Energy Price Shocks and Food Price Dynamics during Geopolitical Crises in the European Union

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Abstract: This study aims to identify the principal determinants of food price fluctuations and to explore the relationship between food and energy price fluctuations during periods marked by geopolitical instability. The research implements the analysis of 27 European Union states, in particular EU–14 (developed, high-income, advanced economies), EU-13 (less developed, emerging economies), over the time from 1995 to 2021. Using the panel data, the study investigates the influence of geopolitical risk and energy market uncertainty on food price dynamics. Empirical findings indicate a significant positive relationship between energy prices and food prices. Changes in gas prices lead to larger changes in food prices because of its central role in various stages of the food supply chain, including production, processing, and distribution. Gas prices are higher in the EU–13 countries than in the EU–14 countries. An increase in gas prices leads to a larger price increase in less developed EU–13 countries than in developed EU–14 countries. Furthermore, the analysis distinguishes between the effects of geopolitical threats and those of geopolitical acts. Geopolitical threats and events have a greater impact on food prices in the EU–13 than in the EU–14, although these factors are significant for both groups. The results reveal that perceived threats, which elevate uncertainty and provoke anticipatory market behavior, exert a stronger and more enduring influence on food price volatility than the geopolitical acts themselves. This finding underscores the critical role of market expectations and risk perception in shaping food price trajectories.

Keywords: agricultural markets, geopolitical crises; energy uncertainty; food prices; food security

1 Introduction

Energy constitutes a critical input in food production, processing, transportation, and distribution. Consequently, fluctuations in energy prices often spill over into food price dynamics, amplifying volatility and shaping both market outcomes and socio-economic

G. Szabó-Szentgróti et al. (eds.), *Proceedings of the Kautz Conference on Business and Economics 2025 (KCBE 2025)*, Advances in Economics, Business and Management Research 381,
https://doi.org/10.2991/978-94-6239-658-6_17

stability. This relationship has gained renewed attention in the context of recent geopolitical crises that have disrupted global commodity markets and exposed the vulnerabilities of the European Union. The interplay between energy price shocks and food price inflation represents not only a pressing economic issue but also a challenge with profound political and social consequences. The EU is particularly sensitive to these developments due to its structural dependence on energy imports, the significance of agriculture and food security in its policy agenda, and its role as a global trading bloc. Energy shocks triggered by supply disruptions, sanctions, shifts in global demand, etc. tend to cascade through agricultural value chains, altering production costs and retail prices. Surges in oil and natural gas prices increase fertilizer costs, raise the expenses of mechanized farming, and elevate transportation outlays. These cost pressures are ultimately transmitted to consumers in the form of higher food prices. Beyond the direct input cost channel, energy price volatility also affects food markets through speculative behavior, policy responses such as export restrictions, and shifts in trade patterns.

Historically, the link between energy and food prices has been well documented, with oil shocks in the 1970s providing early evidence of the strong pass-through effect from energy to agricultural commodities. More recently, the food price crises of 2007–2008 and 2010–2011 highlighted the susceptibility of global food systems to energy price fluctuations, exacerbated by biofuel policies and financialization of commodity markets. However, the current geopolitical context and the war in Ukraine present a qualitatively different scenario for the EU. Russia has been a key supplier of natural gas, oil, and fertilizers to European economies, while Ukraine has played an essential role in global grain markets. The disruption of these flows has generated unprecedented challenges for energy security, food supply chains, and price stability across the continent.

The cascading effects of these shocks are not confined to economic variables alone. Rising food prices have direct consequences for living standards, particularly among vulnerable households that allocate a larger share of their income to essential goods. In the EU, food inflation has already triggered political debates over subsidies, price controls, and fiscal interventions. At the same time, the persistence of energy-related cost shocks raises concerns about the long-term competitiveness of European agriculture and food industries. Thus, the issue transcends short-term inflationary pressures, touching upon broader questions of sustainability, social cohesion, and policy resilience.

The dynamics of energy-food linkages during crises can be explained through cost-push inflation models, supply chain transmission mechanisms, and market expectations. Energy shocks act as external disturbances that propagate through the production network, affecting both intermediate and final goods. The magnitude and speed of transmission, however, vary depending on market structures, policy frameworks, and the availability of substitutes. In the EU context, differences in energy dependency, agricultural specialization, and trade integration across member states imply heterogeneous impacts of energy shocks on food prices. Understanding these variations is crucial for designing effective policy responses that balance market stabilization with the protection of consumers.

2 Literature Review

We conducted the bibliometric study aimed at identifying the relationship between: geopolitical risks and food prices; geopolitical risks and energy prices; energy prices and food prices. For this purpose, we processed the above queries in the Scopus and Web of Science databases for the period 2006-2024. In the Scopus database for this period, there are only 40 documents on the "Geopolitical risks and food prices" request, and 42 documents in Web of Science. Co-occurrence network for 2006-2024 is presented in Figure 1, where we can see the most frequently occurring keywords in publications during this period.

