Volume XVIII Number 2, 2026

International Trade in the Face of War: Agricultural Trade Relations of Ukraine and the EU Countries

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Abstract

The outbreak of war in Ukraine in 2022 significantly reshaped agricultural trade dynamics between Ukraine and the European Union (EU). The main goal of this study is to examine the factors associated with increased exports of Ukrainian agricultural products to EU countries in light of the complex situation that includes the outbreak of war, trade liberalization, and provisional trade bans. The study employs a gravity model to analyze Ukrainian imports of selected agricultural products to EU countries, using monthly data from 2020 to 2023. The Poisson Pseudo-Maximum Likelihood model with high-dimensional fixed effects is utilized. EU countries that are more geographically distant significantly increased their imports of Ukrainian agricultural products, driven by a higher market absorption capacity and robust infrastructure, challenging the traditional assumptions of gravity models. Meanwhile, Ukraine's neighboring countries played a crucial role in absorbing Ukrainian exports due to logistical advantages, regulatory support, and the suspension of tariffs. However, the main effect of trade intensification for these countries was primarily observed in the first year of the war. This study makes a novel contribution by examining the cumulative effects of distance, war, and liberalization on trade volumes, marking the first such analysis in the context of EU-Ukraine relations. The use of monthly data enables us to accurately capture short-term changes in trade, both before and after the onset of the war, offering new insights into how crises reshape trade patterns.

Keywords

Gravity model, international trade, war, agriculture, Ukraine.

Łukasiewicz, J., Bajan, B. and Pawlak, K. (2026) "International Trade in the Face of War: Agricultural Trade Relations of Ukraine and the EU Countries", *AGRIS on-line Papers in Economics and Informatics*, Vol. 18, No. 2, pp. 71-86. ISSN 1804-1930. DOI 10.7160/aol.2026.180205.

Introduction

The European Union (EU) countries are significant buyers of agri-food products from Ukraine. Since the outbreak of war in Ukraine in 2022, the role of Ukraine's neighboring countries in receiving these products has increased significantly. In 2016, when the Deep and Comprehensive Free Trade Area (DCFTA) (L 161/2014, n.d.), entered into force –introducing the gradual reduction and elimination of tariffs on trade between the EU and Ukraine, while maintaining tariff-rate quotas for selected agricultural products, including cereals (notably wheat, maize and barley), sugar, meat, or eggs. In that year, Ukraine's neighboring countries imported 14% of the value of Ukrainian agricultural exports to the EU (Eurostat, 2024). Following Russia's full-scale invasion in 2022, the EU introduced extraordinary Autonomous Trade Measures (ATMs), temporarily suspending TRQs applicable under the DCFTA framework, thereby allowing duty-free and quota-free imports during the period of application of these measures. In 2022, this share increased to 40% (Eurostat, 2024).

However, the war in Ukraine has severely destabilized the market for agri-food products, leading to the highest increase in food prices since 1990 (Abay et al., 2023). It has been a major challenge for Ukraine to find alternative transportation routes for agri-food products due to problems with access to Ukrainian Black Sea ports (Varynskyi et al., 2023). One alternative was to export goods by road and rail, enabling far more agri-food products from Ukraine to reach neighboring countries. This shift translated into a marked reconfiguration of the territorial structure of Ukraine's exports to the EU: neighboring Member States increasingly served not only as immediate destination markets but also as the main entry and redistribution hubs for further shipments into the Single Market. This was possible, among other things, thanks to the EU regulation on the so-called solidarity corridors, which allowed preferential exports of Ukrainian agricultural goods to EU countries without customs duties and quota limits (Bodnar et al., 2024). From June 2022, the European Union liberalized trade with Ukraine and suspended previously existing quotas (PE/21/2022/REV/1, 2022). These measures have contributed to a partial solution to Ukraine's problems with access to global markets, but at the same time, have introduced tensions in European markets.

In Ukraine's neighboring countries, especially Poland, Romania, and Hungary, an excessive influx of certain products was observed, including cereals and oilseed crops (Bulkowska and Bazhenova, 2023; Sterie et al., 2022), resulting in price drops in local agricultural markets and caused dissatisfaction among local farmers (Beluhova-Uzunova et al., 2024; Ostashko, 2023). In response to pressure from farmers, Poland, Hungary, Slovakia, Romania, and Bulgaria initially imposed temporary restrictions on imports of Ukrainian agricultural products to protect their internal market. In Commission Implementing Regulation (EU) 2023/903 of May 2 2023, the European Commission decided to restrict direct imports of certain goods to Ukraine's neighboring countries but allowed their transit to other European Union countries. Due to storage difficulties and weakened profitability of producers, the import restrictions mainly covered wheat, corn, rapeseed, and sunflower seeds (2023/903, 2023).

