_2 d_2 + \beta_3 d_3 + \beta_4 d_2 AFC_i + \beta_5 d_3 AFC_i + \beta_6 AF'_{ijt} + \beta_7 X'_{ijt} + \varepsilon_{ijt} \tag{5}$$

$$FCG_{ijt} = \beta_0 + \beta_1 AFC_i + \beta_2 d_2 + \beta_3 d_3 + \beta_4 d_2 AFC_i + \beta_5 d_3 AFC_i + \beta_6 AF'_{ijt} + \beta_7 X'_{ijt} + \varepsilon_{ijt} \tag{6}$$

where β_0 is the intercept term, β_1 is the baseline change over time (marginal effect before COVID-19), and β_2 and β_3 are initial differences before d_2 (COVID-19 period) and d_2 (post–COVID-19 period), respectively. AFC_i denotes the dummy variable for affected CEE countries, and β_4 and β_5 are the COVID-19 effects in 2020 and 2021–2022, respectively. β_6 denotes a coefficient vector associated with the variables AF'_{ijt} that captures the COVID-19 effect in terms of CEE bilateral trade with other CEE, WE, other OECD countries, and China. β_7 denotes a coefficient vector associated with the control variables X'_{ijt}, such as the GDP of reporting and partner countries and trade costs t_{ijt} specified in Equation (2). ε_{ijt} is the error term.

3.2. Model Estimation Procedure Issues

In our model, one of the most critical tasks is evaluating the credibility of assumptions about common trends in examined variables for the affected CEE and control group countries. We chose the Baltics as our control group because they demonstrated resilience to COVID-19 shocks due to effective government policies. Our choice for this specific control group is based on a graphical analysis of the common trends of average exports reported in Figure 3. The figure reveals an incredible alignment of international trade trends in the Baltic and other CEE countries, allowing us to reasonably expect that the common trend assumption holds in our DiD analysis.
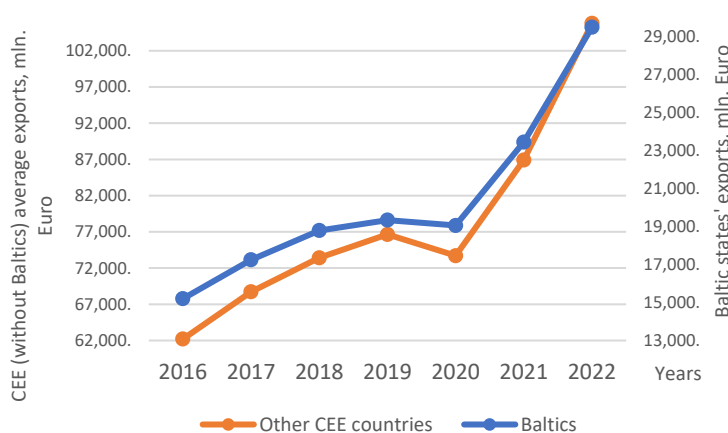

Figure 3. Average exports of CEE countries and the Baltic States. Source: authors' calculations based on Eurostat (2023) data.

To ensure DiD results, we isolate the connections of the control group with other CEE countries: we remove all data series related to export and import flows between the Baltics and other CEE countries.

In the data collection process, we collect data for all eight categories according to the BEC v.5 classifications; thus, we do not have concerns regarding estimation problems that usually occur due to zero trade values in the data. We sum up data by the countries' specific trading features in all these categories.

In our regression estimation, we employ the random effect estimation procedure, which is also suggested by the Hausman test.

3.3. Data and Descriptive Statistics

In our augmented gravity model with embodied DiD, we apply annual data of bilateral trade of CEE countries with other CEE countries, other EU countries (WE), other OECD countries (that are not EU members), China, and other world countries. Our collected monthly data cover the period from January 2018 to December 2022. All of the gross trade data are collected from the Comext database. The data include import and export data for all categories of intermediate, gross fixed capital, and final consumption goods (as mentioned, we use Broad Economic Categories (Rev. 5) classification). We also collect the real GDP data of origin and destination countries from the World Development Indicators database (World Bank 2023). For bilateral distances and some country pair variables data, we search in the CEPII database (Head and Mayer 2014). Trade flow data, together with data on GDP and distances, are transformed into logs. For descriptive statistics, see Table 1.

Table 1. Descriptive statistics of variables in logs.