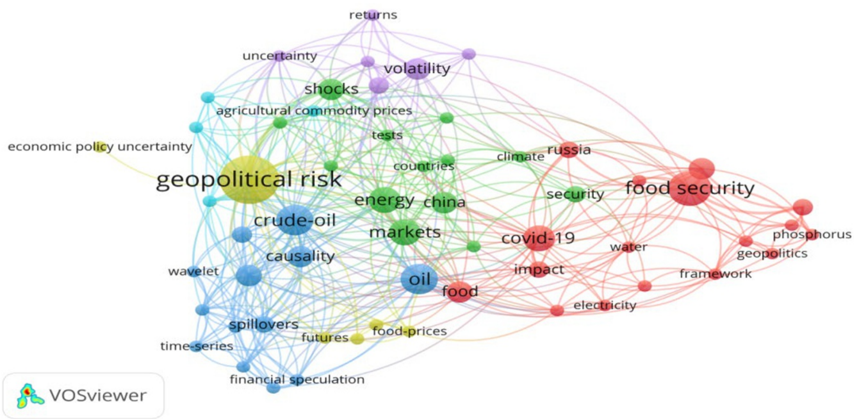

Fig. 1. Co-occurrence network of the "Geopolitical risks and food prices" request for the period 2006–2024.

Source: own processing based on Web of Science database

"Geopolitical risk", in turn, is associated with "Food prices" (see yellow in Figure 1), which confirms the relevance of our research on the impact of geopolitical risks on food prices.

On the "Geopolitical risks and energy prices" request we found 217 documents in Scopus in 2006–2024 and 297 documents in Web of Science database.
We divided the data into three periods (2006–2012, 2013–2019, 2020–2024) and used keyword density maps and co-occurrence network (Figures 2, 3, and 4, respectively) in order to identify which topics are most relevant at the moment and how the dynamics of keywords changed during the periods.

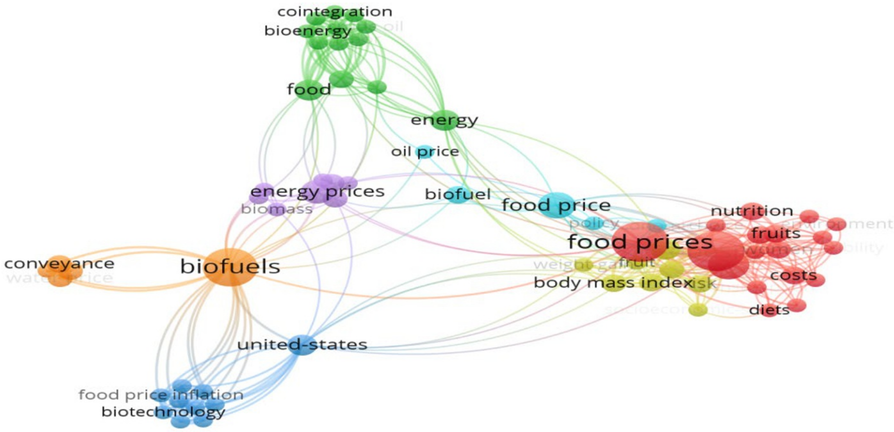

Fig. 2. Co-occurrence network of the "Food prices and energy prices" request for the period 2006–2012.

Source: own processing based on Web of Science database (943 documents)

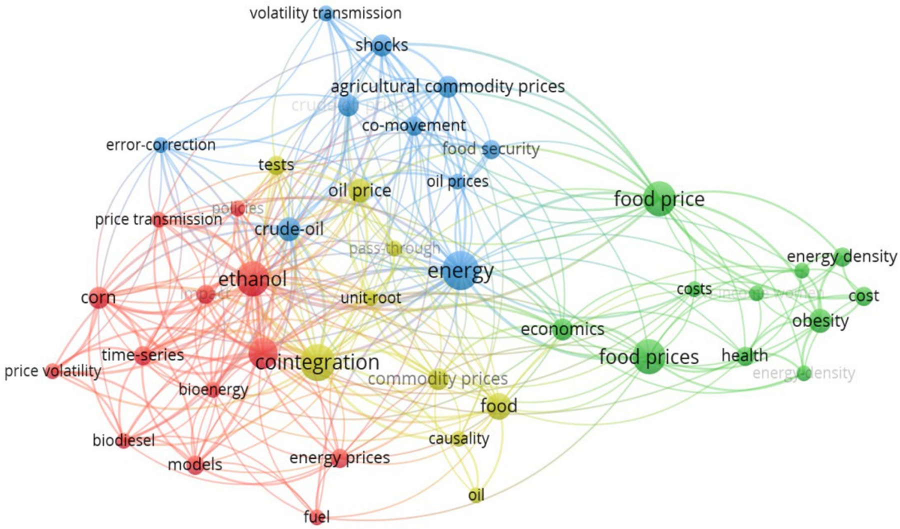

Fig. 3. Co-occurrence network of the "Food prices and energy prices" request for the period 2013–2019.

Source: own processing based on Web of Science database (1897 documents)

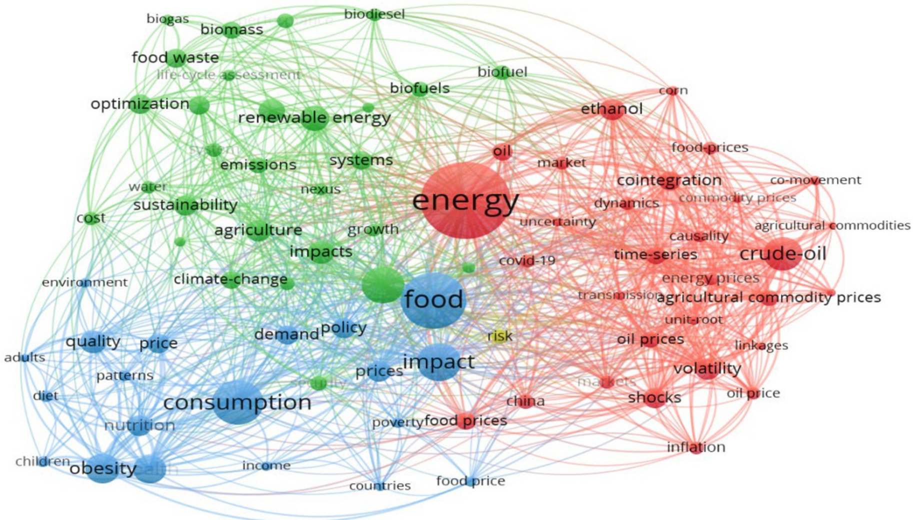

Fig. 4. Co-occurrence network of the "Food prices and energy prices" request for the period 2020–2024.