The issue of excessive inflow of agricultural products from Ukraine to neighboring countries such as Poland, Hungary, and Romania can be explained by the assumptions of the gravity model in international trade. Although the liberalization of trade in agri-food products with Ukraine was introduced at the level of the entire European Union, the countries directly bordering Ukraine felt the most substantial influx of these goods. The gravity model assumes that the shorter the distance between two countries, the greater the trade flow between them should be (De Benedictis and Taglioni, 2011). In practice, Regional Trade Agreements (RTAs) also contribute to increased trade to a greater extent, the shorter the distance between signatory countries (Freeman and Lewis, 2021). Lower transportation costs and easier logistics encourage manufacturers to export their goods to geographically close markets (Giuliano et al., 2014). In the case of agricultural exports from Ukraine, neighboring EU countries may have become an economically advantageous destination, as proximity to the border allowed for quick and relatively cheap transportation of agricultural products, which was necessary when the war broke out. However, the trade situation since the outbreak of the war in Ukraine has been changing dynamically and has been influenced by many factors of different natures. Therefore, a detailed empirical analysis of the topic is needed to draw appropriate conclusions.

The main question is whether the distance remains the primary determinant of trade development between the EU and Ukraine or is more strongly influenced by other factors, such as the war or trade measures introduced in recent years (trade liberalization or partial import restrictions). Therefore, the main goal of this article is to examine the extent to which different factors were associated with increased exports of Ukrainian agricultural products to EU countries, given the extraordinary circumstances. The objective will be achieved using gravity models for selected agricultural products. The analysis focused on the import of major crops and oilseeds, as these were among the most frequently exported agricultural products from Ukraine (Ministry of Agrarian Policy and Food of Ukraine, 2024).

The novelty of the article lies in at least two areas. Firstly, the study employs a gravity model that considers the cumulative impact of war and liberalization processes on trade, going beyond classical determinants, such as distance or GDP previously analyzed in this setup. Secondly, the original contribution is employing monthly data for 2020-2023 to model trade between the EU and Ukraine, allowing us to accurately capture short-term changes in trade, both in the period before the war and after it began. To the best of our knowledge, the study represents one of the first attempts to combine the cumulative effects of distance, war, and liberalization on trade volumes, and it is the first one in the context of UE-Ukraine relations.

The rest of the article is broken down as follows: the next section provides literature review focusing on the EU-Ukraine trade relations. The following part describes the data and research methods used. Afterwards, the research results and their discussion is presented. The last part summarizes the research carried out and contains policy recommendations.

Literature review

In the context of agri-food trade between Ukraine and the European Union, research focuses mainly on two aspects: the impact of trade liberalization resulting from the DCFTA (Frey and Olekseyuk, 2014; Nekhay et al., 2021; Ostashko et al., 2022; Rau, 2014; Tuliakov et al., 2023; Rabinovych, 2024) and the effects of the ongoing Russian-Ukrainian war (Borin et al., 2022; Bulkowska and Bazhenova, 2023; Jagtap et al., 2022; Mbah and Wasum, 2022; Prohorovs, 2022; Steinbach, 2023).

One of the early studies on the potential impact of DCFTA by Nekhay et al. (2012), using the AGLINK-COSIMO model, assessed the consequences of removing tariffs on 14 major agricultural products, such as wheat, oilseeds, and dairy products. The results indicated significant benefits for both sides - farmers' revenues in Ukraine increased by €393 million, and farmers in the EU by €860 million. However, the effects varied by product. According to the forecast, Ukraine would gain primarily in the grains and oilseeds sector but would face challenges adjusting to EU sanitary and quality standards. The potential benefits and challenges of Ukraine's agricultural market liberalization in the context of the DCFTA were also studied by Yatsenko et al. (2017), who noted increased export opportunities and a more significant role for processed food exports to the European market. Moreover, Cherevko (2017) emphasizes the agri-food sector's export potential but also highlights structural weaknesses that could hinder competitiveness in the EU market.