Variables	Mean	Median	Max	Min	Std. Dev.	Skewness	Kurtosis	Obs.
EX	18.52	18.66	25.07	−9.21	2.46	−1.29	13.41	3080
IG	18.13	18.32	24.51	6.26	2.53	−0.60	3.77	3080
CG	15.92	16.47	22.88	−25.33	3.43	−2.11	16.75	3080
FCG	16.82	16.85	23.59	−9.21	2.51	−0.52	6.31	3080
GDP of reporter	24.99	24.74	27.16	23.33	1.01	0.39	2.47	3080
GDP of partner	27.14	27.03	30.65	23.89	1.36	0.22	3.32	3080
Distance	7.79	7.58	9.81	4.01	1.15	−0.09	2.28	3080

4. Empirical Results

4.1. Accounting for Supply Disruptions in GVCs

Table 2 reports the empirical results of our research. The results reveal that COVID-19 had uneven effects on the trade of CEE countries during and after the pandemic ended in late 2020. Our interpretation of the DiD coefficients is provided in Figure 4.
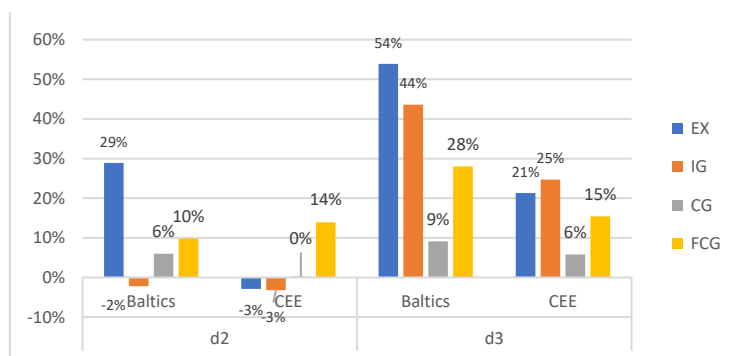

Figure 4. Average percentage change in export (EX) and import of intermediate (IG), capital (CG), and final consumption goods (FCG). Source: authors' calculations based on research results.

Table 2. Estimates of DiD and gravity model panel data LS regression (random effects).

Variables	EX	IG	CG	FCG
	General	General	General	General
(1)	(2)	(5)	(8)	(11)
T*COVID-19	−0.318 ***	−0.010	−0.058	0.041
	(0.084)	(0.058)	(0.199)	(0.078)
T*POST	−0.326 ***	−0.189 ***	−0.033	−0.126 **
	(0.069)	(0.048)	(0.163)	(0.064)
T	−0.683 ***	0.344 ***	0.205	−0.013
	(0.126)	(0.130)	(0.213)	(0.147)
COVID-19 (d2)	0.289 ***	−0.022	0.06	0.098 *
	(0.060)	(0.052)	(0.144)	(0.056)
POST (d3)	0.539 ***	0.436 ***	0.091	0.28 ***
	(0.049)	(0.043)	(0.119)	(0.046)
Rep. GDP	1.2392 ***	0.675 ***	0.45 ***	0.467 ***
	(0.046)	(0.049)	(0.093)	(0.055)
Partn. GDP	0.285 ***	0.239 ***	0.482 ***	0.179 ***
	(0.022)	(0.021)	(0.048)	(0.022)
DST	−0.943 ***	−0.769 ***	−0.794 ***	−0.631 ***
	(0.055)	(0.059)	(0.098)	(0.067)
LANG	-0.225	-0.108	1.762 ***	1.006 **
	(0.379)	(0.397)	(0.621)	(0.453)
CONT	1.097 ***	0.762 ***	-0.259	1.123 ***
	(0.224)	(0.234)	(0.365)	(0.267)
RTA	0.097	0.190	1.076 ***	1.306 ***
	(0.116)	(0.234)	(0.190)	(0.138)
Constant	−12.499 ***	−4.289 ***	−12.462 ***	1.16
	(1.344)	(1.335)	(2.449)	(1.499)
No. of obs.	3080			
No. of CEE	10			

Notes: Significance: * 10%; ** 5%; *** 1%.