Source: own processing based on Web of Science database (1688 documents)

The results show that there have been significant changes in the dominant research topics between those three time periods. In 2020–2024, scientists link energy and food prices with consumption (Figure 4). Also in recent years, there has been a greater analysis of the interaction between various clusters, that is, topics related to "Food prices" are not considered separately, but in close connection with energy, especially with renewable energy sources, that confirms the relevance of interdisciplinary research.

Next, we will consider in more detail what exactly scientists have found out about the mutual influence of food and energy prices and their connection with geopolitical risks. Mei et al. (2020) show within a MIDAS framework that GPR uncertainty consistently raises short-term oil futures volatility and improves one-day-ahead volatility forecasts. Their results highlight that the categorical GPR action index (GPA) offers stronger long-horizon predictive content than the GPR threat index (GPT), underscoring the importance of distinguishing between different forms of geopolitical tensions when modelling oil volatility. Extending the focus beyond oil to broader energy markets, Lau et al. (2023) analyze short-, medium-, and long-run dependence structures among carbon emissions, crude oil, natural gas, and geopolitical risks across BRICS economies using the volatility spillover approach of Diebold-Yilmaz. The authors find that the link between GPR and oil prices is both time-varying and frequency-dependent, with Russia and China exhibiting the strongest GPR levels and spillover effects. Their results show that positive and significant dependence between GPR and oil prices persists across multiple quantiles and periods. Taken together, these studies demonstrate that geopolitical risk materially shapes oil and energy market dynamics through both volatility and dependence mechanisms.

Radmehr & Rastegari Henneberry (2020) examine the impacts (short- and long-term) of exchange rate and energy prices on food prices in Iran using such variables as prices of ten food products, exchange rate (the value of Iranian rial per US dollar), and petroleum prices. The authors used log-log regression:

$$ln\ ln\ FP_{it} = \beta_{0i} + \beta_{1i}\ ln\ ln\ EP_t + \beta_{2i}\ ln\ ln\ EX_t + \varepsilon_{it},$$

where the subscripts $i = 1, 2, \ldots, 10$, are for ten food products, $t = 1,2,\ldots,T$, are for months March 1995 to February 2018; *FP* is the food prices; *EP* represents the energy prices, and *EX* depicts the exchange rate (the value of Iranian rial per USD).

Research examining energy–food price linkages consistently shows that oil and energy markets play a central role in shaping global food dynamics. Nazlioglu and Soytas (2012) find that world oil prices significantly affect a wide range of agricultural commodities, even after accounting for US dollar fluctuations, while Gardebroek and Hernandez (2013) demonstrate that volatility transmission across oil, ethanol, and corn markets has intensified since ethanol became a major gasoline additive, though spillovers remain largely unidirectional from corn to ethanol. Complementing these results, Shaari et al. (2012) and Gohin and Chantret (2010) highlight both the direct cost-channel effects of energy prices on food production and transportation and the longer-term structural linkages between energy and food markets. More recent studies have introduced frequency and regime-sensitive approaches to better capture these complex interactions. Using advanced causality methods, Kirikkaleli and Darbaz (2021) uncover bidirectional causal relationships between energy and multiple food price indices across different frequency bands.

Similarly, Al-Maadid et al. (2017) show that food–energy linkages and volatility spillovers vary substantially across major global events, including the 2006 food crisis and the 2008 financial crisis, emphasizing the importance of accounting for structural breaks. Extending the analysis to broader uncertainty and political tensions, Yousfi and Bouzgarrou (2024) document strong connectedness among clean energy, conventional energy, and food markets, with dependence patterns shifting across crises and conflict periods. Growing attention has also been directed toward geopolitical dynamics. Sun and Su (2024) reveal time-varying bidirectional causality between geopolitical risk (GPR) and food prices, with high GPR generally raising food prices but sometimes generating negative effects due to broader macroeconomic interactions. Their results also show that food prices themselves exert influence on GPR levels, suggesting that food markets can serve as indicators of the geopolitical environment.

Mawejje (2016) assesses the impact of energy and climate shocks on food price dynamics in Uganda. The results indicate a long-run cointegrating relationship between energy prices and food prices. Moreover, temperature shocks are found to have a more pronounced effect on food price variability than rainfall shocks. The study employs a single-equation food price model incorporating lagged vector error correction terms from external (traded) and domestic (non-traded) food markets, the energy market, lagged climate anomalies, and monthly seasonal dummies. Short-run dynamics are captured by including all relevant variables up to the 12th lag.