Cramon-Taubadel et al. (2010), analyzing a potential free trade agreement between Ukraine and the EU and its effects on agriculture, assuming a 50% reduction in tariffs, found mutual benefits from liberalization. The results underscored an increase in the productivity of Ukrainian agriculture and a better ability to cope with competition that followed. Grain production and exports, mainly wheat, were also forecast to increase. In turn, Ostashko et al. (2022) reported a 10.3% increase in agricultural exports from Ukraine to the EU over the first five years after the implementation of the DCFTA. In addition, Tuliakov et al. (2023) indicate that, between 2013 and 2021, trade turnover between the EU and Ukraine increased by an average of 60%. Beyond the growth in trade volume, the DCFTA served primarily as an engine of internal reforms in Ukraine in 2014–2019, forcing changes in technical barriers to trade (TBT) and competition policy, as emphasized by Rabinovych (2024). While these results underscore the clear benefits of trade liberalization between Ukraine and the EU, the war has created new challenges, particularly in transportation and logistics, limiting the full potential of trade integration. Shnyrkov and Chugaiev (2023) noted that the importance of exports of grains, vegetable oils, and other agri-food products has increased. Exports of processed products also increased, suggesting Ukraine's shift from raw material exports to more advanced agri-food products. However, the latest research documents a shift: from full wartime liberalization in 2022 toward selective EU protectionism (Butenko et al., 2025). Since June 2024, the EU has gradually reinstated tariffs and quotas on selected sensitive agricultural products from Ukraine, partially modifying the ATMs (Sirenko and Mikuliak, 2025).

In recent years, Ukraine has benefited from agricultural exports to the EU but has seen a lot of market disruption due to the war. Despite these difficulties, trade integration between Ukraine and the EU is progressing, and the agri-food sector remains a key area of cooperation between partners. The Russian-Ukrainian war, especially its development in 2022, has significantly affected international trade, including the agri-food sector. Shnyrkov and Chugaiev (2023) note that, despite maritime blockades and logistical disruptions, Ukraine has been able to maintain exports to the EU, with grain and vegetable oil exports growing in importance in particular. In the face of these challenges, the EU has become Ukraine's leading trading partner, especially in agricultural products. Moreover, the EU's decisions to suspend tariffs and import quotas on agricultural products from Ukraine have allowed for the maintenance of high levels of exports despite the difficulties associated with the ongoing war.

The literature indicates that trade liberalization has a positive impact on trade. National governments can unilaterally reduce tariffs or introduce preferential reductions for selected trading partners. Both of these approaches result in the creation of trade, as the elimination of trade barriers means that domestic suppliers are often abandoned in favor of more efficiently produced goods from partner countries (Kandogan, 2009). A free trade agreement, or a common border between countries, significantly promotes trade. Additionally, the liberalization and removal of tariff barriers create positive trade effects not only for countries in the resulting free trade zone but also for countries outside the bloc (Yang and Martinez-Zarzoso, 2014).

Despite many positive aspects of trade liberalization, negative ones can also be observed. From the EU's perspective, trade liberalization with Ukraine has disrupted European markets. As Butenko et al. (2025) indicate, the number of notifications concerning sanitary and phytosanitary (SPS) measures for products from Ukraine increased by 18% during 2024, suggesting stricter controls and a perceived need to protect the market. The findings of (Butenko et al., 2025) also point to hidden trade costs stemming from the fact that a one–standard deviation increase in SPS intensity (measured as the logarithm of the number of notifications) translates into a 3.5–4.0% increase in trade costs, which in practice may offset the benefits of zero tariffs. In addition, looking at the effects of liberalization after 2022, sudden price and supply fluctuations triggered tendencies to protect producers and populations at the expense of global food trade stability, resulting in a negative outcome (Kutsmus et al., 2024).

In light of trade theory, trade is significantly affected by the distance between countries and the size of their economies, as measured by GDP (Chaney, 2018). Karemera et al. (1999), while studying the effect of distance on trade in the Pacific region, found that countries closer to each other were more likely to trade due to lower transportation costs, cultural proximity, and similarities in consumption patterns. Their findings confirm that shorter distances between member countries favor trade in integrated regions, such as ASEAN, where trade agreements exist. Thus, in the context of trade liberalization, a small distance can strengthen economic integration by facilitating the exchange of goods between geographically close countries. In turn, Jagdambe and Kannan (2020) used a gravity model to analyze agricultural trade between India and ASEAN (AIFTA). The study covered 50 countries and five major trade agreements (including AIFTA, NAFTA, MERCOSUR, and the EU) from 2005 to 2014. Their results also indicate that a greater distance between countries results in lower trade flows, as it increases transaction costs. At the same time, geographic proximity and a common border are drivers of trade. The closer the countries are, the lower the costs of trade, which promotes increased exchanges between them.

