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INFLATION SPILLOVERS AND GEOPOLITICAL RISKS: EVIDENCE FROM EURO AREA COUNTRIES USING TVP-VAR AND QUANTILE MODELS

Enflasyon Yayılma Etkileri ve Jeopolitik Riskler: TVP-VAR ve Kantil Modelleri Kullanılarak Euro Bölgesi Ülkelerinden Kanıtlar

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Keywords:
Inflation Transmission, European Union, Geopolitical Risks

JEL Codes:
C32, E31, R11

Abstract

This study examines the inflation transmission mechanism across 14 European Union countries, from May 1963 to November 2023. Contrary to the existing literature, this study employs a two-stage approach to examine the spillover effect of inflation in the European Region. The study identifies the inflation spillover effects by applying a time-varying parameter vector autoregressive (TVP-VAR) model with the joint connectedness framework. Moreover, we analyze the relationship between the Total Connectedness Index (TCI) and geopolitical risks (GPR) using the Quantile-on-Quantile (QoQ) model and explore how geopolitical uncertainties influence inflation transmission dynamics. The analysis provides significant contributions to the literature in terms of both methodology and scope by allowing responses to risk shocks of different magnitudes to be measured at quantile levels. The findings show that as Denmark, Germany, and France are highly interconnected with other countries in the region, they have an essential of spreading inflation. Unlike, the global and the US's risk indices, Russia's and Europe's GPR have a more significant impact on inflation. Finally, the interaction between TCI and GPR differ across quantiles, implying the existence of non-linear and asymmetric impacts of geopolitical events on inflation interconnectedness.

Anahtar Kelimeler:
Enflasyon Yayılımı, Avrupa Birliği, Jeopolitik Riskler

JEL Kodları:
C32, E31, R11

Öz

Bu çalışma, Mayıs 1963 ile Kasım 2023 arasındaki dönemde 14 Avrupa Birliği ülkesinde enflasyon yayılma mekanizmasını incelemektedir. Literatürün aksine, bu çalışmada Avrupa Bölgesi'nde enflasyonun yayılma etkisini incelemek için iki aşamalı bir yaklaşım kullanılmaktadır. Çalışmada, zamanla değişen parametreli vektör otoregresif (TVP-VAR) modeli ve ortak bağlantılılık çerçevesi kullanılarak enflasyonun yayılma etkileri belirlenmiştir. Ayrıca, Toplam Bağlantılılık Endeksi (TCI) ile jeopolitik riskler (GPR) arasındaki ilişki, Kantil-üzerinde-Kantil (QoQ) modeli ile analiz edilmiş ve jeopolitik belirsizliklerin enflasyon yayılma dinamiklerini nasıl etkilediği incelenmiştir. Analiz, farklı büyüklükteki risk şoklarına verilen tepkilerin kantil seviyelerinde ölçülmesine olanak tanıyarak hem metodoloji hem de kapsam açısından literatüre önemli katkılar sağlamaktadır. Bulgular, Danimarka, Almanya ve Fransa'nın bölgedeki diğer ülkelerle yüksek derecede bağlantılı olduğunu ve bu ülkelerin enflasyonun yayılmasında önemli bir role sahip olduğunu göstermektedir. Global ve ABD risk endekslerinin aksine, Rusya ve Avrupa'nın GPR'si enflasyon üzerinde daha önemli bir etkiye sahiptir. Son olarak, TCI ile GPR arasındaki etkileşimlerin farklı kantillerde değişiklik gösterdiği ve jeopolitik olayların enflasyon bağlantılılığı üzerinde doğrusal olmayan ve asimetrik etkiler yarattığı tespit edilmiştir.

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1. Introduction

The predictability and stability of inflation are crucial for effective economic planning and decision-making by individuals, firms, and policymakers. Stable inflation rates allow for more accurate forecasting of future costs and revenues, enabling better long-term investment strategies (Mishkin, 2007; Mankiw, 2014). Moreover, predictable inflation helps maintain the purchasing power of money, fostering consumer confidence and promoting overall economic growth (Taylor, 1993; Brown et al., 2023). Due to these advantages, one of the main targets of central banks is to determine the inflation level and it is generally kept in a band between 2-3 percent for developed countries. For instance, the monetary policy of the European Central Bank incorporates a target of 2% inflation for the aggregate of all Eurozone countries (ECB, 2021). Similarly, the Federal Reserve in the United States adheres to a long-term inflation target of 2%, aligning with its dual mandate of promoting maximum employment and price stability. This target is critical for maintaining economic predictability and fostering sustainable growth (Mishkin, 2007; Federal Reserve, 2023).

Notwithstanding, developed countries recognize the importance of maintaining stable inflation levels, inflation, once predominantly associated with developing nations, has become a significant concern in developed economies. Although it was previously believed that developed economies had resolved the issue of inflation through historical processes and that this phenomenon was primarily associated with developing countries, inflation has recently emerged as a significant concern for developed nations. Notably, the European Union, home to several developed nations, has witnessed heightened inflationary pressure in recent years. Geopolitical factors such as ongoing trade tensions between the US and China and the Russia-Ukraine war have exacerbated these pressures, disrupting economic stability and complicating inflation management. In particular, the Russian-Ukraine conflict led to surging energy costs (Gong, 2023; Hu, 2024) and supply chain interruptions (Zimková et al., 2023; Tyagi, 2024), driving inflation rates across European countries, which have faced substantial fluctuations in inflation rates due to these geopolitical disruptions. Due to geopolitical factors, firms in Europe have difficulties in forecasting costs, and consumers have challenges in spending, leading to disruptions in the entire European economy.

Figure 1 displays the inflation rates for specific geopolitical events influencing the European economy. For instance, inflation rates spiked as European countries faced increased energy costs and supply chain disruptions during the Russian-Ukraine war. Still, imported goods' price volatility caused higher production costs leading to higher consumer prices during trade tensions between the US and China.

Thanks to the events mentioned above causing disruptions in the European economy, there is a need to revisit inflation dynamics, particularly paying attention to different geopolitical risks. Conventional approaches to inflation factors deal with classic determinants. Yet, these approaches are incapable of comprehending the current economic conditions. Hence, scholars should apply a more comprehensive framework considering spillover effects on inflation. Especially, rising geopolitical risks, which have direct and indirect effects on the economy via energy prices and input costs, have made it crucial to apply a comprehensive approach to inflation dynamics (Caldara et al., 2019; García et al., 2024). Still, the literature on the spillover effects of inflation is limited. Many studies focus on the relationship between the spillover effect and geopolitical risk mainly use the global geopolitical risk index. Yet, using only the global geopolitical risk index has limitations. The global geopolitical risk index offers an overall risk level by incorporating many geopolitical events and risks associated with different regions in a single framework. This approach neglects local differences. For instance, geopolitical incidents in the US, Russia, and Europe might have varying effects on energy markets and economic structures. A single global indicator is most likely to ignore these effects and might fail to analyze the spillover impacts of geopolitical risk on inflation accurately (Bouri et al., 2023). Hence, it would be hard to comprehend the regional differences in regional geopolitical risks.