The single equation error correction food price model, therefore, is:

$$\Delta p_t^f = \beta_0 + \sum_{j=1}^{12} \beta_{1j} \Delta p_{t-j}^f + \sum_{j=1}^{12} \beta_{2j}^i \Delta x_t + \sum_{j=1}^{2} \beta_{3j} C_{t-1}^j + \sum_{j=1}^{11} \theta_j d_t + \alpha_1 E_{t-1}^e + +\alpha_2 E_{t-1}^d + \alpha_3 E_{t-1}^f + \varepsilon_t,$$

where Δ is the difference operator, p_t^f is the food price index, C_{t-1}^j are lagged climate variables (rainfall and temperature anomalies), x_t is a vector of control variables included in the model, d_t is a vector of dummy variables, E_{t-1}^e; E_{t-1}^d; and E_{t-1}^f are error correction terms from the external food market, domestic food market and energy markets respectively, included in their lagged forms. β_{1j}; β_{2j}^i; and β_{3j}, are short run parameters to be estimated; θ_j are dummy variable coefficients, and α_1, α_2 and α_3 are adjustment parameters.

Taghizadeh-Hesary (2019) examines the linkages between energy price and food prices over the period 2000-2016 by using a Panel-VAR model in the case of eight Asian economies. Their results confirm that energy price (oil price) has a significant impact on food prices. According to the results of impulse response functions, agricultural food prices respond positively to any shock from oil prices.

The authors estimate the effects of oil price fluctuations and other factors on agricultural commodities prices using such empirical econometric model:

$$Agrifood_{it} = \beta_0 + \beta_1 Agriland_{it} + \beta_2 oilp_t + \beta_3 interest_{it} + \beta_4 inf_{it} + \beta_5 Agriem_{it} + \beta_6 GDP_{it} + \beta_7 biofuel_{it} + \beta_8 EX_{it} + \varepsilon_t$$

There *Agrifood* indicates agriculture food price; *Agriland is* agriculture land; *oilp* is global oil price; *interest* represents real interest rate; *inf* is general price inflation rate; *Agriem* denotes employment in agriculture sector, *GDP* and *biofuel* are gross domestic product and biofuel prices. EX_{it} indicates official exchange rate of country *i* at time *t.*

Using a panel-VAR approach for Asian economies, studies show that oil price fluctuations adversely affect food security, emphasizing the need to diversify energy consumption toward an optimal mix of renewable and nonrenewable sources. Biofuel prices, while accounting for less than 2% of food price variance, can amplify global agricultural price pressures, posing risks for vulnerable economies. Beyond energy price effects, consumer responses also shape food security outcomes. Grunert et al. (2023) identify distinct consumer clusters reacting to crises, with heightened price-consciousness and mindfulness in food choices emerging after COVID-19, trends that may support a green transition but introduce new challenges for stakeholders. Jagtap et al. (2022) identified six critical areas within the food supply chain vulnerable to disruption due to ongoing conflict: production, processing and storage, transport logistics, market/retail operations, consumers, food-dependent services, and product quality. Europe and Africa are expected to experience the severest impacts, prompting recommendations to seek alternative supply partners in less-affected regions like North and South America, the Middle East, Australasia, and parts of Asia and Africa. Following the March 2022 conflict outbreak, global food prices rose sharply, maize prices increased by 14.66%, soybean prices by 8.91%, and wheat prices by 24.53%, threatening countries dependent on Russian and Ukrainian imports, particularly Least Developed Countries and Low-Income Food-Deficit Countries, and jeopardizing progress toward zero hunger. The FAO (2023) estimated that an additional 8 to 13 million people could become undernourished globally in 2022–2023, potentially triggering worsening health, poverty, inequality, slower economic growth, and setbacks in achieving the SDGs (Nasir et al., 2022). Taken together, these studies illustrate that food security is influenced not only by energy and biofuel prices but also by geopolitical situation, consumer behavior and supply chain disruptions. However, existing work often examines these factors separately, leaving a gap in understanding how energy volatility, consumer responses, and geopolitical shocks jointly impact food security, particularly in regions highly exposed to external supply and price shocks.

Rahayu et al. (2023) determine factors affecting household consumption of carbohydrate sources were analyzed using the Linear Approximation Almost Ideal Demand System (LA-AIDS) model.

The general formulation of the AIDS equation model is as follows:

$$w_i = \alpha_i + \beta_i \, log \, log \, y \,,$$

where w_i is the share of the i-th commodity expenditure, and y is the income (expenditure). The AIDS demand model is built on a specifically defined cost or expenditure function to represent the structure of individual preferences.

The preference function (c) as a function of the utility u and the value of p is defined in the following logarithmic form:

$$ln\, ln\, c\,(u,p)\ = (1-u)\ ln\, ln\, a(p) +\ u\, ln\, ln\, b(p)\ ,$$

where c is the total expenditure, u is the utility; and p is the price.

García-Germán et al. (2016) determine consumer food prices in country i and period t as follows:

$$cp_{it} = f(wp_t, e_{it}, u_{it}, o_t, w_{it}, g_{it}),$$

where cp is consumer food prices, wp is the price transmission from world agricultural commodity prices, e is exchange rates, u is unemployment rate, o is a world crude oil price index, w are wages, g is economic growth.

Such popularity of food prices changes and food security research is explained by the fact that this issue has a high practical focus, and concerns not only scientists but also authorities and ordinary citizens. Therefore, the problems of identifying key factors that influence food prices and determination of energy prices changes influence on food prices and studying changes in consumer behavior as a result of price changes during crisis periods is extremely relevant.

3 Methodology and Data

The study is structured around testing and confirmation the central empirical hypotheses:

Hypothesis 1. Increases in oil and gas prices result in corresponding increases in food prices.

Hypothesis 2. Gas prices are more significant for less developed EU–13 countries than for developed EU–14 countries. An increase in gas prices leads to a larger price increase in less developed EU–13 countries than in developed EU–14 countries.

