

Modeling the Impact of Geopolitical Conflict on EU Transport Flows

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Abstract: This paper analyzes the impact of the Russia–Ukraine geopolitical conflict on transport flows within the European Union during the period 2020–2024. The research is based on Eurostat data and an aggregated Geopolitical Risk Index, aiming to identify structural changes in the volumes of road, water, and air transport following the escalation of the conflict in 2022. The Chow test was applied to verify the existence of structural breaks, while the Bai–Perron test was used to identify multiple breakpoints. The results confirmed statistically significant structural changes across all transport modes. Water transport demonstrated a long-term declining trend and the highest sensitivity to geopolitical risks, whereas road and air transport stabilized at lower levels after the initial decline. The findings highlight the asymmetric impact of geopolitical shocks on individual transport modes and emphasize the need for long-term monitoring, the development of multimodal analytical models, and the creation of EU-specific geopolitical risk indicators. The study also underlines the importance of strengthening the resilience of European transport systems against external geopolitical disruptions.

Keywords: Geopolitical risk, structural breaks, EU transport, GPR index, Chow test

1. Introduction

Globalization has facilitated international trade and supply chain integration, but it has also increased exposure to geopolitical uncertainty, particularly in regions with fragile stability. Geopolitical risk now significantly influences global and regional economies, affecting trade patterns and transport efficiency [1-3]. Geopolitical instability, marked by conflicts, trade wars, and political tensions, disrupts transport and logistics networks, leading to economic instability and operational inefficiencies [4,5]. The concept of a "permacrisis" reflects ongoing global disruptions, with political

instability affecting economic activity, while the transport sector remains essential for the movement of goods and capital [6].

Geopolitical risks, including conflicts, inflation, and the COVID-19 pandemic, create an unpredictable environment, requiring new risk management approaches in transport systems. The world economy is undergoing structural shifts, marked by economic decoupling and new political alliances, with declining European stability accelerating protectionist trends. EU-Russia trade, once strong, has been severely disrupted by recent geopolitical events. In 2021, EU-Russia trade reached €257.5 billion, but after Russia's invasion of Ukraine, exports to Russia dropped by 58%, and imports by 86%. Although some recovery was observed in Q3 2024, Russia's share in EU imports fell from 9.3% to 1.4% [7]. The conflict has exposed the vulnerability of global trade and transport systems, with sanctions, port blockades, and airspace restrictions disrupting EU-Russia supply chains, particularly in goods, energy, and raw materials [8].

2. Literature Review

Geopolitical risks increasingly shape the global economy, attracting attention from economists, investors, and researchers. Pollins [9] used a gravity model to show how international political factors affect trade flows, demonstrating that both cooperation and conflict alter trade patterns. Barbieri and Levy [10] argued that the economic impact of war on trade is usually temporary, with trade volumes recovering once hostilities end. However, Anderton and Carter [11] found that wars consistently suppress trade during conflicts. Nitsch and Schumacher [12] revealed that terrorist incidents reduce international trade, while Martin et al. [13] confirmed that military conflicts constrain trade openness, although multilateral cooperation may increase bilateral conflicts. Qureshi [14] documented the long-term effects of regional conflicts, with disruptions lasting up to three years in neighbouring disputes and five years in international confrontations. Pham and Doucouliagos [15] showed that terrorist attacks reduce bilateral trade, with effects lasting for several years.

Research consistently affirms that geopolitical risks affect global trade and transport systems, influencing both demand and supply dynamics [16,17]. Liu and Fu [18] found that maritime transport is most sensitive to geopolitical disruptions, followed by air transport, while road transport shows higher resilience. Tsamboulas [19] identified vulnerabilities in transport infrastructures under terrorist threats and proposed mitigation strategies. Geopolitical shocks are linked to higher transport costs, increased freight prices, and reduced demand for transport services [20,21], with operators facing direct losses from cargo destruction during crises [22]. Economic sanctions have become more common, viewed as a less costly alternative to military intervention [20]. A study on "*Economic Sanctions and Trade Flows in the Neighbourhood*" found that sanctions cause significant declines in formal trade, though they can also stimulate informal trade to circumvent restrictions [23].

