

RESILIENT CHAINS AND CHAIN SHORTENING – TRADE EXCHANGE PERSPECTIVE

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Purpose: One of the fundamental ways to strengthen supply chains is by shortening them. This can be reflected in the degree of utilization of chains for exports and imports. This is crucial for efficient supply chain management as it enables simpler and faster logistics operations. However, on the other hand, comparative advantages, resource localization, and cost considerations may lead management decisions to refrain from significant supply chain shortening on a larger scale. Additionally, the increasing level of digitalization in the logistics industry, which supports supply chains, also contributes to this perspective.

The purpose of this study is, therefore, to examine the extent to which recent crisis situations have influenced the exchange of exports and imports, categorized by short, medium, and long supply chains. The Polish economy has been chosen as a reference for this analysis.

Design/methodology/approach: Statistical methods based on time-series analysis were employed in this research.

Findings: Despite the crises, supply chains have not been shortened. It can be observed that in the long term, as well as in the post-pandemic period, there has been a shift in the structure of supply chains towards longer chains, particularly noticeable in import dynamics. The reason why supply chain shortening for the purpose of enhancing resilience is not evident in the data, despite many declarative statements about this approach in empirical research, has been indicated.

Research limitations/implications: The formulated arguments in favor of supply chain lengthening should be confirmed through research in various economies.

Practical implications: The importance of this article lies in providing management decision-making suggestions, particularly regarding supply sources.

Social implications: The establishment of shorter supply chains is crucial for environmental sustainability and meeting customer needs.

Originality/value: Research in this field is often conducted in an aggregated form, without differentiating between various supply chain lengths. In this article, we have taken these factors into account.

Keywords: supply chain management, international trade, pandemic, reshoring, resilience.

Category of the paper: research paper.

1. Introduction

The construction of resilient chains is a relatively new area of research, as evident in the literature review conducted by Kamalahmadi and Parast (2016).

Existing empirical models have highlighted various approaches to building resilient chains (Maryniak, Bulhakova, Lewoniewski, 2021; Shishodia et al., 2023). Based on an extensive review of the literature, we have developed an original classification system comprising five fundamental groups of activities (see Fig. 1).

Given the disruptions caused by the pandemic, as well as war-related events, the vulnerability of long-distance supply chains and the importance of immunizing them through appropriate supply strategies and shortening existing chains have become particularly crucial (Shivajee, Singh, Rastogi, 2023).



Figure 1. Elements of strengthening supply chains.

Source: Own work based on the review of proposed models concerning resistant supply chains.

On one hand, there is a suggestion that companies should decrease their geographical coverage and make their supply chains less globalized. This approach promotes shorter or local supply chains, which enable better inventory control and bring suppliers closer to the buyer. On the other hand, it is emphasized that the nationalization or regionalization of supply chains can increase the risk of disruption. Such a strategy may limit companies' ability to optimize supplier diversification and minimize risk (Anukoonwattaka, Mikic, 2020). These differing views present a dichotomy in supply chain strategies.

It is widely believed that the post-pandemic world will witness a fundamental shift towards greater risk aversion, nationalism, and protectionism. There are discussions about a "legitimacy crisis" of the post-war neoliberal economic order (Abdelal, 2020). However, it is also argued that globalization will continue to be necessary and beneficial. Historical evidence suggests that

supply chains quickly adapt and relocate, leading to cost reductions in production (Contractor, 2022). Furthermore, several arguments support the continuation of globalization in the post-pandemic era, emphasizing the justification of global value chains (GVCs) (see Fig. 2).

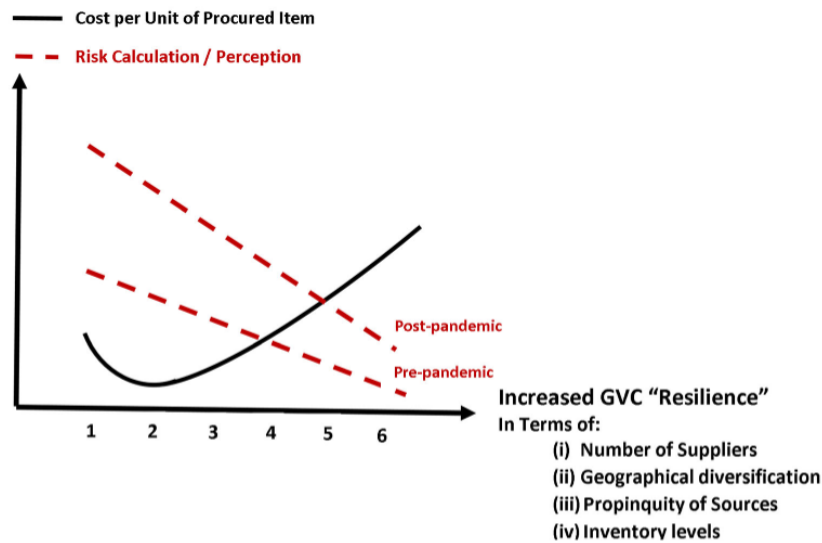


Figure 2. Profitability of reconfiguration of value chains in the perspective of their resilience.