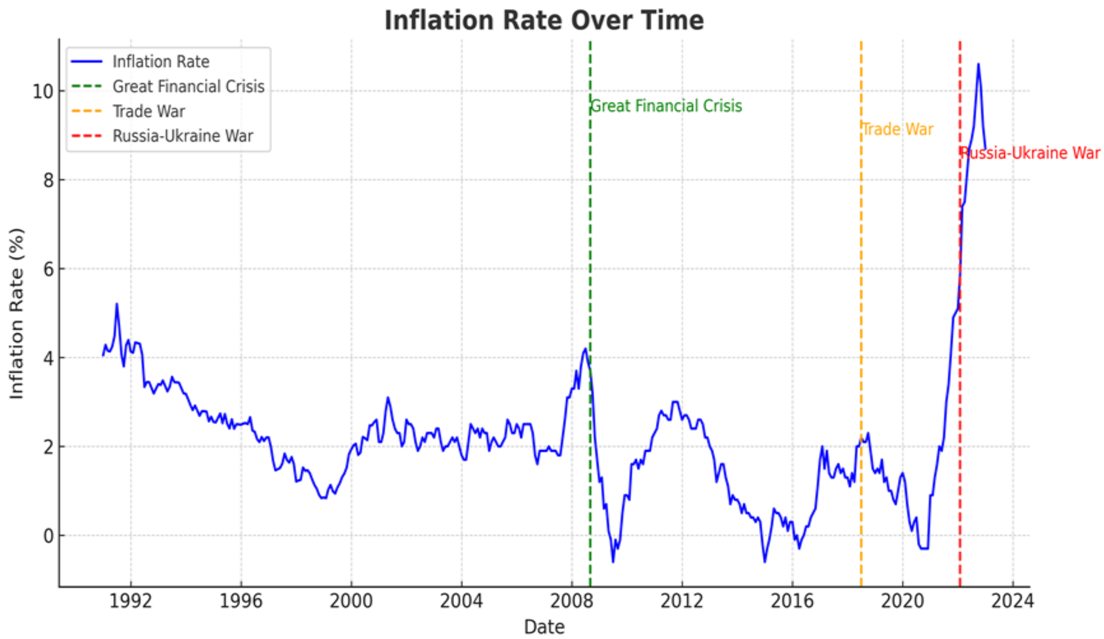


Figure 1. Harmonized Consumer Price Index in Eurozone (1997m12-2024m2)

Contrary to the existing literature, this study employs a two-stage approach to examine the spillover effect of inflation in the European Region. We first obtain the total spillover effect by performing the TVP-VAR model. Second, we incorporate the total spillover effect variable with the Global, European Region, Russia, and the US geopolitical risk indices, and analyze them by employing the QoQ model.

Euro Area forms the core focus of this study as it has a pivotal role in economic and monetary integration in the world. Hence, comprehension of inflation spillover effects and their interaction with geopolitical risks in the region is crucial for taking preemptive actions for possible repercussions.

This analysis method provides significant contributions to the literature in terms of both methodology and scope by allowing responses to risk shocks of different magnitudes to be measured at quantile levels. The findings of the study are crucial regarding policy design and risk management since the paper demonstrates the impact of geopolitical risks on inflation in stationary and dynamic conditions. In addition, employing both the TVP-VAR model and QoQ analysis is one of the paper's originalities enables us to analyze inflation spillover dynamics deeply.

The paper continues as follows. Section 2 provides a comprehensive review of the literature, focusing on inflation spillover dynamics and the role of geopolitical risks. Section 3 describes the data and presents summary statistics, highlighting key variables and their significance. Section 4 elaborates on the methodology, detailing the TVP-VAR and QoQ models employed. Section 5 discusses the empirical results, emphasizing the interconnectedness of inflation spillovers and the impact of geopolitical risks. Finally, Section 6 concludes with policy implications and recommendations for future research.

2. Literature Review

The relationship between inflation and geopolitical risks has been receiving increasing attention from macroeconomic policymakers and academic circles. The effects of geopolitical developments on energy markets, supply chains, and trade flows play a critical role in understanding inflation dynamics. However, studies addressing the regional variations of these effects are limited in the existing literature. Within the scope of the literature review, firstly the general relationship between inflation and geopolitical risks is focused on, then the spillover effects of inflation and the interaction of these effects with geopolitical risks are examined. Finally, studies conducted in the context of the European Region, which is the focus of the study, are evaluated. This comprehensive analysis allows for the identification of gaps in the existing literature and clarifies the contributions of this study.

2.1. Inflation and Geopolitical Risks

The impact of geopolitical threats on inflation has been the subject of conflicting findings in the literature. Some studies suggest that energy price increases (Bouri et al., 2023; Lee et al., 2023; Yang et al., 2023), changes in currency exchange rates (Hui, 2021; Salisu et al., 2022; Hossain et al., 2024), global supply chain disruptions (Ye et al., 2023; Qin et al., 2023), and increased uncertainty (Caldara and Iacoviello, 2022) result in geopolitical risks which lead to higher inflation. Yet some other studies show that geopolitical risk declines investor confidence and thereby reduces demand. Hence, consumers tend to save more than spend in higher geopolitical risk times, which causes a decrease in inflation (Bekaert et al., 2013). Overall, geopolitical risk might increase or decrease inflation and might have inflation-pressure effects in the long or short run.

2.2. Spillover Effect of Inflation and Geopolitical Risk

This study relates spillover effects to geopolitical risk with an extension of macroeconomic dynamics complexity. Many studies suggest that energy costs, trade relations, and regional political uncertainty impact inflation spillover mechanisms. For instance, Caldara and Iacoviello (2022) propose that inflation has a rapid spread in regions with high geopolitical risks, which increases economic uncertainty. The spillover effect is prominent in energy-dependent countries. Forbes et al. (2022) suggest that Germany and France have vital roles in transmitting and receiving inflation spillover effects. The authors also state the economic and trade connections configure the effects. In addition, Köse and Ünal (2025) pinpoint the role of important geopolitical events such as Brexit in cross-country spillover impact.

Policymakers face challenges due to geopolitical uncertainties and financial crises escalating spillover effect. According to García et al. (2024), inflation spillover effects have escalated via financial instability throughout COVID-19. Moreover, Yang et al. (2023) indicate that geopolitical risks have a more substantial impact on industrial demand for oil production than on oil supply disruptions, leading to transient rather than sustained increases in oil prices. In a nutshell, the literature highlights the close interaction among the economy, geopolitical risk, and inflation spillover effects.

2.3. Inflation Spillover Effects and Geopolitical Risks in the Euro Area

Trade bonds, financial integration and regional policies lead to inflation spillover effects in Europe. Table 1 gives a summary of the literature in European countries. The literature performs a diverse set of models to examine the inflation spillover effects in Europe. To illustrate, García et al. (2024) investigate the inflation spillover effects in Europe from 2018 to 2022 by performing structural VAR models. In addition, Bettarelli et al. (2024) how fiscal shocks in a given country affect foreign regions through regional trade linkages with the local projection method and suggest that countries-to-regions fiscal spillovers are positive, statistically significant, persistent, and non-negligible in size. Moreover, Marangoz (2025) finds that oil price shocks with deflationary trends during COVID-19 have inflationary consequences. and the European Central Bank's response to the pandemic-induced economic downturn has affected long-term inflation trends. Similarly, Kang et al. (2019) examine co-influences between inflation cycles of the economies of four Eurozone countries with a wavelet-based measure of synchronization and a directional spillover index approach. Still, Ciccarelli and Mojon (2010) argue that inflation synchronization in core countries was higher than in peripheral countries based on 1985-2009 data.