3. Data and Methods

The aim of the study is to assess the impact of the conflict between Russia and Ukraine on EU transport flows, with a focus on identifying structural changes in transport volumes and assessing the impact of geopolitical risks on road, water and air transport after the break in Q2 2022.

To achieve this goal, it was necessary to implement several follow-up steps:

- ✓ data collection (Eurostat Transport data 2020 Q1 – 2024 Q4, Geopolitical Risk Index GPR, Control variables) and their preparation (cleaning, aggregation by transport mode)
- ✓ descriptive data analysis focused on transport volume trends, their visualization and GPR index
- ✓ identification of structural breaks in relation to Q2 2022 using the Chow test and multiple breaks by individual transport modes using the Bai-Perron test
- ✓ interpretation of the achieved results in relation to structural breaks, assessing the impact of the GPR effect on transport volumes after the break.

3.1 Data Sources

The analysis used quarterly data from Q1 2020 to Q4 2024. Data on transport flows were obtained from the Eurostat database, specifically categorized according to the following source indicators:

- road transport: "Road freight transport [road_go_tq_tott] ";
- water transport: "EU level – gross weight of goods handled in main ports [mar_qg_qm_ewhd] ";
- air transport: "International intra-EU freight and main air transport [avia_goincc] " and "International extra-EU freight and mail air transport [avia_goexcc] ".

As the authors of the GPR index publish data for four European regions (Northern, Eastern, Western, Southern Europe), there is no single indicator for the whole EU. Therefore, an aggregated EU GPR index was created as a weighted average of regional values, where:

- the weights correspond to the number of EU Member States in the respective region,
- Russia and Ukraine are not included (they are not EU members and their inclusion would distort the level of risk within the Union).

3.2 Models and Statistical Tests

To identify structural changes in the relationship between geopolitical risk and transport volumes, three key methodological approaches were applied.

The first method used was the Chow test [24], which allows for the verification of a statistically significant structural break in the parameters of a linear regression model before and after Q2 2022. The regression model (see Eq. 1) was defined as follows:

$$Y_t = \beta_0 + \beta_1 GPR_t + \varepsilon_t, \quad [-] \quad (1)$$

where: Y_t represents the normalized transport volume [t]; GPR_t is the average value of the Geopolitical Risk Index in the same period [-]; β_0 denotes the constant [-]; β_1 is the coefficient for the GPR index [-]; ε_t represents the residual term [-].

The Chow test was applied to road, water, and air transport datasets to detect structural breaks, while the Bai–Perron test identified multiple breakpoints. Moving averages over four quarters were used to interpret long-term trends. Analyses were conducted in R Studio using the "strucchange" and "lmtest" packages for the tests, and "ggplot2" for visualization. The aim was to test the hypothesis that the Russia-Ukraine conflict since Q2 2022 caused significant changes in EU transport volumes. It was hypothesized that water transport would be most sensitive to disruptions, followed by air transport, with road transport being least affected, as confirmed by the breakpoints.

4. Results

As outlined in the methodology, the analytical phase of this research utilized quarterly data from the Eurostat database and Geopolitical Risk Index values. The initial step involved adjusting and harmonizing the dataset for compatibility with the RStudio. Table 1 presents aggregated quarterly data from Q1 2020 to Q4 2024, prepared for statistical analysis in RStudio. The columns "year" and "quarter" represent the time intervals, while the "EU_GPR" column shows the calculated aggregate geopolitical risk index for the EU, derived from regional GPR indices (excluding Russia and Ukraine).

Table 1 Transport Volumes by Mode and EU GPR Index over Quarters (2020–2024).