First, we investigate the overall impact of the COVID-19 pandemic on the export of goods and the import of intermediate (IG), capital (CG), and final consumption goods (FCG). We aim to identify these general trends during the pandemic (d2), i.e., in 2020, and immediately after the pandemic (d3), in 2021–2022. Our research results show that the COVID-19 pandemic negatively impacted the exports of CEE countries during the pandemic and slowed their recovery afterward. It is also evident that the export opportunities for the Baltics and CEE countries were hindered by reduced intermediate goods supply during the pandemic. However, the import of intermediate goods rapidly grew in CEE countries and the Baltics afterward, though the Baltics still enjoyed faster growth. Concerning capital goods, the COVID-19 pandemic negatively affected the growth of imports in CEE countries, while the Baltics were still experiencing growth in imports. It seems the import of final consumption goods was not affected by the COVID-19 pandemic.

At first glance, the COVID-19 pandemic did not affect the demand for goods produced and exported in export destination countries as it hindered production in countries that suffered more severely from the pandemic. However, this might result from decreasing demand in other CEE countries (we do not track this with our DiD specification because the control group data do not include trade flows with CEE countries).

Our results further reveal that CEE countries place greater importance on their GDP for exports (the coefficient ranges from 1.191 to 1.239) than imports. Meanwhile, the GDP of CEE countries' partners is more crucial for capital goods (the coefficient increases from 0.243 to 0.482). Furthermore, trade costs are more significant for CEE exports (the coefficient fluctuates between −0.943 and −0.948) than intermediate and capital goods (the coefficients range between −0.76 and −0.79). The lowest costs are associated with the import of final consumption goods (the coefficient fluctuates around −0.63). Notably, language and regional trade agreement (RTA) scores coincide for importing capital and final consumption goods, indicating that cultural and historical proximity significantly influences the flow of these goods between countries. A shared border with a partner country is only significant for importing capital goods, which seems intuitively predictable, as capital goods are intended for more global markets.

4.2. Robustness Check

To check the robustness of our results, we specify and estimate separate models in which the overall impact of the COVID-19 pandemic is initially determined. Then, we estimate its impact separately for exports and imports according to different country categories during different periods: during the pandemic and post-pandemic. We obtain stable estimates of the control variables included in the evaluated equations, which indicates that the model specification was done correctly, and the estimates are robust.

5. Discussion

The COVID-19 pandemic has had varying effects on different countries, resulting in a significant economic decline in 2020. Overall, the pandemic highlighted vulnerabilities in GVCs (Strange 2020; Hayakawa and Mukunoki 2021; Ayadi et al. 2022; Seuring et al. 2022; Smith and Fatorachian 2023; Yudha and Roche 2023) as disruptions in one segment caused ripple effects across industries and countries (Sawik 2022; Yudha and Roche 2023). The extent of these disruptions differed depending on many factors, such as the partner countries, the structure of sectors, and the nature of the trade relationship between countries, indicating the heterogeneity of the impact of a pandemic on economies. To better cope with emergencies, companies must grasp supply chain uncertainty and implement effective supply chain management to enhance supply chain resilience (Chen et al. 2023).

Our empirical results provide compelling evidence of the relative resilience and adaptability exhibited by CEE countries in the face of the negative impact stemming from the COVID-19 pandemic. This confirms the findings of Petrylé's study (2022), which covers only one of the CEE countries, Lithuania, but provides analogous results that the country's exports were resilient to the impact of the pandemic. Polish companies with greater depth and breadth of internationalization tend to be more resistant to the effects of the pandemic crisis as well (Gorynia and Trąpczyński 2022). Notably, partner countries' GDPs and geographical proximities remained unchanged in their significance for CEE trade, reaffirming regional trade's importance even during a disruptive period. Although there was a decrease in the import of intermediate products during the pandemic, the impact was mitigated primarily due to most imports being from other CEE and WE countries, with a relatively small reduction in imports from these regions. This implies several points. First, CEE countries can diversify their supply chains, allocate alternative sources, or adjust their production processes accordingly. Second, it suggests that participation in regional trade networks helps protect against global disruptions, leading to more robust and resilient trade connections.