Hypothesis 3. Geopolitical threats exert a stronger influence on food prices than direct geopolitical actions.

Hypothesis 4. Geopolitical threats and acts have a greater impact on food prices for the EU–13 than for the EU–14.

The analysis covers 27 European Union member states over the period 1995–2021. To add novelty to our research, we conducted a comparative analysis of the influence of factors on food prices in developed EU–14 countries and in developing EU–13 countries. The focus on EU countries is motivated by their high degree of integration into global supply chains for both food and energy. The EU is strongly dependent on imports of grains, fertilizers, and energy resources from regions characterized by elevated geopolitical risks, particularly the Black Sea area. Interruptions in these supply chains, stemming from armed conflicts, sanctions, or political instability, translate directly into constraints on food supply and consequent price volatility within the EU. Moreover, the EU's structural dependence on imported oil and gas, predominantly from geopolitically unstable regions, together with the energy-intensive nature of agricultural and food production, heightens the region's exposure to fluctuations in global energy markets. This interdependence amplifies the transmission of geopolitical risks to food price dynamics, making the EU a particularly suitable case for investigation. The selected period ensures the availability of harmonized, high-quality, and comparable datasets across member states, thereby facilitating robust econometric modeling. Descriptive statistics of the variables used in the analysis are provided in Table 1. The data sources were FAO, World Bank, Energy-Related Uncertainty Indexes, Geopolitical Risk Index, U.S. Bureau of Labor Statistics.

Table 1. Descriptive characteristics of the indicators for EU countries.

Characteristic	Prfood	Pfood	Qfood	GPRT	GPRA	Poil	Pgas	EUI
Min.	348.9	22.70	384	53.18	45.43	13.13	1.807	13.37
1st Qu.	2857.2	64.75	3813	80.70	65.44	25.12	3.178	18.20
Median	10557.2	85.60	12624	90.64	84.51	54.68	5.744	21.70
Mean	26295.4	83.48	28965	95.03	98.86	55.58	6.481	22.62
3rd Qu.	23174.8	100.35	24664	108.32	110.71	72.65	8.855	26.42
Max.	200509.5	149.16	185512	167.53	251.95	112.01	15.907	37.23

Source: own processing.

Prfood is food and non-alcoholic beverages (in current prices, million euro); *Pfood* is the percentage change in price in each year compared to the base year 2015; *Qfood* is food and non-alcoholic beverages quantity (food consumption), in million euro; *Poil* and *Pgas* are oil and gas prices respectively; *EUI* – energy-related uncertainty indexes; *GPRT* – geopolitical threats; *GPRA* – geopolitical acts.

The variables GPRT and GPRA were derived from the Geopolitical Risk Index (GPR), which is subdivided into eight categories (Geopolitical Risk Index, 2024). Elevated GPR values reflect an increased intensity of adverse geopolitical events, a higher likelihood of future negative developments, and greater expected severity of such events. Geopolitical acts typically produce observable consequences, such as disruptions in supply or rising production costs, whereas geopolitical threats are more strongly associated with uncertainty-driven volatility in prices.

However, aggregating both indexes into a single composite index may obscure important distinctions and diminish the explanatory power of econometric models. For instance, a terrorist attack may increase the overall GPR value without materially affecting food or energy supply chains. In contrast, a regional conflict in a major grain-exporting area may substantially raise food prices while generating only a modest rise in the aggregate GPR. Consequently, disaggregating threats and acts enables more precise identification of causal mechanisms relevant to food and energy systems.

Geopolitical acts are generally immediate in nature and exert region-specific impacts, which can propagate through international markets, for example, disruptions of Black Sea grain exports during the Russia–Ukraine conflict. By contrast, geopolitical threats often operate with a temporal lag and a broader scope, influencing markets indirectly through speculation and anticipatory adjustments. Accounting for these temporal and geographical distinctions enhances predictive accuracy. Accordingly, the separation of GPRT and GPRA within the analytical framework improves the model's capacity to differentiate between realized shocks and anticipatory market responses.

Then we examine factors influenced prices in developed EU–14 countries and less developed EU–13 countries to analyze which factors had a greater impact across country groups. The list of countries that are included in EU–14 and EU–13 is shown in Table 2.

Table 2. List of EU–14 and EU–13 countries.

Category	List of EU countries
EU–14 (developed, high-income, advanced economies)	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden
EU–13 (less developed, emerging economies)	Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovak Republic, Slovenia

Source: own processing.

In this study, EU member states are divided into two groups (EU–14 and EU–13) to account for structural heterogeneity that may influence the transmission of energy price shocks to food prices during geopolitical crises. The distinction between EU–14 and EU–13 is used in economic, financial, and policy research to capture structural differences between older, more developed EU members and newer, less developed or transition-economy members. The EU–14 countries are long-standing members with advanced institutional frameworks and high levels of economic development, whereas the EU–13 countries represent emerging or transition economies still undergoing structural and nominal convergence. EU–14 members are typically classified by international institutions such as IMF, World Bank as high-income, advanced economies, with long-established market institutions. EU–13 countries are generally upper-middle-income or emerging economies, with shorter histories of market capitalism, undergoing structural convergence toward EU–14 levels. Also, many empirical studies in economics, energy, inflation, and development use this exact classification (Alsaleh & Abdul-Rahim, 2021; Alsaleh & Abdul-Rahim, 2025; Brodny & Tutak, 2024; Borović et al., 2024). This grouping is therefore analytically meaningful, as it reflects persistent differences in economic structure, income levels, price dynamics, and market development that may influence the factors affecting prices. This distinction allows us to identify cross-group heterogeneity in price dynamics and to assess whether geopolitical crises amplify asymmetries in food price responses across different stages of economic development within the European Union. The descriptive characteristics of the indicators for EU–14 and EU–13 countries are presented in Table 3.