More recent studies have focused on the effects of geopolitical risks on inflation. Köse and Ünal (2025) emphasized that Brexit and transformed inflation dynamics in Europe and caused the spillover effects to differ. Forbes et al. (2022) showed with network analysis that Germany and France played net spreader roles, while Eastern European countries tended to be more affected. Pham and Sala (2022) found that financial imbalances accelerated the spillover effects after the 2008 global crisis, while Hall et al. (2023) found that inflation effects on peripheral economies intensified in the post-COVID-19 period. Bouri et al. (2023) Using the TVP-VAR connectivity model and QoQ analyses for the period 1963-2022, it was stated that geopolitically induced inflation caused inflation rates to move simultaneously in the North American and European economies, and this situation provided important clues for policymakers. As a result, inflation spillover effects in Europe are not limited to economic dynamics but are also deeply affected by factors such as energy prices and geopolitical risks. Studies in the literature aimed at understanding the complexity of these effects emphasize the need for new approaches in regional policies and the management of global shocks.

Table 1. Key Studies on Inflation Spillover and Geopolitical Risks in the Euro Area

Author (Year)	Data Range	Method	Finding
Ciccarelli and Mojon (2010)	1985–2009	Factor model with inflation synchronization indices	Core EU countries exhibit higher inflation synchronization than peripheral ones.
García et al. (2024)	1999–2013	Structural VAR models	Inflation spillovers are unidirectional from the USA to Europe, especially during crisis.
Kang et al. (2019)	1975–2017	Wavelet-based measure of synchronisation and a directional spillover index approach	Inflation cycles of the largest selected Eurozone economies lead those of the selected non-Eurozone economies
Windberger and Zeileis (2014)	1990 – 2010	Generalized Logistic Model with Structural Break Tests	Structural breaks in inflation dynamics suggest the potential influence of geopolitical or economic factors.
Bettarelli et al. (2018)	1993–2020	Local projection method to a panel of 222 NUTS-2 regions in 20 European countries	Countries-to-regions fiscal spillovers are positive, statistically significant, persistent, and non-negligible in size.
Köse and Ünal (2025)	January 2013–2020 December	Difference-in differences methodology	A nation departing from the EU may have inflationary issues, particularly in the sectors of energy and transportation.
Hall et al. (2023)	2015–2022	VAR and Spatial models	Post-COVID, inflation spillovers intensified, particularly towards peripheral economies.
Bouri et al. (2023)	May 1963 to November 2022	TVP-VAR Connectedness and Quantile on Quantile	Geopolitical-led inflation drives synchronization of inflation rates across North American and European economies.
Yang et al. (2023)	January 2000 to July 2022	Time-Varying Parameter Structural Vector Autoregression (TVP–SV–VAR)	Geopolitical risks have a more substantial impact on industrial demand for oil production than on oil supply disruptions, leading to transient rather than sustained increases in oil prices.
Marangoz (2025)	2010-2023	TVP-VAR model	Oil price and geopolitical shocks with deflationary trends during COVID-19 have inflationary consequences.

As a result, as summarized in Table 1, while there have been significant studies in the literature on the spillover effects of inflation in European economies, the effects of geopolitical risks have not been examined in sufficient detail. Existing studies generally address geopolitical risks at the global level, but do not deeply examine the specific effects of these risks on European economies. For example, Bouri et al. (2023) found that global geopolitical risks increased inflation synchronization in North American and European economies but did not focus on the effects of regional risks.

Euro Area forms the core focus of this study as it has a pivotal role in the economic and monetary integration in the world. Hence, comprehension of inflation spillover effects and their interaction with geopolitical risks in the region is crucial for taking preemptive actions for possible repercussions.

In this study, four different types of geopolitical risks (global, Russian, US, and European-specific risks) were examined and inflation spillover effects in Europe were analyzed. This approach, which specifically addresses the effects of regional risks, fills an important gap in the literature and provides a comprehensive contribution to how the economic dynamics of Europe are shaped by geopolitical factors.

3. Data

This study investigates the inflation transmission mechanism among European Union member countries, including Germany, France, Italy, Spain, the Netherlands, Denmark, Sweden, Poland, Belgium, Austria, Switzerland, Norway, and Finland, covering the period from May 1963 to November 2023, and examines the impact of geopolitical risks on this transmission. The extensive data range covers various economic, political, and geopolitics crises, including the Eurozone crisis, the 2008 global financial crisis, the COVID-19 pandemic, and the Russia-Ukraine war, supporting the accuracy of the analyses conducted in the study. In more detail, we use non-seasonally adjusted consumer price indices (CPI) obtained from the Federal Reserve Economic Database, along with the growth rate from the same period in the previous year, to analyze inflation dynamics. For each country, inflation growth rates from the same period in the previous year are illustrated in Fig.2. As seen in Fig.2, many European countries have been adversely affected in terms of inflation by the oil crisis in the late 1970s, the 2007-2088 global financial crisis, and most recently, the Ukraine-Russia war.

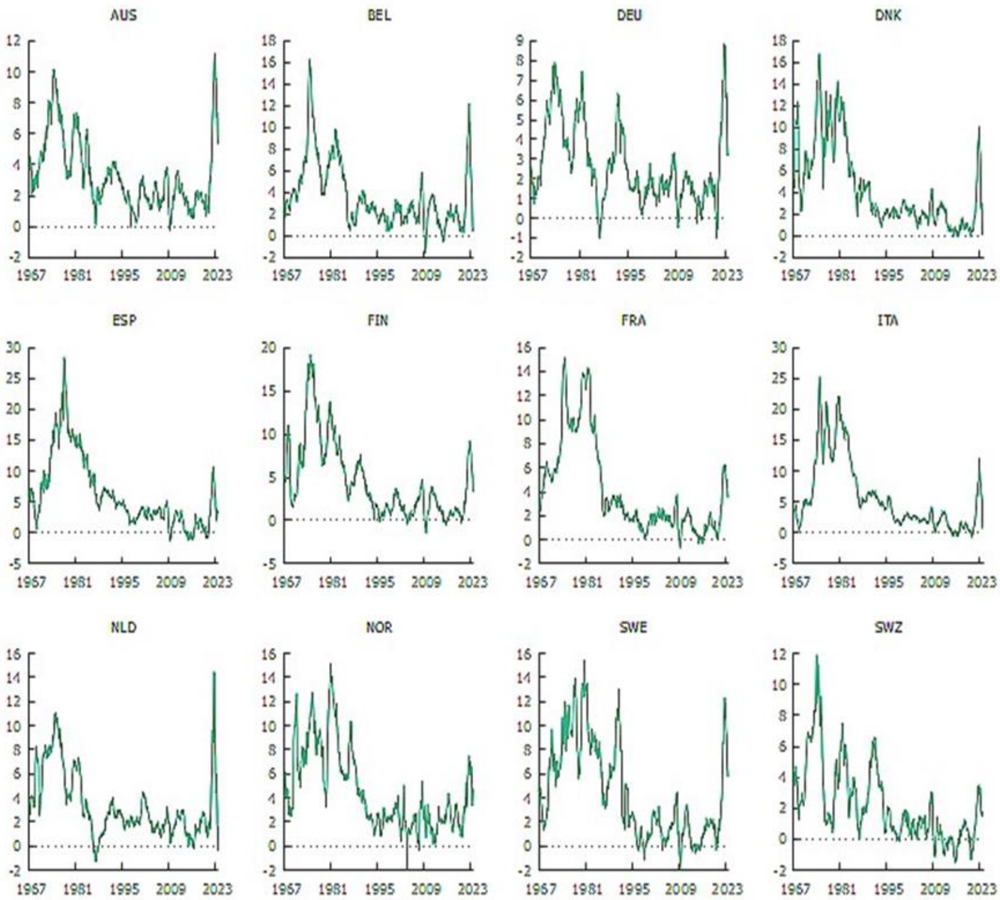


Figure 2. European Countries Inflation Rates (1967-2023)