Conversely, war tends to act as a brake on trade by tightening controls, protectionism, and breaking supply chains. On the other hand, post-conflict efforts to rebuild and stabilize the economy sometimes emerge, which can foster openness to trade and new economic alliances (Barbieri and Levy, 1999; Martin et al., 2008; Taylor and Glick, 2005). Such cases occurred, for instance, after World War II, when the creation of institutions such as the General Agreement on Tariffs and Trade (GATT) fostered greater economic openness (Irwin, 1994; McKenzie, 2020).

However, the literature does not currently provide studies considering the simultaneous effects of geographic distance and armed conflict on trade volumes. Separate studies show that distance and war can significantly impact trade, but their cumulative impact remains unknown. With global crises such as the war in Ukraine, the role of distance and armed conflict is becoming increasingly complex. Understanding their collective impact on trade is key to formulating policies promoting trade stability. Our study fills an existing research gap by analyzing the cumulative effects of geographic distance and armed conflict on trade volumes between the EU and Ukraine.

Materials and methods

We constructed our gravity models based on panel data for 27 EU countries regarding import volumes from Ukraine, considering 39 crop and oilseed products, as these are among Ukraine's most exported agricultural products. We use monthly data for the period 2020-2023 to evaluate the change between years without war (2020-2021) and with war (2022-2023).

Trade data was retrieved from the Comext-EUROSTAT database (EUROSTAT, 2024) using the 8-digit level disaggregation of the Harmonized Commodity Description and Coding System (HS). A complete list of products used is given in the supplementary files (S1). We employed the monthly data on imports in kilograms from Ukraine to EU-27 countries as a dependent variable. Such an approach is chosen as it provides a more accurate assessment of trade flows, as it is not influenced by price changes or exchange rate variations as in the case of monetary trade values (Lewis, 2017).

The great circle distance between the capitals of EU countries and the Ukrainian capital was employed to estimate the geographic distance. This approach, while straightforward, is widely used in gravity models as a reliable proxy for spatial interaction in trade analysis (Head and Mayer, 2014). Following the tradition of gravity models, the distance and the GDP were used as independent variables in their logarithmic form (Anderson and van Wincoop, 2003). The data on nominal quarterly GDP in USD retrieved from the EUROSTAT database were used (Eurostat, 2025). The quarterly GDP data were linearly interpolated to get a monthly representation of the GDP.

The rest of the variables are binary, indicating a war at Ukraine's territory, shared border, trade ban to countries bordering Ukraine for certain products, and two variables regarding tariff-rate quotas (TRQs). The complete list of variables is given in Table 1. In the case of the war dummy, we decided that the trade had been affected since March 2022, as the war started on the 20th of February, but its major part was not affected. The trade ban variable was set to 1 (signifying trade restrictions but possible transit) from March 2023 for Bulgaria, Hungary, Poland, Romania, and Slovakia. The ban included specific products from barley, rape, sunflower, and wheat products.

To account for the fact that the war could have affected trade asymmetrically across importers, we include interaction term between the war dummy and share border. This variable equals 1 for border countries (e.g., Poland, Hungary, Slovakia, Romania) in the war months and 0 otherwise. The interaction tests whether imports to neighboring countries increased specifically because they were neighbors during wartime (e.g., due to logistical re-routing and land transport advantages), rather than due to war or border proximity alone. The interaction coefficient therefore captures how much larger (or smaller) the war effect is for bordering countries compared to non-border countries.

We decided to account for TRQs employing two variables, one indicating if TRQs exist as a trade barrier and the second indicating if TRQs for a certain period are exceeded. Together, these variables account for a dual effect of TRQs on trade. First, within the quota, TRQs restrict trade by capping the number of imports eligible for lower tariffs (Bureau et al., 2019) (in the case of imports of analyzed products from Ukraine to the EU, the tariff within the quota is 0). Second, once the TRQ threshold is exceeded, higher out-of-quota tariffs can significantly deter additional trade (Muchopa, 2021). The information about existing TRQs between Ukraine and the EU and their exceedance was retrieved directly from DCFTA and special regulations on trade, effectively abolishing TRQs from June 2022.