Table 3. Descriptive characteristics of the indicators for EU–14 and EU–13 countries.

Characteristic	EU–14 countries			EU–13 countries		
	Prfood	Pfood	Qfood	Prfood	Pfood	Qfood
Min.	793.5	48.58	1163	348.9	22.70	384
1st Qu.	12329.1	70.68	13707	1921.2	55.29	2434
Median	20287.8	86.84	21987	3714.3	83.90	5013
Mean	45967.1	86.34	50392	8018.5	80.54	9147
3rd Qu.	78612.4	100.71	84740	8566.8	100.00	9950
Max.	200509.5	134.77	185512	62560.0	149.16	59824

Source: own processing.

To assess the influence of geopolitical risks and energy uncertainty on food price dynamics, a panel data approach was used. This methodological framework allows for the incorporation of latent, unobservable heterogeneity across countries, thereby capturing country-specific effects. Furthermore, in order to mitigate the risk of omitted variable bias arising from factors that vary over time but remain constant across countries, the specification incorporates time-fixed effects.

$$Pfood = \alpha_i + \beta_1 \times GPRT_{it} + \beta_2 \times GPRA_{it} + \beta_3 \times Poil_{it} + \beta_4 \times Pgas_{it} + \beta_5 \times EUI_{it} + \varepsilon_{it} \qquad (1)$$

where: *i* denotes the countries considered (*i* = 1,…,14 and *i* = 1,…,13); *t* are the years (t = 1995,…,2021); *GPRT* – geopolitical threats; *GPRA* – geopolitical acts; *Poil* and *Pgas* – oil and gas prices respectively; *EUI* – energy-related uncertainty indexes; α_i – the specific individual effect of each country, and is included in the model to take into account any factor that could influence the geopolitical risks and energy uncertainty beyond the explanatory variables included; β – model parameters that measure the effects of a change in independent variable in the period *t* for the *i*-th country.

The main challenge in the application of panel data techniques lies in determining the appropriate model specification, namely whether to employ a pooled regression, a fixed-effects model, or a random-effects model. To address this issue, estimations were conducted under both fixed-effects and random-effects frameworks in order to identify the most suitable specification for the data. The fixed effects model treats each α_i as a constant in the regression, while the random effects model treats α_i as a component of random disturbance (Wooldrige, 2022). The presence of country-specific effects was evaluated using statistical tests appropriate to the panel data framework. For the fixed-effects specification, an F-test was employed, while the Breusch-Pagan test was applied in the case of the random-effects specification. In both instances, the null hypothesis assumes that α_i is identical across all countries. Failure to reject this hypothesis implies that a pooled regression is sufficient, and the model can be consistently estimated using ordinary least squares (OLS). Conversely, rejection of the null supports the adoption of either fixed or random effects, with the F-test and Breusch-Pagan test indicating the relative superiority of these models compared to the pooled specification. The adoption of panel data techniques in this study is further justified by several methodological advantages inherent to this approach. First, panel models allow for the explicit consideration of heterogeneity across observational units, thereby capturing unobservable country-specific characteristics that may influence food price dynamics. Second, the combined cross-sectional and temporal dimensions of panel datasets enable the construction of more complex empirical models capable of accounting for both structural differences and temporal evolution. Third, panel data facilitate the analysis of dynamic processes, making it possible to trace adjustment mechanisms over time. Fourth, the approach mitigates potential aggregation bias by retaining variation at the country level. Finally, panel data enhance the information content of the sample by increasing variability, reducing risks of multicollinearity, and expanding degrees of freedom, which in turn improves the efficiency and robustness of parameter estimation (Baltagi, 2008).

4 Results

Panel data models were estimated to empirically validate the proposed hypotheses: namely, that increases in natural gas prices exert a stronger influence on food prices than increases in oil prices, and that geopolitical uncertainty is positively associated with food price growth, with geopolitical threats exerting a greater effect than direct geopolitical actions. Statistical testing for individual and temporal effects, along with the application of the

Hausman specification test and evaluation of determination coefficients, indicated that the fixed-effects specification provides the most appropriate framework for the analysis. The final estimation results of the fixed-effects panel model, assessing the impact of geopolitical risks and energy-related uncertainty on food prices, for EU–14 countries are presented in Table 4.

Table 4. The results of the panel data model of the geopolitical risks and energy uncertainty impact on food prices for EU–14 countries.

Balanced Panel: n = 14, T = 27, N = 378					
Residuals:					
Min.	1st Qu.	Median	3rd Qu.	Max.	
-25.2605	-7.8246	-1.4642	6.6897	43.7656	
Coefficients:					
	Estimate	Std. Error	t-value	Pr(>|t|)	
GPRT	0.449698	0.033401	13.4634	< 2.2e-16	***
GPRA	0.145028	0.016713	8.6773	< 2.2e-16	***
Poil	0.260563	0.042250	6.1671	1.874e-09	***
Pgas	0.864289	0.338052	2.5567	0.01098	*
EUI	0.255624	0.143615	1.7799	0.07593	.
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1					
Total Sum of Squares: 126880					
Residual Sum of Squares: 52146					
R-Squared: 0.589					
Adj. R-Squared: 0.56839					
F-statistic: 102.896 on 5 and 359 DF, p-value: < 2.22e-16					

Source: own processing.