Source: [25-28]

year	quarter	EU_GPR	road mode, thousand tonnes	water mode, thousand tonnes	air mode, tonnes
2020	1	0.16	3060173	838731	463537.1
2020	2	0.08	3097205	791905	447272.3
2020	3	0.12	3448431	802663	498031.2
2020	4	0.12	3412766	832505	544403.9
2021	1	0.10	3147425	821379	534363.4
2021	2	0.15	3577702	851289	559625.4
2021	3	0.10	3491225	864284	550676.2
2021	4	0.21	3432552	867008	599016.5
2022	1	0.70	3262876	841269	523418.9
2022	2	0.48	3535664	893977	504127.8
2022	3	0.27	3462113	871326	507881.8
2022	4	0.24	3324587	854657	535472.5
2023	1	0.24	3166058	840741	503447.7
2023	2	0.19	3431907	856455	484472.4
2023	3	0.19	3312290	838092	467306.9
2023	4	0.21	3206784	831708	511304.4
2024	1	0.22	3049632	807849	481897.4
2024	2	0.21	3347574	856917	494378.1
2024	3	0.15	3324195	828171	485914.1
2024	4	0.19	3323950	817465	518546.1

The freight transport data are categorized into three main modes of transport: "road tonnage" indicates the total volume of goods transported by road; "water tonnage" represents the total volume of goods transported by waterway; "air tonnage" includes the total volume of goods transported by air. Data adjustment was necessary to ensure compatibility with analytical software and enable effective quantitative analysis of structural breaks and trends using the statistical tests outlined earlier. The vertical axes of the graphs are scaled differently for road, water, and air transport due to the varying ranges and units of the data; therefore, it is recommended to compare trends within each transport mode rather than across modes.

4.1 Chow Test

The empirical analysis aimed to identify structural breaks in transport volume time series across different transport modes in the EU. Assuming the Ukraine conflict was an external shock disrupting trade and transport, the Chow test [24] was applied to detect significant changes in regression parameters. To evaluate the impact of the 2022 geopolitical shock, the Chow test was used with a linear model defined in Subchapter 3.3. Separate models for road, water, and air transport were tested, with Q2 2022 chosen as the breakpoint, marking the escalation of geopolitical tensions and disruptions in European logistics and supply chains (see Eq. 2).

$$F = \frac{SSR_p - (SSR_1 + SSR_2)/k}{SSR_1 + SSR_2 / (n_1 + n_2 - 2k)}, \quad [-] \quad (2)$$

where: SSR_p — the sum of squared residuals from the pooled model (without division into subperiods) [-]; SSR_1, SSR_2 — the sum of squared residuals from models before and after the assumed breakpoint (in this case, Q2 2022) [-]; k — the number of parameters in the model [-]; $n_1 + n_2$ — the number of observations before and after the breakpoint [-].

Formally, the null hypothesis (H_0) was defined as the absence of a structural break in the regression relationship, while the alternative hypothesis (H_1) assumed the existence of a change in the model parameters after the selected period (see Eq. 3).

$$H_0: \beta_1 = \beta_0 \text{ (there is no structural break)} \quad (3)$$

$$H_1: \beta_1 \neq \beta_0 \text{ (there is a structural break in 2022 Q2)} \quad F_{\alpha}(k, n_1 + n_2 - 2k) \quad [-]$$

If the calculated F-value exceeds the critical value $F_{\alpha}(k, n_1 + n_2 - 2k)$ or if the p-value $< \alpha$ (0.05 or 0.01), the null hypothesis is rejected, confirming the existence of a structural break.

The F-statistic and p-value results for each mode of transport are presented in Table 2. The results clearly indicate that, for all three modes of transport, the null hypothesis was rejected, thereby confirming the existence of a statistically significant structural break in the second quarter of 2022. This point marks a disruptive shift in the dynamics of transport volume.

Table 2 Results Chow test for road, water and air transport modes. Source: authors

Mode	F-stat	p-value	break-quarter	n
Road	3.426486	0.046785449	2022 Q2	20
Water	4.568254	0.019723140	2022 Q2	20
Air	5.623182	0.009622036	2022 Q2	20

Graphical representations (Fig. 1-3) show a steady increase in transport performance during 2020–2021, followed by a sharp decline or stagnation starting in 2022Q2. The most pronounced change occurred in air transport (Fig. 1), with a highly significant p-value (0.005). This shift was influenced by both the geopolitical shock and the post-COVID-19 period.