Source: Contractor, 2022, p. 159.

Thus, one needs to analyze the redundancy in the form of multiple suppliers and increasing inventory levels, as well as the geographic diversification and proximity to sources of supply, in the context of potential risks, raw material and component prices, and final product prices.

The division of labor, economies of scale, the low absorptive capacity of domestic markets, and the advantages of locating operations in less developed countries contribute to the increase in exports, imports, and the internationalization of supply chains.

However, research has confirmed that trading partners with lower risk and the ability to quickly recover import volumes have less vulnerable supply chains, while individual countries have varying levels of vulnerability in their logistics and transport systems (Jomthanachai et al., 2022). In globally distributed supply and production networks, the mode of delivery to the production plant differs in terms of transportation costs, tariffs, and stoppages (Sardesai, Klingebiel, 2023). This aspect became particularly evident during the recent war-related crisis, marked by a significant rise in fuel prices and the introduction of EU directives and "Fit for 55" packages.

Studies have shown a significant negative impact of the financial crisis and COVID-19 on international trade (Bricongne et al., 2021; Hayakawa, Mukunoki, 2021). However, it should be emphasized that these effects were considerably mitigated within a relatively short period of time. Additionally, the strong impact of COVID-19 on international trade has highlighted the need for increased industrial production in the US and EU countries to enhance self-sufficiency and independence (Coquidé et al., 2022). It has also been noted that since the war in Ukraine, the so-called global geopolitical risk index has significantly increased, reaching levels not seen since the beginning of the Iraq war in March 2003 (Caldara, Iacoviello, 2022). However,

the willingness to leave high-risk zones largely depends on factors such as the cost of relocating supply chain links, the size of operations, labor costs, insurance costs, capital intensity of the business, legal possibilities, and choice of political blocs. Moreover, an international company with a high level of imports from a foreign economy may have less incentive to change sources of supply after a geopolitical shock (Ruta, 2022). Recently, attention has also been paid to various transport-related indicators that indicate a slowdown in the negative effects associated with oil and diesel prices, both globally and in Europe (Polska Organizacja Przemysłu i Handlu Naftowego, 2023).

All these contradictions imply that slogans advocating for chain shortening to enhance resilience are not straightforward and unambiguous.

Therefore, in this study, we adopted a macroeconomic perspective that reflects the management decisions made at the enterprise level, aiming to answer the question of whether the recent crises have significantly influenced international trade in terms of the length of supply chains.

The international exchange of goods between Poland and other countries has been chosen as the focal point of this investigation.

2. Shortening supply chains from the point of view of international trade – research methodology

Among the various strategies and initiatives aimed at shortening supply chains to enhance resilience (Fig. 3), while also considering the potential risks associated with complex supply chains, several approaches have been identified in the literature. These approaches are highlighted by researchers such as Amighini et al. (2023), BCI (2023), Deppermann et al. (2018), Hertz (2001), Kamakura (2022), Lee (2022), and The White House (2021).

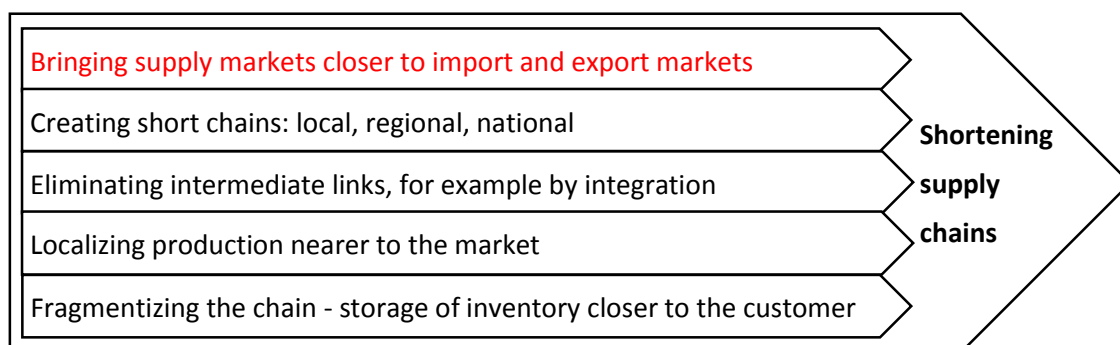


Figure 3. Shortening input and output supply chains.

Source: own work.

This study focuses on the first dimension, specifically international trade. Previous studies have predominantly concentrated on aggregated results related to various macroeconomic indicators such as GDP, inflation, or unemployment. In this study, we adopt a perspective that examines the structural and dynamic differences in the context of the length of supply chains.