The final estimation results of the fixed-effects panel model, assessing the impact of geopolitical risks and energy-related uncertainty on food prices, for EU–13 countries are presented in Table 5.

Table 5. The results of the panel data model of the geopolitical risks and energy uncertainty impact on food prices for EU–13 countries.

Balanced Panel: n = 13, T = 27, N = 351					
Residuals:					
Min.	1st Qu.	Median	3rd Qu.	Max.	
-42.1897	-12.0984	-1.9047	10.4097	64.8343	
Coefficients:					
	Estimate	Std. Error	t-value	Pr(>|t|)	
GPRT	0.676753	0.050898	13.2963	< 2.2e-16	***
GPRA	0.236978	0.025468	9.3048	< 2.2e-16	***
Poil	0.407802	0.064382	6.3341	7.735e-10	***

Pgas	1.602495	0.515131	3.1108	0.002027	**
EUI	0.487903	0.218844	2.2295	0.026450	*
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1					
Total Sum of Squares: 282160					
Residual Sum of Squares: 104290					
R-Squared: 0.63037					
Adj. R-Squared: 0.6115					
F-statistic: 113.581 on 5 and 333 DF, p-value: < 2.22e-16					

Source: own processing.

The estimation results confirm that increases in both natural gas and oil prices exert upward pressure on food prices. However, the magnitude of the effect is stronger for natural gas than for oil.

Gas prices are more significant for EU–13 countries than for EU–14 countries. And an increase in gas prices will lead to a larger price increase in less developed EU–13 countries than in developed EU–14 countries. Traditionally, oil has been considered the primary driver of food price volatility, as it is refined into gasoline, diesel, and kerosene, which are critical inputs in agricultural production. Agricultural machinery such as tractors and harvesters relies predominantly on diesel, while transportation of agricultural products is heavily dependent on oil-based fuels for trucks, trains, and ships. Consequently, higher oil prices generally increase costs at multiple stages of the agri-food supply chain, including production, processing, packaging, transport, and storage. In contrast, the present findings suggest that although oil prices indirectly influence food prices through their effect on gas prices, fluctuations in natural gas prices have a more immediate and pronounced impact. This result can be explained by recent developments in the European energy market.

The volatility of gas prices, amplified by the European energy crisis and the Russia-Ukraine war, has generated asymmetric price shocks: gas prices rose faster and more sharply than oil prices. One major consequence has been the surge in fertilizer costs, which in some cases increased by a factor of two to three. As a result, many farmers reduced fertilizer use, leading to lower yields and heightened food price inflation. In addition, natural gas is essential for greenhouse heating, food storage, and other energy-intensive processes within agriculture. In economies with extensive gas utilization in the agri-food sector, such as the European Union, the transmission of gas price shocks to food prices is particularly strong and direct. The analysis also demonstrates that geopolitical threats exert a greater influence on food prices than geopolitical acts. Furthermore, the results show that geopolitical threats and geopolitical acts have a greater impact on food prices for the EU–13 than for the EU–14, although these factors are significant for both groups of countries. This finding can be attributed to several mechanisms. First, threats generate uncertainty and anticipation, prompting speculative behavior and precautionary actions among market participants. Such anticipatory dynamics often result in price increases even before actual disruptions materialize. In contrast, once a geopolitical event occurs, its immediate effects may already be incorporated into market expectations, thereby dampening subsequent price responses. Second, geopolitical threats tend to increase the risk premium embedded in food prices, as traders and producers adjust for the possibility of future supply disruptions or trade restrictions. Furthermore, perceived threats can disturb global supply chains by encouraging precautionary behaviors such as stockpiling, rerouting shipments, or implementing trade barriers, all of which contribute to higher costs and market volatility. Governments may also respond preemptively to such risks by imposing policy measures, including export restrictions, strategic stockpiling, or price interventions, which further amplify food price fluctuations. Beyond these direct channels, threats exert psychological effects on both consumers and market participants, potentially fueling speculative trading, panic buying, or hoarding, which reinforces price instability. Importantly, the consequences of geopolitical threats often persist over the long term, influencing investment decisions, trade relations, and the stability of global supply chains even after the immediate threat has receded. Differentiating between realized geopolitical acts and perceived threats thus provides a more robust analytical framework for understanding food price dynamics. While acts produce tangible and region-specific shocks requiring rapid policy responses (e.g., securing alternative supply chains or mobilizing emergency reserves), threats necessitate strategies to manage uncertainty, such as enhancing market transparency, strengthening risk management mechanisms, and fostering international cooperation. By distinguishing between these two dimensions of geopolitical risk, policymakers and researchers can better anticipate and mitigate the multifaceted impacts on global and regional food markets.

While the GPR Index is widely used as a broad measure of geopolitical tensions, it is not sector-specific and does not differentiate between shocks directly affecting European energy markets. This sectoral irrelevance may attenuate estimated coefficients if the index captures events unrelated to energy or food markets, potentially biasing results toward zero. We therefore interpret the GPR-related estimates cautiously and complement them with robustness exercises using alternative proxies. To assess whether results depend on the choice of geopolitical proxy, we re-estimate our baseline model using the Trade Policy Uncertainty (TPU) Index (Trade Policy Uncertainty, 2025) and the World Uncertainty Index (WUI). We take Daily Trade Policy Uncertainty Index and calculated the average for 1995-2021 and quarterly data for the World Uncertainty Index and calculated the average for 1995-2021. We were unable to use other indicators that could also serve as a proxy variable due to the lack of data comparability. For example, the Sustainability Uncertainty Indexes only have data for 2022-2025, while the Financial Stress Indicator only has data for 1889-2016. Also, there is no publicly available dataset for the Global Conflict Risk

Index (GCRI) which also fits under the proxy variable. The publicly accessible documentation describes model methodology and risk-score visualizations, but does not deliver a downloadable full panel for 1995-2021.