Table 2 presents summary statistics of inflation rates across various countries. The highest average inflation rates are observed in ITA, followed by ESP, SWE, and FIN, while the lowest average rates are associated with DEU, NLD, and BEL. Regarding inflation rate variability, ITA, ESP, SWE, and FIN exhibit higher variability, whereas DEU, NLD, and BEL show lower variability. Notably, all inflation rates display significant right-skewness and leptokurtosis, except for NLD, which does not exhibit significant leptokurtosis. Moreover, none of the inflation rate series pass the Jarque and Bera (1980) normality test. Autocorrelation and ARCH/GARCH errors are detected in all inflation rates at least at the 1% significance level, with stationarity confirmed at least at the 10% significance level.

Table 2. Descriptive Statistics

Country / Inflation	AUS	BEL	DNK	DEU	FRA	FIN
Mean	3.371	3.638	4.377	2.698	4.127	4.55
Variance	5.228	8.901	14.416	4.009	14.766	19.327
Skewness	1.181**** (0.000)	1.531*** (0.000)	1.164*** (0.000)	0.852*** (0.000)	1.204*** (0.000)	1.261*** (0.000)
Ex. Kurtosis	0.888*** (0.000)	2.623*** (0.000)	0.389* (0.055)	0.004 (0.876)	0.400** (0.050)	1.054*** (0.000)
JB	181.076*** (0.000)	462.766*** (0.000)	158.650*** (0.000)	82.678*** (0.000)	169.590*** (0.000)	212.759*** (0.000)
ERS	-2.762*** (0.006)	-3.369*** (0.001)	-2.594*** (0.010)	-2.843*** (0.005)	-1.759* (0.079)	-2.305** (0.021)
Q (10)	3255.904*** (0.000)	3238.912*** (0.000)	3220.448*** (0.000)	3220.249*** (0.000)	3603.276*** (0.000)	3480.516*** (0.000)
Q2(10)	3136.053*** (0.000)	3077.111*** (0.000)	2947.507*** (0.000)	3075.234*** 0.000)	3478.905*** (0.000)	3410.347*** (0.000)
Country / Inflation	**ITA**	**NLD**	**NOR**	**ESP**	**SWE**	**SWZ**
Mean	5.88	3.393	4.571	6.303	4.434	2.272
Variance	33.327	7.315	11.22	33.007	15.583	6.255
Skewness	1.328*** (0.000)	1.162*** (0.000)	0.945*** (0.000)	1.268*** (0.000)	0.669*** (0.000)	1.164*** (0.000)
Ex. Kurtosis	0.812*** (0.001)	0.815*** (0.000)	0.034 (0.749)	1.192*** (0.000)	-0.654*** (0.000)	1.024*** (0.000)
JB	219.529*** (0.000)	172.523*** (0.000)	101.785*** (0.000)	223.356*** (0.000)	63.149*** (0.000)	184.152*** (0.000)
ERS	-2.170*** (0.000)	-2.925*** (0.004)	-2.445*** (0.015)	-1.558*** (0.000)	-2.399** (0.017)	-1.950* (0.052)
Q (10)	3517.756*** (0.000)	3163.942*** (0.000)	3251.585*** (0.000)	3530.342*** (0.000)	3322.996*** (0.000)	3303.482*** (0.000)
Q2(10)	3244.925*** (0.000)	3410.347*** (0.000)	2820.312*** (0.000)	3343.444*** (0.000)	3036.965*** (0.000)	3132.329*** (0.000)

Note: *, **. *** denotes a significance level of 10, 5%, and 1% significance level, respectively. JB: Jarque and Bera (1980) normality test, ERS: Elliott et al. (1996) unit root test, AUS: Austria, BEL: Belgium, DNK: Denmark, DEU: Germany, FIN: Finland, FRA: France, ITA: Italy, NLD: Netherlands, NOR: Norway, ESP: Spain, SWE: Sweden, SWZ: Switzerland

Furthermore, we also utilize the Geopolitical Risk Index (GPR) developed by Caldara and Lacoivello (2022) to examine its impact on inflation. The index is calculated by quantifying the occurrence of adverse geopolitical events within each newspaper monthly, expressed as a proportion of the total number of news articles. This search encompasses eight distinct categories:

War Threats, Peace Threats, Military Buildups, Nuclear Threats, Terror Threats, Beginning of War, Escalation of War, and Terror Acts. We also consider utilizing various geopolitical risk indices, including the GPR indices of Europe, the global domain, Russia, and the United States.

4. Methodology

4.1.TVP-VAR-Based Connectedness Framework

We use the TVP-VAR model. The TVP-Var model enables us to make a dynamic, time-sensitive analysis. Still, we perform the extended joint connectedness methodology proposed by Balcilar et al. (2021). The models of Diebold and Yılmaz (2012; 2014) and Antonakakis et al. (2018) are improved by the joint connectedness model. Thus, our comprehensive approach provides us with a more accurate analysis than static or rolling-window-based methods.

The TVP-VAR (1) model is as follows:

$$y_{\mathrm{t}} = C_{\mathrm{t}} y_{\mathrm{t}}{}^{-1} + e_{\mathrm{t}}, e_{\mathrm{t}} \sim N(0, H_{\mathrm{t}}), \tag{1}$$

$$vec(C_{\mathrm{t}}) = vec(C_{\mathrm{t}}{}^{-1}) + w_{\mathrm{t}}, w_{\mathrm{t}} \sim N(0, Q_{\mathrm{t}}). \tag{2}$$

We are able to transform the model into its moving average (TVP-VMA) to grasp the propagation of shocks by using the Wold decomposition theorem:

$$y_t = \sum_{k=0}^{\infty} D_{k,t}\, e_{t-k} \tag{3}$$

We can calculate the Generalized Forecast Error Variance Decomposition (GFEVD) with the formula above (Koop et al., 1996; Pesaran and Shin, 1998). GFEVD quantifies the proportion of variance in one variable that can be attributed to shocks from other variables.