**Fig. 1** Chow test visualization for air transport. Source: authors

In road and water transport (Fig. 2, 3), the structural break was statistically significant but moderate, indicating gradual adaptation within logistics networks. The decline in volumes is attributed to heightened uncertainty, route disruptions, and shifts in demand.

**Fig. 2** Chow test visualization for road transport. Source: authors

These findings provide robust evidence that the 2022 conflict significantly impacted EU transport systems, with varying intensity across modes, and confirm the Chow test's suitability for assessing structural changes due to geopolitical events.

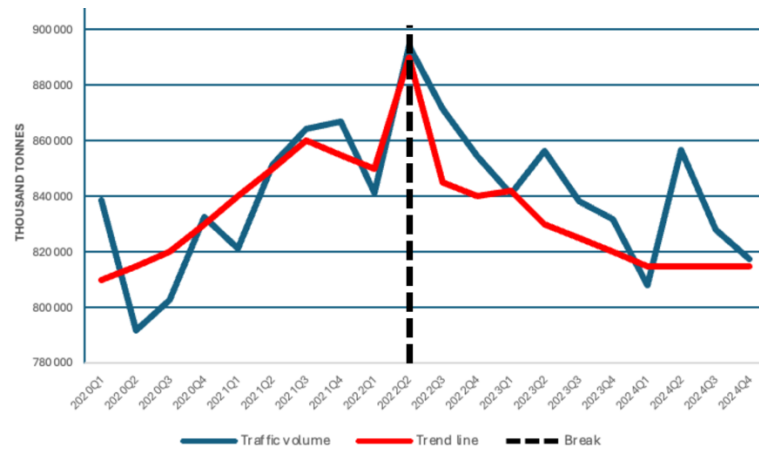


Fig. 3 Chow test visualization for water transport. Source: authors

4.2 Analysis of Post-Conflict Transport Volume Trends in the EU

Based on the identified structural break in 2022Q2, an additional post-break trend analysis, results in Table 3, was conducted with the aim of verifying the long-term direction of development for individual transport modes within the European Union.

Table 3 Post-break trend analysis of road, water, and air transport modes in the EU. Source: authors

Mode	estimate	std.error	statistic	p-value
Road	-18175.055	12442.579	-1.460714	0.178105916
Water	-5808.464	1560.467	-3.722260	0.004753987
Air	28949.630	15849.480	1.826535	0.101049959

The road transport shows a negative trend ($\beta = -18175$), but without statistical significance ($p = 0.178 > 0.05$), indicating stabilization after the initial decline due to the conflict. By 2023, volumes settled at a lower level, reflecting the adaptability of road networks to new geopolitical conditions.

Water transport displays a significant negative trend ($\beta = -5808$, $p = 0.0047 < 0.01$), indicating a persistent decline post-2022. This suggests that water transport was most affected by geopolitical factors, including disruptions in maritime and inland corridors, uncertainty in the Black Sea region, and trade redirection within the EU.

The time evolution of air freight transport in the EU shows a gradual recovery after a sharp decline in 2022, with a slight upward trend since early 2023. The red regression line indicates a positive slope ($\beta = +28,950$ tons per quarter; $p = 0.101$), suggesting recovery, although not statistically significant, after two years of stagnation.

The 2022 geopolitical shock had an asymmetric impact on transport modes. Water transport declined persistently, while road and air transport stabilized at lower levels. These results support the hypothesis that the Ukraine conflict caused both short-term disruptions and long-term structural changes, underscoring the need to strengthen EU transport resilience and diversify routes to address geopolitical volatility.

4.3 Bai-Perron Test

The Bai–Perron test was applied to identify multiple structural breaks within the time series. The procedure identified breakpoints in 2022Q3 for road transport, 2022Q1 for water transport, and 2021Q4 for air transport and the number of breaks ($h = 8$) for each transport mode. The results of the analysis are presented graphically, with the X-axis representing the number of possible breaks (0 indicating no detected break, and 1 representing a single identified break).