The gravity model framework employed in this study underwent rigorous pre-validation steps to ensure the robustness of the results. This included stationarity testing, multicollinearity diagnostics, and a strategy to address seasonality and zero trade flows in the dependent variable.

Seasonality is a well-documented characteristic of agricultural trade flows, driven by factors such as harvest cycles, climatic conditions, and shifting demand patterns (Cipollina and Salvatici, 2010). To address this, monthly dummies are included in the gravity model to control for unobserved, time-specific effects that could bias the estimation results

Variables	Type	Description	Symbol
Dependent variable			
Import quantity	continuous	Quantities in kg	QUANTITY_IN_KG
Independent variables			
Nominal GDP	continuous	Logarithmic form	ln_GDP
Distance	continuous	Great circle distance between capitals Logarithmic form	ln_Distance
War dummy	binary	War (1) No war (0), war from March 2022	wardummy
Shared border	binary	Shared border (1) No border (0)	Shared_border
Trade ban	binary	Trade ban (1), No trade ban (0), ban for selected products from May 2023	ban
Tariff-rate quota (TRQs)	binary	TRQs exist as a trade barrier (1), TRQs do not exist as a trade barrier (0)	TRQs
Tariff-rate quota exceeded	binary	TRQ is exceeded (1), TRQ is not exceeded (0)	TRQ_exceeded
War dummy x Shared border	Interaction (binary)	Interaction term between the war dummy and the shared border	int_war_border

Source: Own compilation.

Table 1: Variables used in gravity models.

(Serlenga and Shin, 2007). Monthly dummies effectively capture variations in trade flows that arise from agricultural seasonality, ensuring that these time-specific factors do not confound the estimated coefficients (Heerman and Sheldon, 2018).

Multicollinearity was assessed using the Variance Inflation Factor (VIF), which measures what portion of the variance of the estimator is caused by the correlation of the variables in the model, according to the formula (James et al., 2021):

$$VIF = \frac{1}{1 - R_j^2} \quad (1)$$

where:

VIF - variance inflation factor;

R^2 - coefficient of determination;

j - independent variable.

The average VIF value is well below the commonly used thresholds of 10 or 4 more strictly (O'brien, 2007), with the highest observed VIF being 5.63 for the variable TRQs (Table 2). The mean VIF was consistently low across specifications, ranging from 1.17 to 2.13, indicating an absence of significant multicollinearity. Consequently, all variables were retained in the model without the need for adjustment.

Variables	VIF	1/VIF
TRQs	5.63	0.1777
wardummy	5.43	0.1843
month_dummy5	1.94	0.5154
month_dummy3	1.94	0.5161
month_dummy4	1.94	0.5161
month_dummy10	1.86	0.5386
month_dummy9	1.86	0.5387
month_dummy11	1.86	0.5387
month_dummy8	1.86	0.5387
month_dummy12	1.86	0.5387
month_dummy7	1.86	0.5387
month_dummy6	1.86	0.5387
month_dummy2	1.83	0.5455
ln_Distance	1.42	0.7061
shared_border	1.38	0.7250
ln_GDP	1.10	0.9130
ban	1.08	0.9230
TRQ_exceeded	1.02	0.9817
Mean VIF	2.09	

Source: Own compilation.

Table 2: Results of the variance inflation factor (VIF) for variables used in models.

To avoid spurious regressions, we tested GDP for stationarity. The Levin-Lin-Chu unit root test was applied to the logarithm of GDP across panels (Levin et al., 2002). The results strongly rejected the null hypothesis of non-stationarity, confirming that the data is stationary (adjusted t* = −44.6884, p<0.001).

Our import data (dependent variable) contains numerous zero trade flows, which pose challenges for traditional estimation techniques like Ordinary Least Squares (OLS). Log-linearizing the gravity model excludes zero flows or requires arbitrary adjustments, introducing biases (Martin and Pham, 2020). Additionally, OLS is inconsistent under heteroskedasticity, which is pervasive in trade data (Sukanuntathum, 2012). To address these issues, alternative methods like Poisson Pseudo-Maximum Likelihood (PPML) have been proposed to ensure robustness against both zero flows and heteroskedasticity (Santos Silva and Tenreyro, 2006). The PPML estimator addresses these issues by directly estimating trade flows in levels, making it robust to heteroskedasticity and capable of handling zero trade values without transformations (Santos Silva and Tenreyro, 2011). Furthermore, PPML ensures interpretable coefficients as elasticities and is robust to non-stationary dependent variables (Fally, 2015). The PPML estimator maximizes the following pseudo-log-likelihood function:

$$\mathcal{L}(\beta) = \sum_{ijt} [Trade_{ijt}\ ln(\hat{Trade}_{ijt}) - \hat{Trade}_{ijt}] \quad (2)$$

where:

$\hat{Trade}_{ijt} = exp(X'_{ijt}\beta)$ represents the predicted trade flow in the model. It is derived by exponentiating a linear combination of the explanatory variables (X_{ijt}) and their corresponding coefficients (β). This functional form ensures that the predicted trade flow remains strictly positive, aligning with trade data's non-negative nature (Santos Silva and Tenreyro, 2006).

Tradeijt is observed trade flow (can be zero or positive).

To estimate β, the PPML estimator solves the following first-order conditions:

$$\sum_{ijt} [Trade_{ijt} - \hat{Trade}_{ijt}]\, X_{ijt} = 0 \quad (3)$$

This condition ensures that the weighted residuals sum to zero, where the weights depend on the predicted trade flows. Unlike log-linearized

OLS models, PPML works directly with trade flows in levels. The logarithm of zero is undefined, but PPML avoids this issue because it does not require a log transformation of the dependent variable.

The PPML estimator was selected as the best fit for our models. However, we also employed high-dimensional fixed effects (HDFE) since the HDFE framework provides a computationally efficient way to incorporate fixed effects, controlling for unobserved heterogeneity without explicitly generating dummy variables (Correia et al., 2020). Instead of estimating the fixed effects directly, the HDFE transforms the data by de-meaning it within each group to "absorb" the fixed effects. We employed the product fixed effects for our models to account for unobservable, time-invariant characteristics specific to each product. Fixed effects for countries or time were excluded to prevent key variables, such as ln_Distance, wardummy, and shared_border, from being dropped due to collinearity. These variables are constant across specific dimensions (e.g., ln_Distance and shared_border within countries) or vary only by time (wardummy), making them absorbed when corresponding fixed effects are included. The models avoid such issues by focusing on product-level fixed effects, allowing these critical explanatory variables to remain in the analysis. Our approach is consistent with the recommendation to select fixed effects strategically, ensuring that they do not absorb the variation of interest in the independent variables (Head and Mayer, 2014). Using product fixed effects captures essential heterogeneity across product categories while preserving the explanatory power of variables like distance, which are central to the gravity framework.

Lastly, we applied cluster-robust standard errors for each country-product pair, which ensures robust inference by addressing within-cluster correlation specific to each country-product combination. Clustering at the country-product level accounts for shared shocks or dependencies within each product-country combination over time, ensuring robust statistical inference. This step complements the use of product fixed effects by addressing correlated errors that fixed effects alone cannot handle (Cameron and Miller, 2015). Therefore, our first model was specified as follows:

$$
\begin{aligned}
E(Trade_{ijt}) = \exp\,(&\beta_0 + \beta_1 \ln(GDP_{it}) + \\
&+ \beta_2 \ln(Distance_{ij}) + \beta_3 Ban_{ijt} + \beta_4 TRQs_{ijt} + \\
&+ \beta_5 Wardummy_t + \beta_6 Shared_{Border_{ij}} + \\
&+ \beta_7 TRQ_{Exceeded_{ijt}} + \\
&+ \sum_{m=2}^{12} \delta_m MonthDummy_m + \gamma_p)
\end{aligned} \tag{4}
$$

where:

$Trade_{ijt}$ represents trade flows in kilograms between Ukraine (i) and importer j at time t;

δ_m represents coefficients for the monthly dummy variables, explicitly included to capture time effects for months $m = 2,\ldots,12$ (the first month serves as the reference category);

γ_p represents product fixed effects, absorbed using HDFE.