The primary objective of the empirical analyses was to investigate the extent to which recent crisis situations have influenced changes in export and import patterns within short, medium, and long supply chains. To achieve this main goal, we have established the following specific objectives:

- determine the level of dynamics in Polish trade in terms of value, quantity, and structure,
- estimate the monthly dynamics of changes in trade,
- identify the directions of trade development in structural terms, categorized into short, medium, and long chains.

Based on preliminary studies, it is assumed that supply chains tend to lengthen when there is an increase in trade flows over longer distances, leading to destinations in import and export directions remaining largely the same. The division of supply chains into different lengths is based on a geographical, arbitrary distance from Poland. Short chains encompass Poland's trade with neighboring countries, excluding Russia due to its vast territory. Medium chains involve exports and imports within Europe, while the remaining countries are considered part of the long chains.

For our research, we utilized time series data obtained from the statistical office's international trade databases. Although the time series method is used to study supply chains, it is not widely popular. For instance, searching for "supply chain" yields 142,280 thousand articles, but when combined with "time series," the search narrows down to 765 articles, with only a few percent being relevant to the given topic.

Among the most frequently cited works, some employ time series to study demand (Fattah et al., 2018; Willemain, Smart, Schwarz, 2004; Aviv, 2002; Nguyen et al., 2021; Gilbert, 2005). Another thematic strand, which is also frequently cited, explores the environmental impact of supply chain activities and aspects of corporate social responsibility (Acquaye et al., 2017; Norris, 2006).

Furthermore, time series analysis is used to test the resilience of flows and analyze foreign trade. For example, it is employed to forecast the demand for critical raw materials in terms of ensuring smooth flows (Polat, Yücesan, Gül, 2023), and to assess the impact of imports and exports on economic development (Du et al., 2019).

3. Results of the study

Figures 4 and 5 present graphs illustrating the value of Polish imports and exports of goods expressed in euros for three types of supply chains. The short chains represent imports (exports) from (to) all neighboring countries of Poland, excluding Russia. The medium chains encompass all other European countries, excluding Russia. The long chains include all non-European countries. The graphs reveal a consistent upward trend in international exchange on both sides.

The data also exhibit two notable features. Firstly, there is a decrease in exchange at the onset of the COVID-19 pandemic, beginning in 2020. This decline is observable in both exports and imports, across all chain lengths. Secondly, a significant change in trend is visible after 2020. To confirm this change, we conducted Chow tests for structural shifts. The baseline model assumes a linear trend in the series:

$$y_t = \alpha + \beta t + \varepsilon_t \quad (1)$$

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$$y_t = \alpha + \beta t + \varepsilon_t \quad (2)$$

To assess structural changes, we assumed that both the slope and intercept (representing the level and trend) had altered following the outbreak of the COVID-19 pandemic in March 2020. Table 1 presents the regression results, including estimated coefficients and their standard deviations, the regression's value, and the outcomes of Chow's test (test statistics and p-values).

As depicted, the trend for all supply chains (both in exports and imports, across all chain lengths) was positive. The coefficients represent the average monthly changes in the analyzed variables. For instance, the highest increase was observed in exports to neighboring countries (export-short). On average, the value of these exports has been growing by 49.767 million euros per month. The export to non-European countries (export-long) exhibited the slowest growth rate, but still experienced a consistent increase, with an average monthly change of 13.391 million euros.

We conducted a Chow's test to investigate the hypothesis that the onset of the COVID-19 pandemic caused a shift in the series' trend. We employed the following segmented model to evaluate if it better captured the data:

$$y_t = \begin{cases} \alpha_1 + \beta_1 t + \varepsilon_t, & \text{for observations before the change} \\ \alpha_2 + \beta_2 t + \varepsilon_t, & \text{for observations after the change} \end{cases} \quad (3)$$

The null hypothesis in the test assumes no structural break (i.e., and), indicating no change in the trend. The results of Chow's test indicate that there was indeed a structural change in the trends of all the analyzed chains, as all p-values were below 0.05.

Table 1.

Time trends and the results of the Chow's tests for values of export/import

Series	α (sd)	β (sd)	R^2	Chow's test: F-statistics (p-value)
Export – short	-591.300 (249.642)	49.767 (1.572)	0.8645	134.149 (0.000)
Export – medium	239.819 (269.928)	49.534 (1.700)	0.8439	90.250 (0.000)
Export – long	-243.045 (63.4209)	13.391 (0.399)	0.8774	101.013 (0.000)
Import – short	675.834 (222.203)	36.713 (1.399)	0.8142	89.5002 (0.000)
Import – medium	651.516 (235.342)	38.967 (1.482)	0.8149	113.368 (0.000)
Import – long	-1947.21 (237.287)	34.360 (1.494)	0.7710	294.645 (0.000)

Source: Own calculations.