Both TPU and WUI indicators capture dimensions of geopolitical or policy-related tension that are not explicitly embedded in the GPR and therefore allow us to evaluate whether the GPR's lack of sectoral specificity biases the results. The findings remain qualitatively unchanged, indicating that the baseline results are not driven by the GPR's lack of sectoral specificity. Across both EU–14 and EU–13 samples, the estimation results obtained with TPU and WUI remain highly consistent with the baseline findings. In all specifications, energy prices retain their significant and positive impact on food price growth, with natural gas prices continuing to exert a larger and more statistically robust effect than oil prices. This confirms that the observed energy-food price linkage does not depend on the choice of geopolitical proxy.

5 Discussion

The results of this study underscore the complex relationship between food prices, geopolitical risks, and energy uncertainty. The evidence indicates that fluctuations in food prices are driven not only by traditional supply and demand factors but are also significantly influenced by global geopolitical events and energy market instability. These interdependencies carry important implications for food security, economic stability, and policy formulation. A central finding is that geopolitical risks, including armed conflicts, trade restrictions, and diplomatic tensions, etc. directly affect food prices by disrupting supply chains and altering international trade patterns. Conflicts in major agricultural regions can reduce production and increase transportation costs, amplifying food price volatility. Similarly, trade sanctions and export bans arising from geopolitical tensions can generate artificial scarcity, resulting in price surges at both domestic and international levels. Addressing these challenges requires coordinated policy responses, international cooperation, and strategic investments in sustainable agricultural and energy systems. Several important questions remain unresolved. The temporal dimension, specifically, the lag between the occurrence of a geopolitical risk and its effect on food prices, requires further investigation. In addition, the role of financial speculation in energy and food markets in amplifying price volatility is not fully understood. It also remains to be determined whether food price spikes driven by geopolitical risks and energy uncertainty are predominantly transitory or lead to structural, long-term shifts in global food markets. Moreover, the effectiveness of policy interventions in mitigating the impacts of geopolitical risks on food prices continues to be a subject of debate. Finally, the consequences of food price fluctuations for vulnerable populations warrant further study, as these outcomes involve complex interactions among economic, political, and global market factors. Future research should aim to develop predictive models that capture these dynamics more precisely, thereby enhancing the resilience of food markets to geopolitical and energy-related shocks.

6 Conclusion

We investigated the effects of geopolitical risks and energy uncertainty on food prices in 27 EU countries over 1995–2021, distinguishing between developed (EU–14) and developing (EU–13) members. Panel data analysis reveals that increases in gas and oil prices significantly raise food prices, with gas exerting a stronger effect. Although oil prices influence gas prices, their direct impact on food prices is weaker. Since gas is a crucial component of the supply chain for food production and distribution, changes in gas prices have a more immediate and direct impact on food prices compared to changes in oil prices. Changes in gas prices lead to larger changes in food prices because of its central role in various stages of the food supply chain, including production, processing, and distribution. Gas prices are more significant for EU–13 countries than for EU–14 countries. An increase in gas prices leads to a larger price increase in less developed EU–13 countries than in developed EU–14 countries.

Simulation results further show that geopolitical threats exert a greater influence on food prices than actual geopolitical actions. Geopolitical threats shape expectations and trigger speculative price shifts, producing longer-lasting effects than realized acts. These findings confirm that uncertainty and anticipation mechanisms magnify the influence of geopolitical risks on food markets. Furthermore, geopolitical threats and acts have a greater impact on food prices for the EU–13 than for the EU–14, although these factors are significant for both groups of countries.

The study highlights the importance of integrating food security, energy policy, and geopolitical risk management. The pronounced sensitivity of food prices to gas costs underscores the need for resilient supply chains, contingency measures, and support for domestic production to reduce import dependence. Policymakers can draw on these results to design strategies that stabilize food prices, mitigate energy shocks, and strengthen economic resilience.

During the research, the following limitations were identified. Firstly, the division of EU states into “developed” and “developing” groups is not officially recognized, though it revealed heterogeneous effects across country clusters. Secondly, we should be skeptical about the reliability and applicability of the “geopolitical risk index” when analyzing its impact on the price index. The index aggregates diverse events without accounting for sectoral relevance or time lags. For example, the GPR reached 500 in 2001 following the September 11 attacks, despite negligible effects on food supply chains, while during the Russia–Ukraine war it stood at 300 despite severe disruptions to agricultural trade. This mismatch demonstrates that the GPR reflects broad geopolitical tensions rather than specific food-related risks. In this regard, we conducted a robustness test with alternative proxies the Trade Policy Uncertainty Index and the World Uncertainty Index. The findings remain qualitatively unchanged, indicating that the baseline results are not driven by the GPR's lack of sectoral specificity. Future research will focus on the emergence of new energy powers, the role of renewable technologies, and their implications for food prices and consumption patterns.

Acknowledgment: The paper was funded by the EU NextGenerationEU through the Recovery and Resilience Plan for Slovakia under Project No. 09I03-03-V01-00157 and the Scientific Grant Agency of the Ministry of Education, Science, Research and Sport of Slovakia, and the Slovak Academy of Sciences within the project VEGA 1/0646/2023.

Conflict of interest: The author declares no conflict of interest.

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