We also specified the second model, which additionally includes the interaction term between the war dummy and the shared border. Such a solution was chosen based on the data observation, showing a significant increase in imports into countries bordering Ukraine immediately after the start of the war compared to other EU countries. Therefore, the second model was specified as:

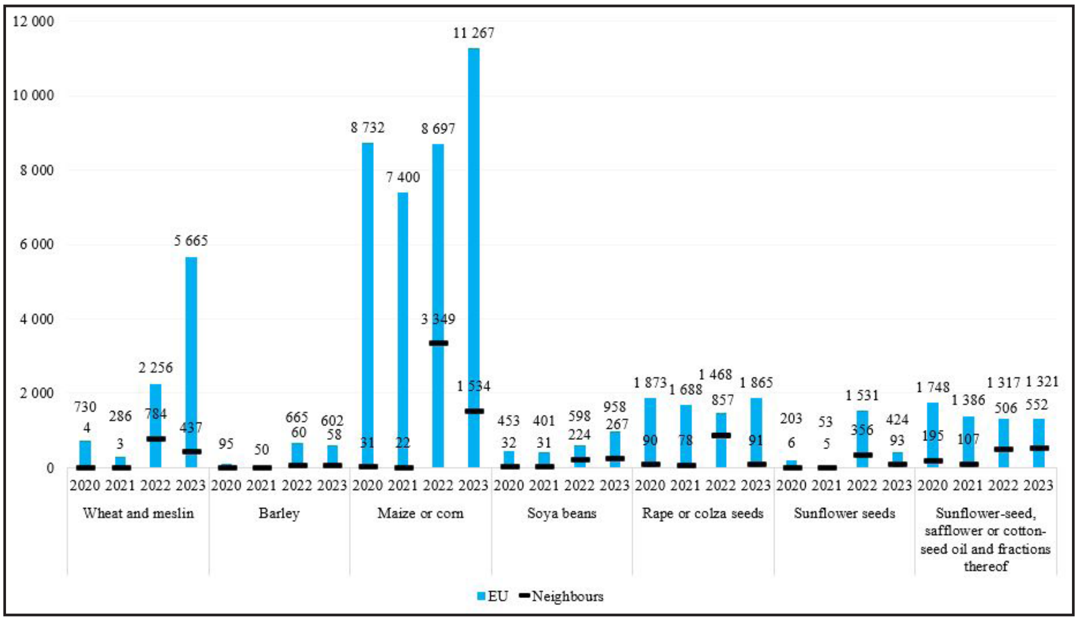
$$
\begin{aligned}
E(Trade_{ijt}) = \exp\,(&\beta_0 + \beta_1 \ln(GDP_{it}) + \\
&+\beta_2 \ln(Distance_{ij}) + \beta_3 Ban_{ijt} + \\
&+\beta_4 TRQs_{ijt} + \beta_5 Wardummy_t + \\
&+\beta_6 Shared_{Border_{ij}} + \beta_7 TRQ_{Exceeded_{ijt}} + \\
&+\beta_8 \left(\mathrm{Wardummy_t} \times \mathrm{Shared_{Border_{ij}}}\right) + \\
&+ \sum_{m=2}^{12} \delta_m MonthDummy_m + \gamma_p)
\end{aligned} \tag{5}
$$

The study is based on the gravity model, which emphasizes the importance of geographical proximity as a key factor influencing trade flows. However, it does not directly account for the relationship between distance and transport costs, which may be affected by factors such as infrastructure quality, trade agreements, or geopolitical barriers (Brancaccio et al., 2020; Clarifying Trade Costs, 2009). Although the study discusses the dynamics of trade between Ukraine and the EU under conditions of war and trade liberalization, it does not include precise estimates of transport costs. This limitation arises from the difficulty in distinguishing which products were transported by land and which by sea, depending on the country. Another obstacle was the lack of comprehensive data on the modes of transport used, which ultimately impacted costs. This limitation prevented the consideration of differences in the cost structure associated with maritime and land transport and the inclusion of variations in sea and land distances between Ukraine and EU countries. However, such an approach is commonly applied in different studies (e.g., Arvis et al., 2016; Fang and Shakur, 2018).

Results and discussion

In 2022, the onset of the war in Ukraine led to a notable increase in the inflow of agricultural products into the EU market. This growth was driven by multiple factors, including the EU's solidarity corridors, which facilitated the preferential export of Ukrainian agricultural goods, the suspension of tariffs and quotas, and the need to find alternative transport routes due to the blockade of Black Sea ports (Bulkowska and Bazhenova, 2023).