The pandemic has also affected trade in CEE countries, mainly through reduced demand for their exports. This demand reduction significantly affected categories of differentiated products (which often have unique features) in trade with other CEE markets. Similarly, there has been an increase in demand for homogeneous goods, which are more standardized (see Figures 1 and 2). This result confirms the vulnerability and

ripple effect of GVCs. This aligns with the results of Smorodinskaya et al. (2021) and suggests some practical implications for the development of resilience strategies. First, businesses should consider supply chain adaptation to accommodate a shift toward more homogeneous goods. Second, companies should consider strengthening their integration and sharpening their specialization within the regions (for instance, the Baltic region). As Smorodinskaya et al. (2021) indicate, this possible switch from globalization to regionalization may form new practices for sub-regions in the EU. Even before the pandemic, there were some indications of concern about the sustainability of global supply chains. The main conditions aggravating international trade include excessive tariffs in trade wars, rising transportation costs, and environmental concerns that have led to debates about shortening supply chains (Sodhi and Tang 2021). COVID-19 has also exposed the negative aspects of globalized supply chains, which is why Seuring et al. (2022) call for the localization of supply chains, including Europe, as a separate region. A recent WTO (2023) report highlights a drastic shift from "hyper globalization" to "globalization." Seuring et al. (2022) identify locality as a critical opportunity to reorganize supply chains effectively. The advantage of local supply chains is that they shorten transportation distances, reduce costs, require shorter delivery times, meet customer requirements faster, and facilitate supply management, all of which contribute to the resilience of supply chains to global shocks. Nevertheless, this does not imply that companies should change their input procurement from foreign to domestic suppliers. As Hayakawa and Mukunoki (2021) suggest, sourcing could exacerbate the negative impact of COVID-19 on the domestic economy. Therefore, it is more related to the diversification and resilience of the entire trade.

We did not observe a substantial decline in demand for the CEE countries' goods in the WE countries. This observation implies that CEE countries managed to maintain their position in the GVCs within the WE countries and demonstrated resilience in their roles as suppliers or producers of intermediate goods within these value chains. It also suggests that CEE countries are deeply integrated into WE supply chains and rely on these markets as essential export destinations. A previous study by Barbero et al. (2021) finds a small positive effect on exports from low- and middle-income countries to high-income countries at the beginning of the pandemic. Low- and middle-income countries are gradually increasing their trade volumes and enjoying more benefits due to the greater impact of globalization on them. This growth of international trade flows from relatively lower-income to high-income countries also confirms the results of our study. Furthermore, we did not identify significant changes in demand for goods from larger CEE countries in China and other global countries, which remained relatively stable through the pandemic.

The impact of shocks on international trade and the subsequent consequences that markets face suggest several policy implications. First, governments and businesses must cooperate to create and implement strategies for supply chain resilience. This may include establishing guidelines or offering incentives for companies to assess and improve their supply chain resilience, particularly in the face of uncertainties. Second, collaboration within specific regions should be encouraged, as it enhances the resilience of regions or countries. Therefore, policymakers could support initiatives that promote regional cooperation and potentially incentivize businesses to specialize within specific regions. In line with this research, the CEE countries demonstrated resilience in maintaining trade connections within the WE region.

6. Conclusions

In this research, we aimed to explore the impact of COVID-19-induced disruptions on supply chains, their transmission effects within CEE countries, and the CEE countries' resilience to shocks. This study presents a comprehensive framework for understanding the implications of the COVID-19 pandemic on international trade and GVCs within the CEE countries. Our research findings validate the ability of the CEE region to sustain trade

connections with WE countries. Additionally, the swift rebound in the import of goods highlights the CEE countries' ability to adapt to disruptions in the supply chain and resilience to pandemic shocks.

Furthermore, our findings suggest a shift in trade patterns during the COVID-19 pandemic. According to our results, CEE exports suffered significantly from the pandemic and did not recover fully even in the post-pandemic period. What affected production in CEEs mostly was the plunge in intermediate and capital goods imports. Although the former recovered afterward, the control group still prevailed. We found that final consumption goods imports resisted the COVID-19 pandemic; however, recovery was sluggish.

Our research results suggest that countries that managed to deal with the COVID-19 pandemic much more successfully did not suffer such a significant plunge in their trade flows as countries that suffered from the pandemic severely. However, the sudden drop in intermediate goods supply hindered international trade for all countries.

In conclusion, our study demonstrates the importance of adopting advanced trade models to assess the impact of short-term trade shocks and GVC vulnerabilities. Thus, future research should focus on developing models that will address the complexity of pandemic-induced shocks within specific regions or groups of countries. Such efforts will enhance the understanding of the evolving landscape of international trade and its resilience in the face of challenges.

Notes

1. Available at Forecasted global real GDP growth 2024|Statista.
2. Idem.
3. Blank sailings in maritime transport increased up to 20% in 2020: available at https://www.usitc.gov/research_and_analysis/tradeshifts/2020/special_topic.html (accessed on 26 December 2023).

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