4.2. Extended Joint Connectedness Approach

TVP-VAR connectivity method is able to monitor and reduce spillovers in networks. The model enables policymakers to adjust their economic and political strategies. However, the model has some pitfalls. To overcome these shortcomings, A TVP-VAR approach is proposed by Antonakakis et al. (2018). This model detects the dependency on arbitrary sliding window sizes more accurately and sensitively. In addition, different normalization methods and joint spillover indices have been introduced by Caloia et al. (2019) and Lastrapes and Wiesen (2021). Finally, the extended joint connectivity framework derived from the TVP-VAR connectivity model is suggested by Lastrapes and Wiesen (2021). This model has the capability of computing complicated measures like directional and group-level connectivity indices. Moreover, the model offers a more detailed analysis of the link among variables. The generalized connectedness measure for a specific variable j is defined as:

$$R_{\mathrm{j}} \leftarrow \cdot,_{\mathrm{t}} = \frac{(\sum_{k=0}^{P-1} u_j'\, D_{k,t} \Gamma_t N_j (N_j' \Gamma_t N_j)^{-1} N_j' \Gamma_t D_{k,t}' u_j)}{(\sum_{k=0}^{P-1} u_j'\, D_{k,t} \Gamma_t D_{k,t}' u_j)} \tag{4}$$

where $D_{k,t}$ is the time-varying impulse response coefficients. $D_{k,t}$ captures the dynamic effects of shocks on the variables over time. Γ_t is the covariance matrix and reflects the variability and interrelations among the shocks at a given time. Lastly, N_j is the contribution of other variables in the system and helps to measure the influence of each variable on the others. The joint TCI is then calculated as the average contribution of all variables:

$$JTCI_t = \frac{1}{L}\sum_{j=1}^{L} R_{j\leftarrow .,t}^{int,from} \quad (5)$$

This index is between 0 and 1. As the index value comes closer to 1, interconnectedness becomes stronger. In sum, the extended joint connectedness approach, with its ability to capture dynamic relations, is a robust measure for examining inflation spillover effects.

4.3. Quantile on Quantile Regression

The QoQ approach is relatively new and has started to become a prominent model in the literature. The model is able to analyze fluctuating correlations between dependent and independent variables in the entire distribution (Sim and Zhou, 2015). Unlike classical models, the QoQ model examines variables' quantiles by considering distributional dependencies and nonlinear correlations. Thus, the model is likely to detect the effect of extreme values and events. As the effect of geopolitical risks on economic indicators is nonlinear and asymmetric, QoQ model is one of the best fits to examine. Moreover, high geopolitical risks have more impact on inflation than low ones (Ding et. al, 2022; Umar et al., 2022). Our aim is to analyze the diverse effects of GPR on certain levels of the Total Spillover Effect. We include the lagged values of GPR to capture the delayed impact of geopolitical risks on economic dynamics.

This approach allows us to reflect on the temporal dynamics since geopolitical risks propagate through inflationary processes in a timely manner. The QoQ method is as follows:

$$Y_t = Y^{\tau}(X_t) + \mu_t^{\tau} \quad (6)$$

where Y_t is the dependent variable, X_t denotes the independent variables, and τ is the quantile level. μ_t^{τ} is the error term, $Y^{\tau}$is an unknown function capturing the non-linear relationships. The bandwidth value of h = 0.05, following Sim and Zhou (2015). We adapt the general QQ equation to analyze the interactions between TCI and GPRs. We also incorporate the methodology of Bouri et al. (2023) in our analysis. Our model includes lagged GPR indices to evaluate the delayed effects on TCI. The model's equation is as follows:

$$TCI_t = TCI^{\tau}(GPR_{t-h}) + \mu_t^{\tau} \quad (7)$$

where TCI is the dependent variable, denoting the degree of connectedness. The independent variables are the lagged values of geopolitical risk indices (Global, U.S., Russian, and Euro-area geopolitical risks). These lagged values are denoted as GPR_{t-h},. The quantile level, τ, shows heterogeneous impacts. TCI^{τ}, demonstrates the nonlinear and quantile-dependent relationship between the lagged GPR indices and TCI. Finally, μ_t^{τ} is the error term. This specification enables a nuanced understanding of how geopolitical risks interact with economic interconnectedness.

5. Empirical Results

5.1. Total Connectedness

TCI evaluates how one variable influences another, on average. A rise in this index suggests greater interconnections among members (variables) in the network, which increases overall risk since a system shock can readily propagate to others. Conversely, a decline in the index denotes diminished connections between network members, indicating a decreased ability to affect other economies when an inflationary shock hits a specific market.

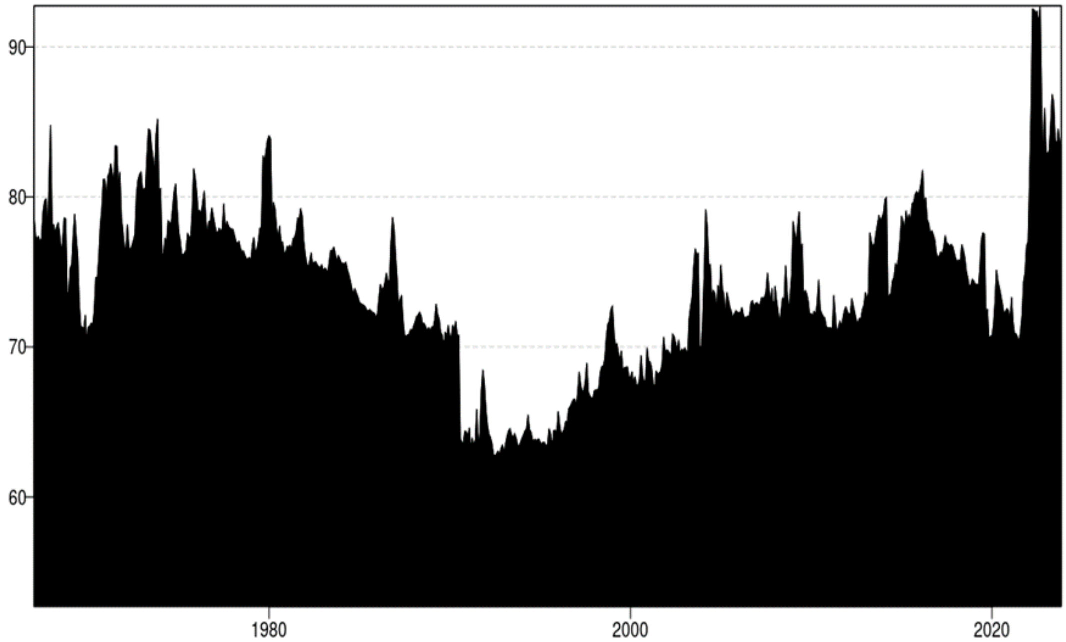


Figure 3. Total Connectedness Index (TCI)

Figure (3) shows the TCI, which measures the spillover effect of inflation among European countries from January 1967 to November 2023. In general, the TCI followed a fluctuating course and experienced significant increases during certain periods. More specifically after the turn of the millennium, as a result of deeper economic connectivity among European nations, inflation shocks have been more strongly transmitted to one another. Processes like the Eurozone's formation and the adoption of a unified currency have strengthened economic ties, leading to this. Major global shocks such as the 2008 Global Financial Crisis intensified this relationship (Barunik and Krehlik, 2018). In addition, the Arab-Israeli wars in the 1970s led to an oil embargo, and caused energy prices to soar, and formed inflationary pressures. Moreover, the peak of TCI in the table shows that the COVID-19 pandemic and the Russia-Ukraine War spread quickly through economic linkages between European countries, suggesting that regional economies are far more vulnerable to macroeconomic shocks. In sum, the figure demonstrates that geopolitical threats have a substantial impact on European countries.