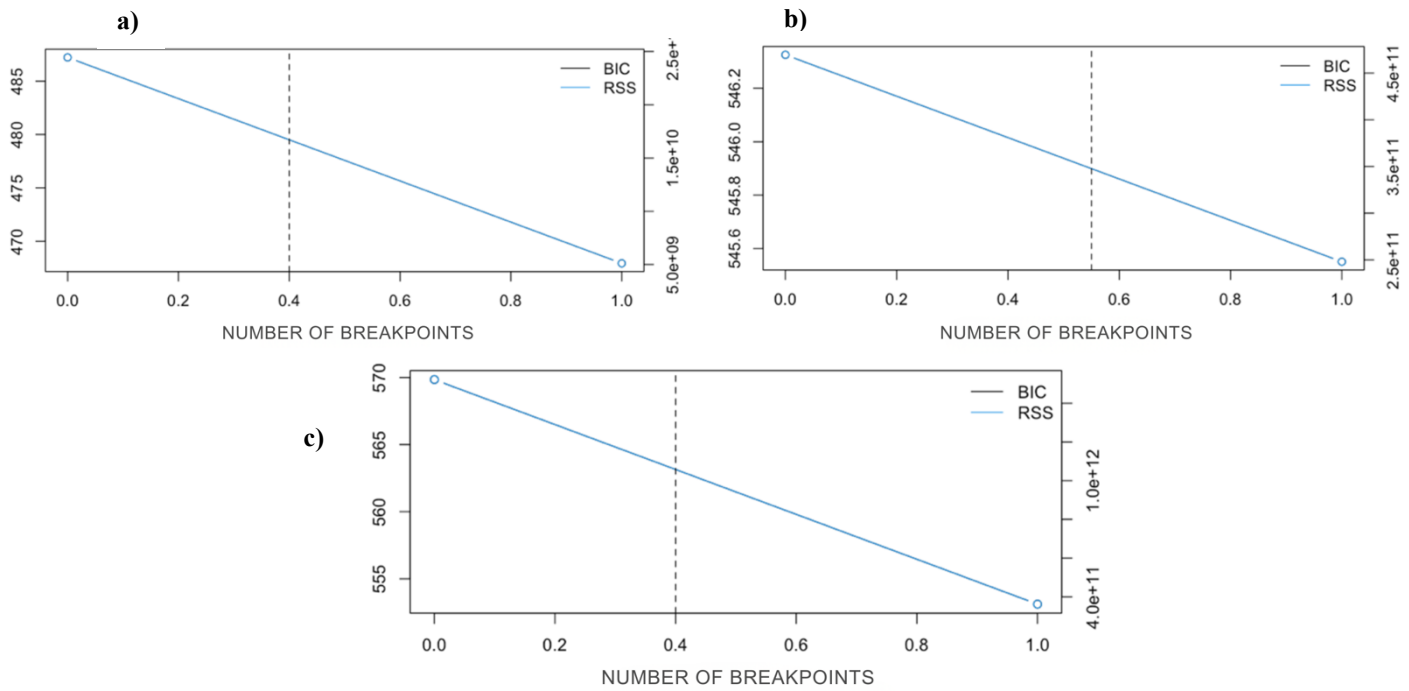


Fig. 4 Bai-Perron test visualization for (a)road (b)water and (c)air transport. Source: authors

Results for each transport mode include: **road transport** (Fig. 4(a)): a significant break in 2022Q3, indicating a delayed impact of the conflict on road transport; **water transport** (Fig. 4(b)): a break in 2022Q1, suggesting early disruptions due to geopolitical factors, especially in the Black Sea region; **air transport** (Fig. 4(c)): a break in 2021Q4, reflecting the impact of the second wave of the COVID-19 pandemic before the conflict.