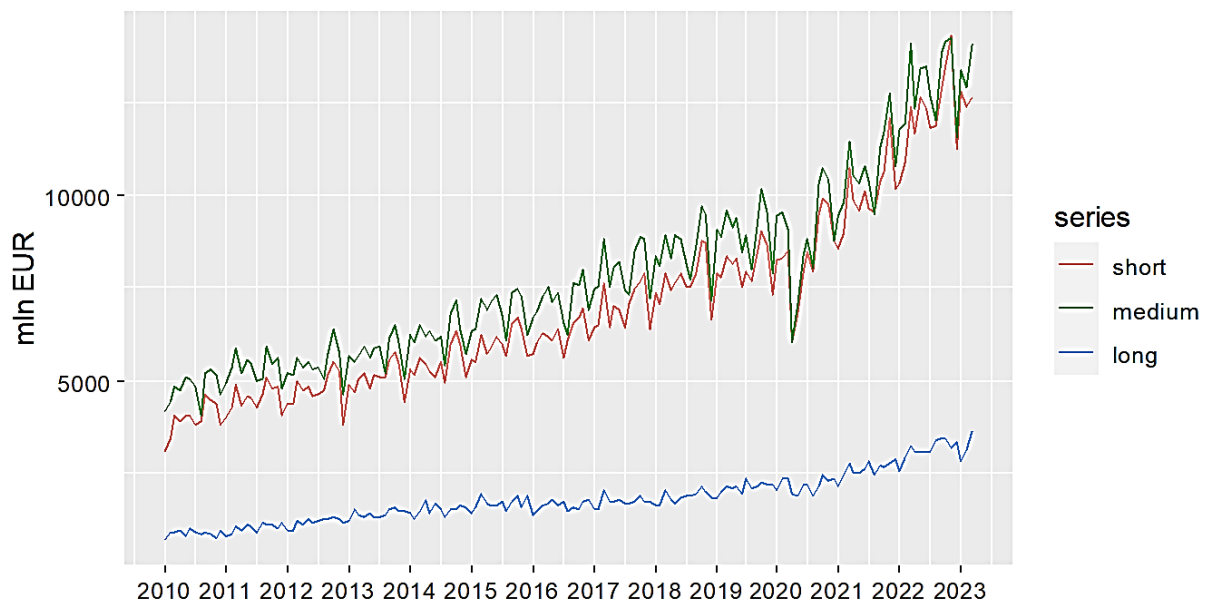


Figure 4. Export from Poland (in mln €).

Source: Polish Statistical Office.

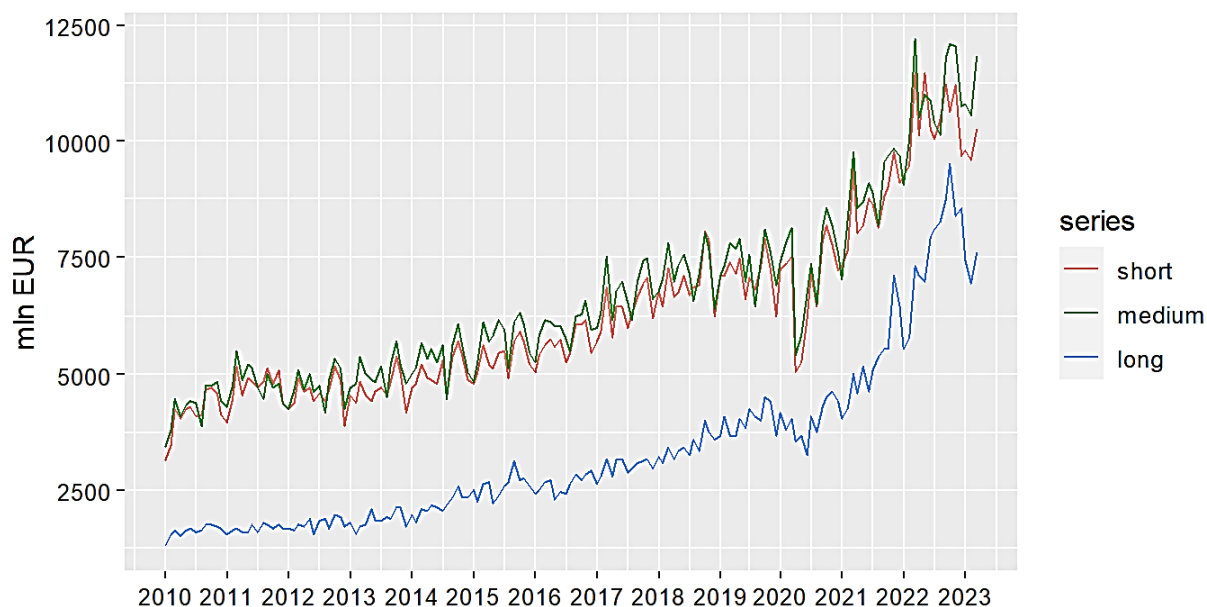


Figure 5. Import to Poland (in mln €).

Source: Polish Statistical Office.