5.2. Averaged Connectedness

Table 3 displays the spillover effect of inflation and the TCI. The TCI indicates the level of economic dependencies among countries and the transmission of inflation shocks to each other. According to Table 3, each country’s own TCI has significant weight in inflation spillover effects. To illustrate, Germany has a 29.95% effect on its own inflation spillover.

The results show that countries' own TCI values have a significant weight in inflation spillover effects. For example, Germany’s share in its own inflation spillover effect is 29.95%. Still, Switzerland’s own share is 36.26%. Besides, France’s effect on Germany’s inflation spillover is 14.89%. Strong economic ties between the two countries increase inflation spillover dynamics.

Table 3 also demonstrates that " the most receiver" country in the table is Austria. Austria has a NET value of -26.31, and it is most likely to be exposed to external shocks in the system with a NET value of -26.31. Likewise, Norway and the Netherlands pose negative NET values and tend to be affected by energy supply volatility. On the contrary, Denmark and Germany are “the most transmitters” of inflation spillover effects with a NET value of +59.18 and 38.79, respectively. That is, Germany has a powerful effect on other countries in the region via energy prices and production costs. These findings are in line with many studies in the literature. To illustrate, Devereux et al. (2023) suggest that Germany has strong fiscal and monetary spillover effects. A fiscal stimulus of 1% of GDP in Germany might result in an average increase of 0.2% of GDP in countries like France, Spain, and the Netherlands.

Moreover, the analysis displays heterogeneous effects. To give an example, Denmark has a negative effect (-12.47) on Sweden, implying that they have disparities in energy supply security and policy preferences. On the other hand, Belgium and the Netherlands have strong ties regarding trade and trade. Our results demonstrate that inflation spillover dynamics are significantly impacted by geopolitical risks, economic connections, and energy dependency. These findings are consistent with studies in the existing literature emphasizing the heterogeneous nature of inflation dynamics (e.g., Diebold and Yılmaz, 2014; Antonakakis et al., 2018).

Table 3. Averaged Connectedness Table

	AUS	BEL	DEU	DNK	ESP	FIN	FRA	ITA	NLD	NOR	SWE	SWZ	From
AUS	21.21 (0.00)	8.55 (2.28)	14.68 (10.54)	6.03 (-0.25)	5.62 (1.71)	8.09 (2.96)	9.65 (6.01)	2.65 (-1.26)	4.31 (-1.09)	4.34 (-2.08)	6.25 (3.02)	8.62 (4.44)	78.79
BEL	6.27 (-2.28)	21.58 (0.00)	10.55 (1.42)	9.58 (4.73)	4.8 (0.65)	6.4 (-0.09)	14.89 (7.10)	2.78 (-2.55)	3.5 (-1.09)	4.14 (0.23)	5.61 (1.43)	9.91 (2.39)	78.42
DEU	4.13 (-10.54)	9.13 (-1.42)	29.95 (0.00)	4.26 (-2.88)	4.31 (-5.83)	6.39 (-5.36)	8.14 (-1.58)	2.88 (-9.22)	3.78 (-7.08)	4.93 (-0.10)	8.81 (0.72)	13.29 (4.53)	70.05
DNK	6.29 (0.25)	4.85 (-4.73)	7.15 (2.88)	35.77 (0.00)	7.08 (-8.11)	3.01 (-13.16)	7.49 (-10.32)	7.29 (-10.78)	5.32 (-1.37)	2.43 (-12.47)	5.4 (-4.06)	7.93 (2.72)	64.23
ESP	3.9 (-1.71)	4.14 (-0.65)	10.14 (5.83)	15.19 (8.11)	20.4 (0.00)	4.02 (-1.18)	8.46 (1.71)	11.23 (4.08)	4.35 (0.70)	3.8 (-0.91)	9.77 (4.12)	4.61 (-0.42)	79.6
FIN	5.12 (-2.96)	6.49 (0.09)	11.76 (5.36)	16.18 (13.16)	5.2 (1.18)	22.65 (0.00)	6.42 (2.14)	4.18 (0.36)	3.15 (-4.61)	3.81 (0.52)	5.17 (0.89)	9.86 (3.35)	77.35
FRA	3.63 (-6.01)	7.79 (-7.10)	9.73 (1.58)	17.82 (10.32)	6.74 (-1.71)	4.28 (-2.14)	19.93 (0.00)	6.67 (-6.91)	5.54 (-2.64)	3.39 (-4.14)	8.89 (1.01)	5.6 (0.42)	80.07
ITA	3.91 (1.26)	5.33 (2.55)	12.1 (9.22)	18.07 (10.78)	7.15 (-4.08)	3.82 (-0.36)	13.58 (6.91)	12.71 (0.00)	3.46 (-0.26)	5.66 (1.00)	9.19 (1.40)	5.02 (1.63)	87.29
NLD	5.4 (1.09)	9.1 (1.09)	10.87 (7.08)	6.7 (1.37)	5.05 (0.70)	7.77 (4.61)	8.19 (2.64)	3.73 (0.26)	26.34 (0.00)	6.16 (1.90)	4.96 (2.31)	5.75 (1.40)	73.66
NOR	6.42 (2.08)	3.91 (-0.23)	5.03 (0.10)	14.91 (12.47)	4.71 (0.91)	3.29 (-0.52)	7.54 (4.14)	4.66 (-1.00)	4.25 (-1.90)	33.28 (0.00)	6.99 (2.09)	5.01 (1.46)	66.72
SWE	3.23 (-3.02)	4.17 (-1.43)	8.09 (-0.72)	9.46 (4.06)	5.64 (-4.12)	6.06 (0.89)	7.88 (-1.01)	7.79 (-1.40)	2.83 (-2.31)	4.9 (-2.09)	33.38 (0.00)	6.55 (-2.45)	66.62
SWZ	4.17 (-4.44)	7.52 (-2.39)	8.75 (-4.53)	5.2 (-2.72)	5.04 (0.42)	6.51 (-3.35)	5.12 (-0.42)	3.39 (-1.63)	2.57 (-3.18)	6.47 (1.46)	9.01 (2.45)	36.26 (0.00)	63.74
TO	52.47	70.97	108.85	123.41	61.33	59.63	97.36	57.23	43.05	50.03	80.05	82.15	886.53
Inc.own	73.69	92.55	138.79	159.18	81.73	82.28	117.28	69.94	69.39	83.31	113.44	118.41	TCI
NET	-26.31	-7.45	38.79	59.18	-18.27	-17.72	17.28	-30.06	-30.61	-16.69	13.44	18.41	73.88
NPT	4	4	9	8	6	3	7	3	2	5	9	8	

In addition, the study also graphically visualizes the Net Pairwise Directional Connectedness between countries. This network graph (Figure 4) reveals the directions of economic connectivity and influences between countries. Blue nodes (e.g., Denmark (DNK), Germany (DEU), Sweden (SWE)) represent the central countries of the network, while yellow nodes (e.g., Italy (ITA), Netherlands (NLD), Austria (AUS)) represent the peripheral countries. Central countries have stronger connections and play an influencing (transmitter) role, while peripheral countries are generally the receivers.