These findings support the hypothesis of varying sensitivity and adaptability across transport sectors, showing that geopolitical risks influence transport dynamics at different points in time.

5. Discussion

The results of the analysis confirm that the development of transport flows in the EU in the period 2020–2024 was influenced by a combination of fading pandemic factors and a new geopolitical shock in 2022. The identified structural changes are therefore not exclusively linked to the Russia-Ukraine conflict, but reflect the cumulating of several simultaneously acting macro-shocks that changed the logistical behavior of companies and the demand for individual transport modes. The sensitivity of individual transport sectors to geopolitical risks corresponds to previous findings in the literature. Liu

and Fu (2022) identified high sensitivity of maritime transport to geopolitical disruptions, whereas Pollins (2004) and Barbieri & Levy (2019) emphasize the adaptive capacity of road and air transport, which corresponds with our observations of stabilization in certain modes. Our findings also support studies indicating asymmetric and delayed responses of transport modalities to geopolitical shocks (Martin et al., 2018; Hummels et al., 2020).

The identified structural breaks represent a conservative estimate of the actual geopolitical impact, as changes caused by the energy crisis, disrupted supply chains, inflation and the restoration of air traffic after the pandemic also entered the analyzed period. These parallel shocks cause transport volumes to respond with a time lag, which is in line with research emphasizing the heterogeneous and gradual adaptation of transport systems to exogenous events. The limits of the current approach are mainly related to the use of an aggregated geopolitical risk index, which does not capture the different sensitivities of individual EU regions or specific trade flows. Existing indices, including the Caldara–Iacoviello GPR (2024), are robust for macroeconomic analyses, but less suitable for detailed assessment of infrastructure or sectoral impacts. For this reason, the regional variability of risk may be underestimated and some shocks may have a stronger effect than the aggregated data show.

The current conflict has also triggered several secondary processes – rerouting trade routes, circumventing sanctions through third countries or changes in the commodity structure of imports – whose effects will be felt over a longer time horizon and are not yet fully visible in quarterly indicators. Transport systems respond to geopolitical impulses gradually, which means that the actual intensity of disruptions may be higher than the data indicate up to 2024. The findings highlight the need for more detailed monitoring of geopolitical impacts, the use of time-lagged models and the construction of more accurate indicators of geopolitical risk at the European Union level. The omission of macroeconomic and control variables does not undermine the main objective of this study, as the analysis is not intended to estimate a fully specified causal relationship between geopolitical risk and transport volumes. Instead, it focuses on identifying structural breaks in transport dynamics. Tests such as Chow and Bai–Perron detect significant changes in time patterns regardless of whether they are driven by multiple exogenous shocks. Variables such as GDP, inflation, seasonality, and energy prices may affect the magnitude of transport fluctuations, but are less likely to alter the identification of the break itself, linked to the geopolitical event in Q2 2022. Thus, omitted variables limit causal interpretation rather than the validity of the identified structural change.

6. Conclusion

The analysis confirmed that the geopolitical shock in 2022 had a significant impact on the development of transport flows in the European Union. The Chow test showed a structural break in the second quarter of 2022 across all transport modes, while the Bai–Perron analysis complemented

the different timing of the response of individual sectors. Water transport experienced the earliest and most persistent decline, road transport underwent a delayed but rapid adaptation to a lower level, and air transport stabilized after the pandemic fluctuations without signs of long-term stagnation.

These results should be seen in the context of the accumulation of macroeconomic and logistical shocks that affected European transport networks in the period 2020–2024. As the development of transport volumes responds to geopolitical events gradually, the identified changes likely capture only part of the future impacts of the ongoing conflict. At the same time, the use of an aggregated geopolitical risk index at EU level does not allow for the precise identification of regional differences in sensitivity. In the long term, the findings point to the need to strengthen the resilience of European transport systems to external shocks. Future research should focus on time-lagged models, more detailed regional data, and the development of more accurate geopolitical risk indicators tailored to the EU structure. Such approaches will allow for better capturing the cumulative effects of geopolitical instability and identifying lasting changes in European logistics networks.

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