Figures 6 and 7 depict graphs illustrating the value of Polish imports and exports of goods expressed in thousand tons (kt). The overall trend shows an increase, although not as significant as in the series expressed in euros. To examine the presence of structural changes, we estimated the trend line and conducted Chow's test for structural shifts, assuming that the change occurred following the onset of the COVID-19 pandemic in March 2020.

As shown in the table, both exports and imports have increased across all lengths of supply chains. The import from the rest of the world (long supply chains, excluding European countries) experienced the most rapid growth, with an average monthly increase of 15.569 kt. On the other hand, the smallest increase was observed in exports to long distances, with the tonnage of this export rising by an average of 3.807 kt per month.

The results of Chow's test indicate a structural change in the trend of imports and exports for long and medium distances. However, there was no significant change in the trend of exports and imports for short distances.

Table 2.

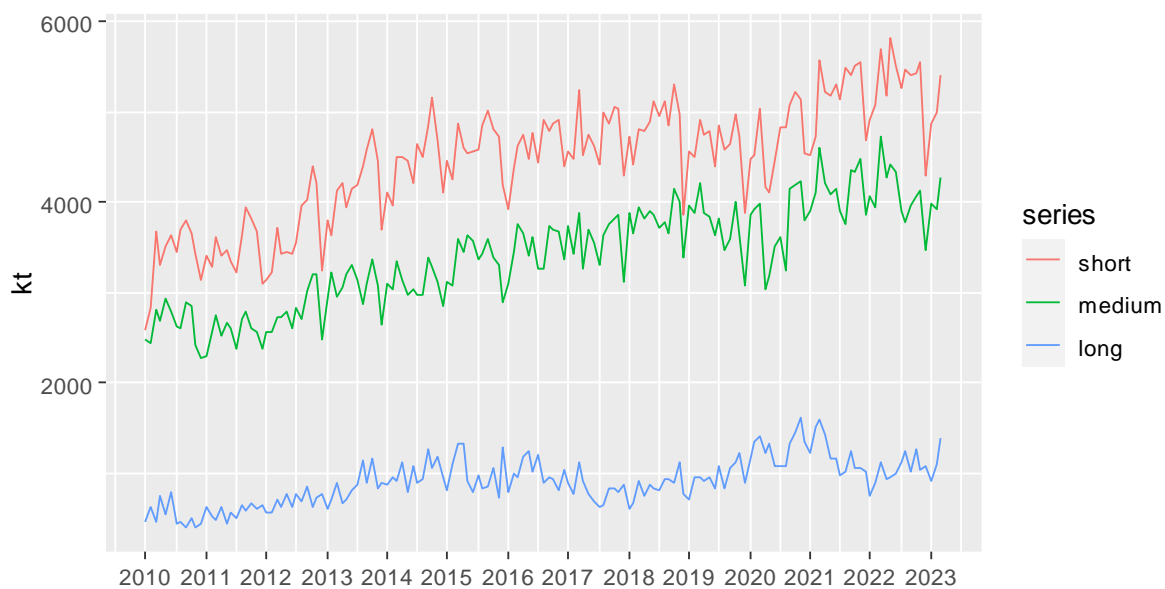
Time trends and the results of the Chow's tests for tonnage of export/import

Series	α (sd)	β (sd)	R^2	Chow's test: F-statistics (p-val)
Export – short	2641.624 (105.341)	11.919 (0.663)	0.673	3.045 (0.050)
Export – medium	1775.503 (74.2067)	10.742 (0.467)	0.771	3.203 (0.043)
Export – long	334.606 (52.849)	3.807 (0.333)	0.454	9.562 (0.000)

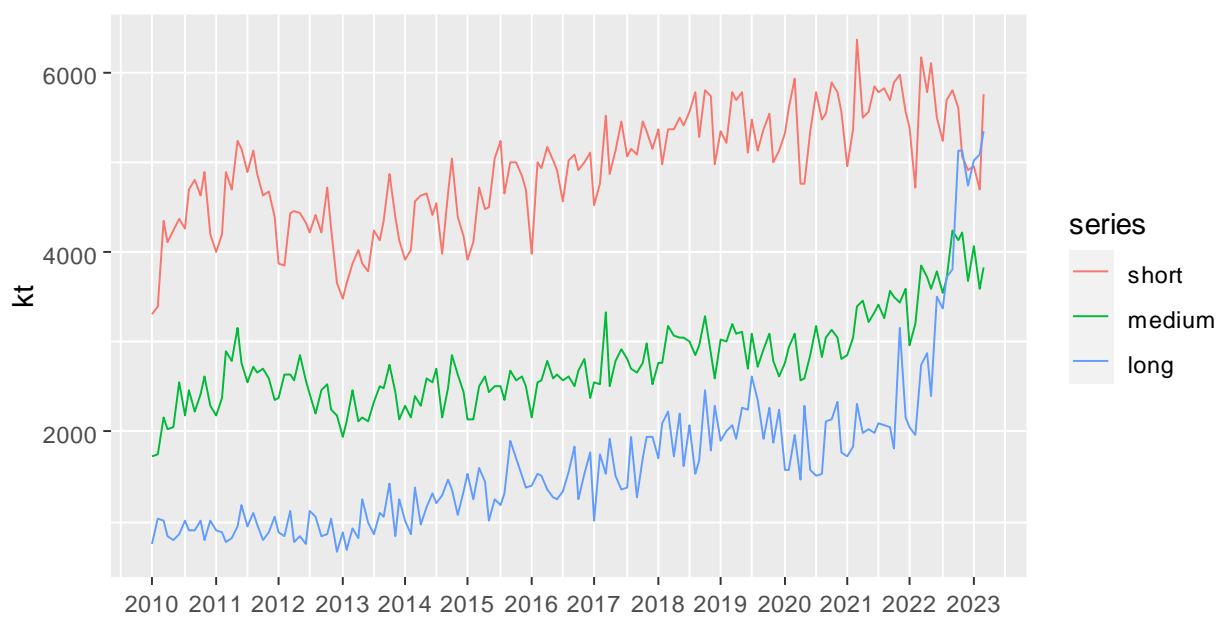
Cont. table 2.