Denmark and Germany, as the central actors of the network, exert extensive economic influences. Denmark particularly influences Sweden, Norway, and the Netherlands, while Germany has strong ties to France and Belgium. The thickness of the lines reflects the intensity of influences between countries. In contrast, peripheral countries such as Austria and Switzerland have more limited connections. The graph clearly shows the core-periphery dynamics in the economic system and the roles of countries in economic relations.

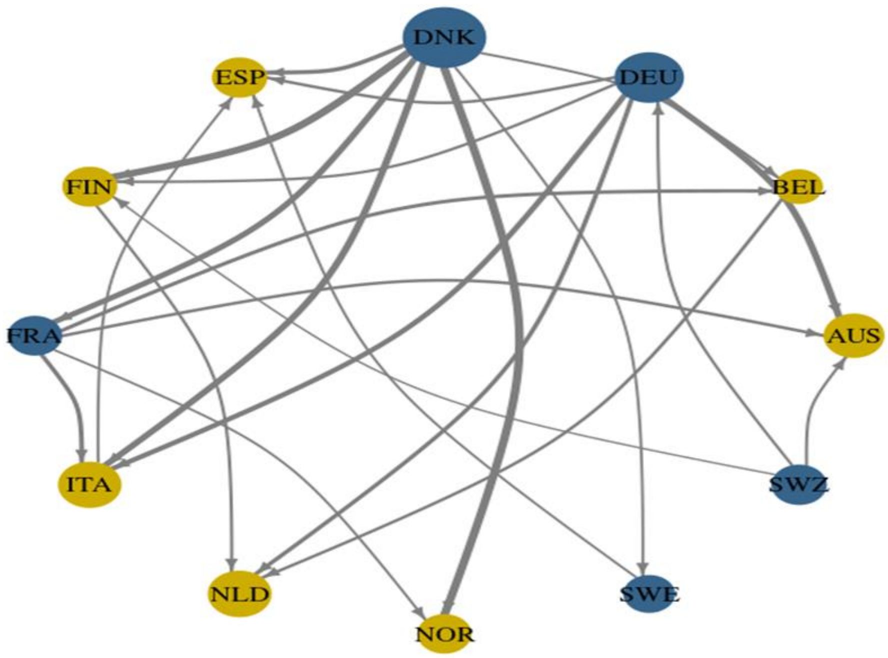


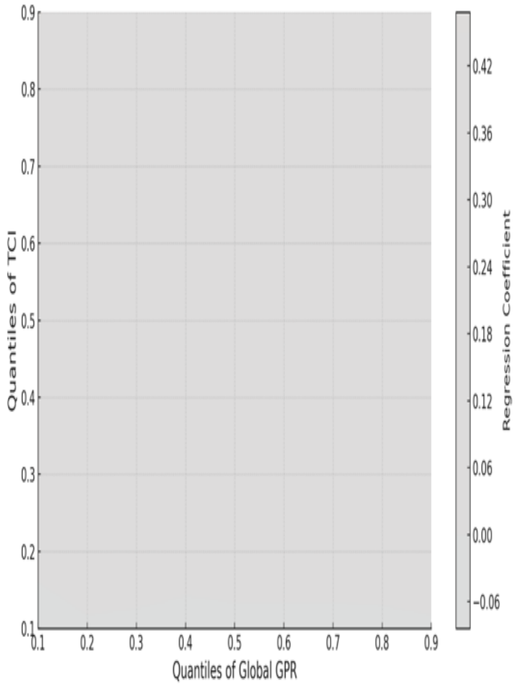
Figure 4. Net Pairwise Directional Connectedness

5.3. Result of Quantile-on-Quantile Method

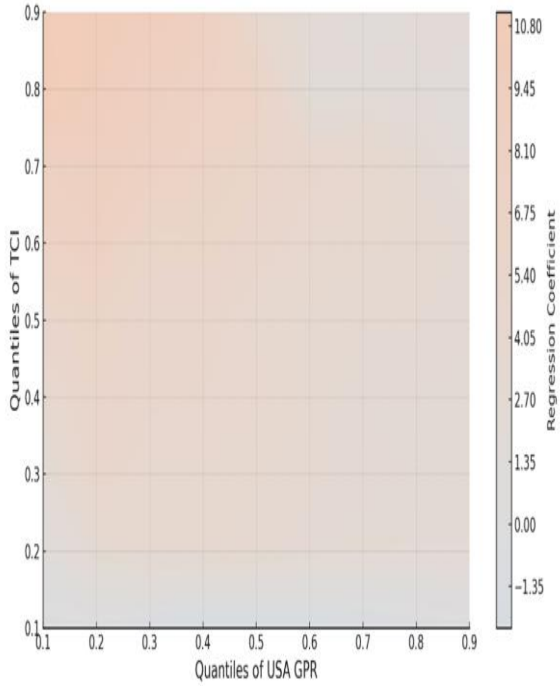
This section outlines the main empirical findings of the QoQ analysis examining the interaction between the TCI and GPR across four groups: global, U.S., Russian, and Euro-area GPRs. The analysis explores how different quantiles of TCI respond to the corresponding quantiles of GPR, with the slope coefficient, $\beta_1(\theta, \tau)$, capturing the effect of the τ-th quantile of GPR on the θ-th quantile of TCI.

To account for the delayed effects of GPR on TCI, lagged values of GPR were included in the analysis, determined by Schwarz lag selection criteria. Furthermore, since the coefficient ranges of the GPR indices differ significantly across groups, the heatmap visualization focuses on the Euro area GPR, which exhibits the highest coefficients in the QQ interaction with TCI. This allows for a clearer interpretation of the most pronounced relationships between geopolitical risks and connectedness. Figures 5 illustrate several key findings from the analysis. The results demonstrate that the relationship between TCI and GPR varies significantly across different groups, including global, U.S., Russian, and Euro-area GPRs.

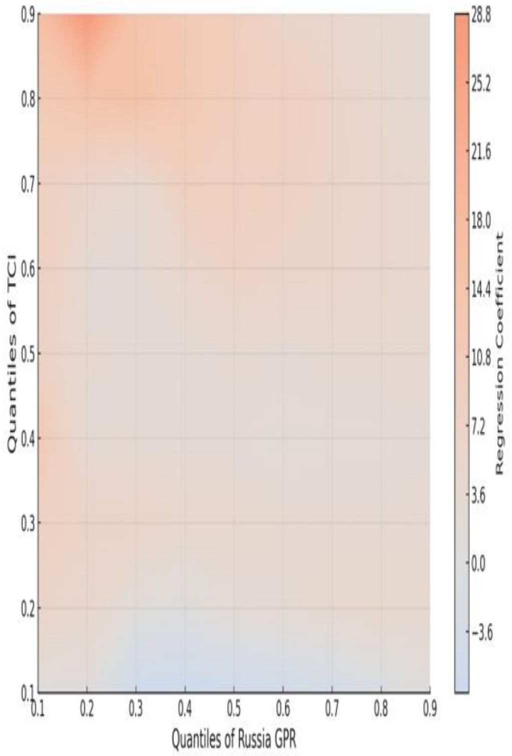
a) Impact of Global GPR on TCI



b) Impact of USA GPR on TCI



c) Impact of Russia GPR on TCI



d) Impact of Europe GPR on TCI

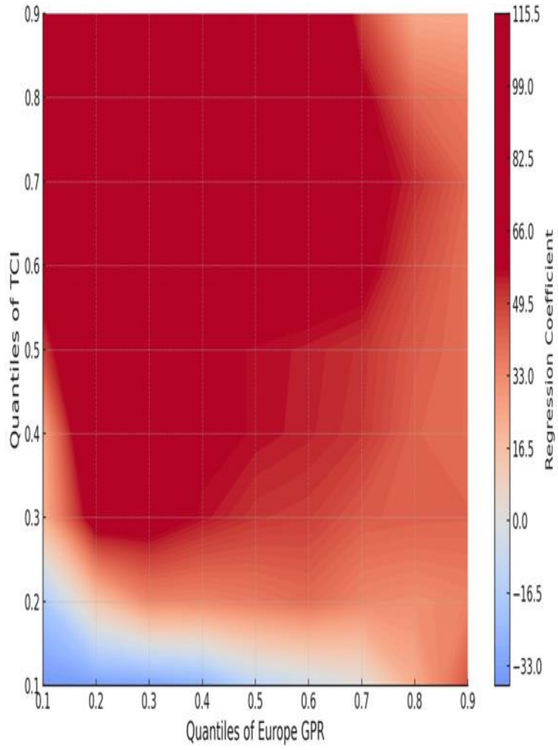


Figure 5. Quantile-on-Quantile Analysis: TCI vs. Geopolitical Risks (Russia, USA, Global, Euro)

At high quantiles, the results indicate that geopolitical risks significantly amplify the interconnectedness among economies, implying that implementing proactive measures is important, as these risks can exacerbate inflation spillover effects. For example, during the Russia-Ukraine conflict, energy price volatility had a disproportionate impact on inflation dynamics in European economies.

In global GPR, the effect on TCI is almost negligible. The dominance of gray tones in the graph indicates that global risks do not exhibit a significant relationship with TCI. This result suggests that the effect of global risks is diluted and that analyses conducted at the regional level may be more explanatory. These results are consistent with Chatziantoniou and Gabauer (2021), who found the influence of global GPR on market interconnectedness, particularly on TCI, is less significant globally but more pronounced regionally.

In the US, the relationship between geopolitical risks and TCI is generally observed to be positive in low and medium quantiles (light orange tones). However, these effects generally exhibit a weaker intensity. In high quantiles, this positive effect is seen to be slightly more pronounced. However, a strong relationship does not emerge as in Europe. This finding supports the results of Eldor and Melnick's (2004) results, implying that political events have a weaker direct impact on stable markets than major geopolitical shocks.

The impact of Russian GPR on TCI is relatively weak but still positive in Russia compared to Europe. The effect is weakly positive at lower and medium quantiles (0.2-0.7). Besides, at higher quantiles, the impacts do not increase. Yet, Russian GPR is comparatively stronger than the US and Global GPR in terms of TCI, highlighting the pivotal energy role of Russia and regional risks (Ahmed et al., 2022; Foglia et al., 2023).

Geopolitical risks have varying effects with quantiles on TCI in Europe. European GPR is negative (blue areas) at low quantiles (0.1-0.3). In addition, it is relatively strong (dark red areas) at medium and high quantiles (0.5-0.9). Hence, we conclude that economic interconnectedness is weaker during periods of low geopolitical risk in Europe. As geopolitical risks increase, economic systems become more tightly connected and markets more integrated. Particularly at the highest quantiles (0.7-0.9), the impact of GPR is significant, suggesting that in high-risk environments, the European economy becomes more interconnected, and risk management mechanisms are more actively implemented. The varying effects of Eurozone GPR, with negative impacts at lower quantiles and strong positive impacts at higher quantiles, support findings on Europe's interconnected financial and energy markets. Dai et al. (2022) and Chatziantoniou and Gabauer (2021) show that increased geopolitical risks might cause strict economic connections and active risk management strategies within the Eurozone.

6. Policy Implications and Conclusion

This study analyzes how the inflation spillover in Europe is affected by GPR using the Connectedness model and QoQ methods. The results show that despite the limited impact of the Global and the US GPR index, Russia and Europe's indices have a significant effect on the TCI. Particularly, as Russia has a central role in energy markets, its GPR index is prominent and has a powerful regional influence. The dependence on the Russian energy supply makes the effect more pronounced, especially in energy-importing European countries. There is a strong correlation between Russia's GPR and inflation at higher percentiles, implying that economic systems in these regions are more sensitive to energy supply shocks and that geopolitical risks can significantly shape inflation dynamics. Hence, energy price volatility is likely to exert pressure on inflation through spillover effects on production costs and consumer prices. Therefore, Russia's geopolitical risks vary on regional risk exposure and the fragility of energy supply chains. In brief, QoQ analysis suggests that effects are heterogeneous on average and at different quantile levels. That is the magnitude and direction of geopolitical shocks on inflation spillovers differ depending on the circumstances.

In line with Foglia et al. (2023), the findings show that the Global and US geopolitical risks have a weak effect on regional spillovers. In addition, the study shows that Russia, being a prominent energy supplier, has a significant influence on inflation spillovers in Europe. This finding is supported by the works of Ahmed et al. (2022) and Stern (2014), who suggest that energy-importing countries are vulnerable to supply shocks. Moreover, as Dai et al. (2022) underpin that high energy prices lead to higher production costs and consumer price pressures in times of high geopolitical risk and tensions, this paper has similar findings in quantile-specific sensitivity to geopolitical risks. Consistent with López and Papell (2012) and Dai et al. (2022), who suggest energy security and infrastructural investment requirements diminish economic fragility, diversifying energy sources, and investing in renewable energy sources are essential for the European economy.

These findings highlight the importance of policies to diversify energy supply. Renewable energy investments and infrastructure development projects that will increase energy supply security in Europe can reduce inflationary pressures caused by geopolitical risks. In addition, integrating a framework that evaluates the impact of geopolitical risks into monetary policies can create an economic structure that is more resilient to the spread of inflation. Strengthening regional cooperation and crisis management mechanisms can also contribute to maintaining economic stability in high-risk environments.

Central banks might regularly overview inflation targeting strategies and might use dynamic models. Therefore, they would be able to anticipate energy price fluctuations and geopolitical shocks. Moreover, central banks might adopt flexible interest rate policies to overcome energy-driven inflationary pressures. In addition, central banks should organize foreign exchange reserves to diversify the currencies used for energy imports.

Regarding energy policies, policymakers might invest in renewable energy and energy diversification projects to reduce dependence on Russia for energy supply. In the longer term, European economies should establish common reserve systems and promote economic diversification in non-energy sectors to enhance energy security.

Declaration of Research and Publication Ethics
This study which does not require ethics committee approval and/or legal/specific permission complies with the research and publication ethics.

Researcher's Contribution Rate Statement
I am a single author of this paper. My contribution is 100%.

Declaration of Researcher's Conflict of Interest
There is no potential conflicts of interest in this study.

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