Import – short	3336.776 (115.143)	10.465 (0.725)	0.570	3.018 (0.052)
Import – medium	1496.465 (82.120)	8.407 (0.517)	0.627	37.516 (0.000)
Import – long	-688.251 (156.687)	15.569 (0.987)	0.613	97.503 (0.000)

Source: Own calculations.

**Figure 6.** Export from Poland (tonnage, kilotons).

Source: Polish Statistical Office.

**Figure 7.** Import to Poland (tonnage, kilotons).

Source: Polish Statistical Office.

It is particularly interesting to note the changes in import over long distances. After the onset of the COVID-19 pandemic, there was a decrease in this type of import. However, starting from 2022, there was a rapid increase. Figure 8 displays the graph of import from Russia, and by comparing it with Figures 4 and 5, we can deduce that the rise in import over long distances was influenced by the war in Ukraine. Following the outbreak of the conflict, goods that were previously imported from Russia were substituted with imports from non-European countries. The decrease in the import from Russia was mainly caused by the decline of supplies of mineral fuels (natural gas and crude oil). Figure 8 depicts the dynamics of overall import from Russia and import of mineral fuels.

Our claim is that there were two structural breaks in the trend of long-distance import. The first break was associated with the impact of COVID-19, which resulted in a reduction in import levels. The second break occurred due to the war in Ukraine and led to an increase in the import trend. To test this hypothesis, we have estimated the following model:

$$import_t = \alpha + \beta_1 t + \beta_2 covid + \beta_3 war \cdot t + \varepsilon_t \quad (4)$$

The variables ‘covid’ and ‘war’ are dummy variables that take the value of 0 before March 2020 and February 2022, respectively, and 1 after these dates. The parameter β_1 represents the change in the level of import after the beginning of the pandemic, while β_2 represents the changes in the trend (slope) after the outbreak of the war in Ukraine. Table 3 presents the estimation results, indicating that all the explanatory variables are statistically significant. The coefficient of determination (R-squared) for this regression is [the actual value is missing from the provided text].

To examine whether the assumed structural breaks in the regression equation hold, we conduct a test of linear restrictions. The null hypothesis is as follows:

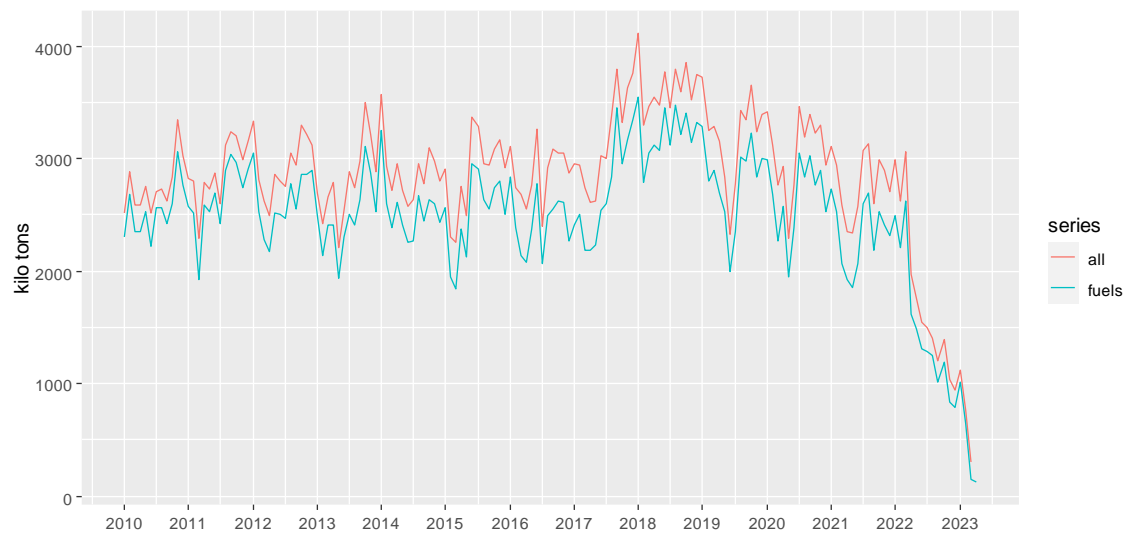
$$H_0: \beta_2 = \beta_3 = 0 \quad (5)$$

(i.e., there was no structural change either in the level of import or in the trend). The test statistic for this hypothesis was $F(2, 155) = 84.442$, with a p-value lower than 0.01%. This indicates that we must reject the null hypothesis, suggesting that there were indeed structural changes.

According to the results presented in Table 3, the onset of the COVID-19 pandemic caused a decrease in long-distance imports by 220.253 kt. The outbreak of the war led to a structural change in the trend of this import. Prior to the war, it had been increasing on average by 11.863 kt per month. However, after the outbreak of the war, the rate of change increased by over 50% to 19.584 kt per month.

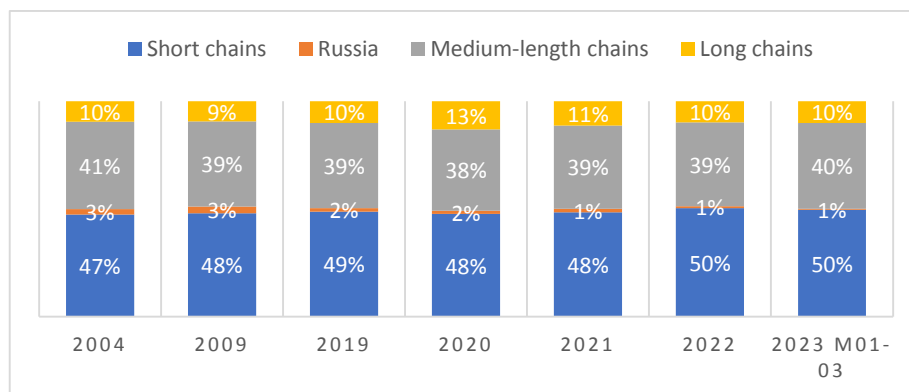
Table 3.*Regression for long-distance import (from non-European countries)*

Variable	Parameter	t-value	p-value
<i>const</i>	223.935	1.593	0.113
<i>t</i>	11.863	11.650	0.000
<i>covid</i>	230.253	1.973	0.050
<i>war · t</i>	7.721	12.741	0.000

**Figure 8.** Volume of import from Russia – all import and import of mineral fuels (tonnage, kilotons).

Source: Polish Statistical Office.

From the perspective of the main objective of this study, which is to investigate changes in the potential shortening of supply chains, the aspects discussed are especially evident when considering the structural approach, particularly in terms of the tonnage of exports and imports (refer to Figures 9 and 10).

**Figure 9.** Volume of export from Poland (in tonnage).

Source: Polish Statistical Office.

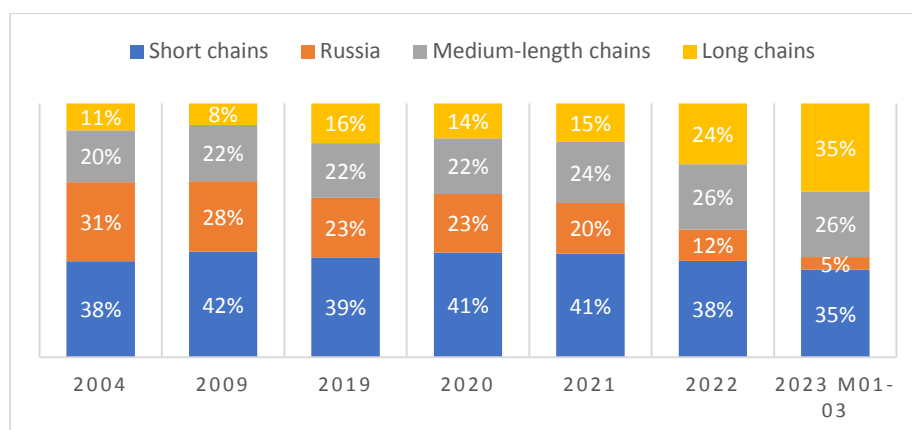


Figure 10. Volume of import to Poland (in tons of transport).

Source: Polish Statistical Office.

Based on the results obtained, it can be concluded that there has not been reduction in the length of supply chains, both in the long-term and in the post-pandemic period. Additionally, there has been an increase in the proportion of long chains in imports. In the last year of the analyzed observations, this could be attributed to the search for alternative sources of raw materials that lack close substitutes. However, it is important to note that this trend also occurred in the previous period.

Between the years 2004 and 2023 (1st quarter), noticeable growth in the export direction (measured in kilograms) is observed for India, Nigeria, and Saudi Arabia. The United States and China have been significant exporters in the realm of long supply chains for years. Within medium supply chains, Poland primarily exports to the Netherlands, France, and the United Kingdom, with the last two countries consistently ranking in the top five since the beginning of the analyzed period. Regarding short supply chains, Germany (currently with over 50% share) and the Czech Republic have dominated since 2004. Notably, Ukraine's share has significantly increased due to geopolitical changes.

The largest importers (measured in kilograms) are Egypt, Colombia, and China, with China being consistently at the forefront since the start of the research period. Norway and the Netherlands have been dominant within medium supply chains for years. As for short supply chains (involving neighboring countries to Poland), goods are predominantly imported from Germany, Ukraine, and the Czech Republic.

4. Conclusions

The disruptions in supply chains, especially those caused by the COVID-19 pandemic and the Russian war with Ukraine, along with other factors such as maritime piracy, Chinese blockades in 2022, and climate changes, have highlighted their vulnerability due to countries'

dependence on import and export ties, particularly those at a great geographical distance. Consequently, research reports emphasize aspects of international flows, such as reliance on suppliers and value creation in subsequent links of the supply chain (Ambroziak et al., 2023; Amighini et al., 2023).

The most common method of strengthening supply chains is to increase inventory levels and then diversify suppliers. However, relatively few companies have completely abandoned Chinese suppliers (EBRD, 2022), and this applies to Poland as well. Research conducted by the European Bank for Reconstruction and Development indicates that Poland's participation in global supply chains is increasing. There is a growth in global production linked to the supply chain as a percentage of total production and an increase in the sophistication of exports. This shift results in Poland moving up the value chain.

Studies show that some countries have chosen to shorten their supply chains due to the impact of COVID-19 and the war in Ukraine. However, such a trend has not been observed in Poland (Ambroziak, 2023). On the contrary, the structure of supply chains indicates a growing burden of goods on long routes both in the long-term perspective and in the post-pandemic period. This trend is also observed in other economies. Despite researchers indicating firms' readiness for production relocation and providing numerous examples of such actions, the chances of supply chain shortening becoming the leading strategy for mitigating risks created by the pandemic or the war in Ukraine are limited (Ambroziak et al., 2023).

While shortening supply chains could reduce the risk of disruptions, rising transportation costs are another important consideration. These costs include increasing CO₂ emissions fees, higher fuel costs (despite a decline in 2023 with a forecasted slight increase in the second half of the year), rising wages for drivers, and increased insurance costs for goods on longer routes. However, this factor weakens the observed economic slowdown process in Poland since mid-2023. It implies a lower purchasing power and, consequently, a demand for inexpensive products manufactured in distant countries with lower wages and less stringent regulations.

Additionally, the obtained results can be explained by the following factors:

1. The process of production relocation is time-consuming and involves significant investments, which may delay the visible effects of supply chain shortening on a larger scale.
2. The increasing volume of e-commerce orders from China and other countries in the region, accelerated by the pandemic, despite the growth dynamics of this industry in Poland in mid-2023, contributes to the continued lengthening of supply chains.
3. During the pandemic, customers shifted their expenditures from unavailable services to goods, generating trade in products, many of which originated from distant corners of the world.
4. Many raw materials are only available in distant countries, leading to substitutions of Russian raw materials, which are more closely associated with reshoring than nearshoring.

5. Participation in global supply chains for the purpose of specialization based on comparative advantages aligns with trade theory and is considered an optimal approach.
6. Supply chain shortening likely applies primarily to selected critical raw materials and components and occurs through the localization of critical inventory closer to the final recipient, which requires confirmation in future research.
7. Supply chain transparency is increasing through digitization.

Furthermore, Poland is an attractive location for the consolidation and deconsolidation of imported and exported goods from distant countries. Despite the pandemic and war crises, the warehousing market has remained in good condition. Poland is also one of the main beneficiaries of changes in global production chains after the pandemic, ranking fourth globally and first among European firms in terms of preferred production relocation locations (PKO Bank Polski, 2022). Consequently, it is assumed that unlocking supply chains and prior foreign investments will lead to continued export growth, even in an unfavorable environment. However, a decline in import-dependent inventories and changes in consumption patterns may negatively impact imports (PKO Bank Polski, 2023). Presently, there are significant planned investments related to the relocation of semiconductor production to European countries, including Poland. Therefore, potential suppliers for the Original Equipment Manufacturer (OEM) sector will generate additional imports and boost export results to shorter distances.

Acknowledgments

This article was prepared as part of „The project financed within the Regional Initiative for Excellence programme of the Minister of Education and Science of Poland, years 2019-2023, grant no. 004/RID/2018/19, financing 3,000,000 PLN”.

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