The most significant increase in imports was observed in the countries bordering Ukraine (Poland, Hungary, Slovakia, Romania) (Figure 1). This is directly in line with the gravity theory developed in the past (e.g., Anderson, 1979; Bergstrand, 1985; Deardorff, 1998) and more recently (e.g., Allen et al., 2014; Eaton et al., 2016). Due to geographical proximity and the possibility of land transport, these countries became natural recipients of products such as wheat, corn, rapeseed, and oilseeds, which were particularly significant for Ukraine's exports. Corn imports to neighboring countries increased more than 150-fold when comparing 2021 to 2022. However, the substantial growth of imports, or even the import dependency ratio, as measured by the share of imports from Ukraine in overall imports of individual countries, may not accurately reflect the trade-related consequences of trade shifts for agricultural markets and food security if imports constitute a small share of domestic supply. Therefore, the ratio of imports to domestic production is a more relevant measure for recognizing import dependence. Before the Russia-Ukraine war, the share of corn imports from Ukraine to Central and Eastern European Countries was marginal (less than 0.5%), but during the war, it increased, reaching almost 16.5% before import bans were introduced in May 2023. A similar trend, though to a lesser extent, was also observed in the case of wheat, where the share of Ukrainian imports in the domestic production of EU countries increased from around 0% to 3% (EUROSTAT, 2024). Ukraine has been an important wheat supplier to EU countries during the analyzed period. In total, 2023 wheat imports from Ukraine accounted for around 50-60% of total EU wheat imports, whereas before the war began, in 2021, they accounted for around 10%. The critical importance of grain and oilseed



Source: Own calculations based on COMEXT-Eurostat data

Figure 1: Imports of agricultural products from Ukraine to Ukraine's neighbors and other EU countries in 2020-2023 (mln of tons).

imports from Ukraine to various world subregions, including European countries, has already been discussed by Hamulczuk et al. (2023). Based on the share of imports from Ukraine in domestic use, they showed that the most import-dependent regions, such as Northern Africa and Western Asia, might have experienced the suspension of grain deliveries from Ukraine the most. Still, at the same time, due to the high import-dependency ratio, Southern and Western European countries could also be threatened.

Despite the significant growth in the inflow of agricultural products to Ukraine's neighboring countries, the data also indicate an increase in the flow of Ukrainian products to more distant EU states. A detailed analysis of the data revealed a rise in imports, both in terms of quantity and value, to countries such as Germany, Italy, and Spain. This growth was slower than that observed in Ukraine's neighbors, which resulted from higher transportation costs and limited availability of Ukrainian products in the early stages of the conflict. Nevertheless, the visible growth in imports to these countries suggests the potential for further trade diversification within the EU. The identified trends confirm that transportation costs dependent on the distance between countries limit agricultural exports. Such regularity is in line with analyses by, Jayasinghe and Sarker (2008), focusing on agri-food trade in NAFTA countries and with the study by Hatab et al. (2010), who analyzed the main factors affecting Egypt's agricultural exports to major trading partners from 1994 to 2008. However, transportation costs are not the only factors determining the value of bilateral trade flows. Our observations might settle that, as previously shown by Paiva (2005), Hatab et al. (2010), and Melece and Hazners (2014), GDP per capita in trading partner countries and agriculture's contribution to GDP in exporting countries are also critical for shaping mutual agri-food trade flows.

In 2023, a continued increase in the inflow of agricultural products to EU countries can be observed. However, for countries neighboring Ukraine, the effects of temporary import restrictions introduced by Poland, Hungary, Slovakia, Romania, and Bulgaria on products such as wheat, corn, rapeseed, and sunflower seeds are evident. In the case of corn, this decline was more than twofold, dropping from nearly 3.5 billion tons in 2022 to 1.5 billion tons in 2023. As for Ukraine's neighboring countries, their share of Ukraine's agri-food imports was 17% in 2021, 40% in 2022, and 29% in 2023. These results highlight the dynamic nature of agricultural trade between Ukraine and the EU, shaped by both geopolitical factors and market adjustments. Those trade drivers often result from trade liberalization, and their impact on bilateral trade has already been investigated (e.g., Huchet, Mouël and Vijil 2016; Matkovski, Lovre and Zekic 2017). It results from their estimations employing a gravity model that the trade liberalization has positive effects on the intensification of trade flows between the signatories of the trade agreement at the expense of countries not involved in the preferential trade area, which usually are located at a greater distance.

The gravity models were constructed to assess whether distance remains the primary determinant of trade development between the EU and Ukraine in the context of war and the implemented trade measures, such as trade liberalization or partial import restrictions. The results of both models are given in Table 3. In the case of the first model, the coefficient for ln_GDP is 0.6537 ($p = 0.000$), indicating a statistically significant relationship between the economic size of EU countries and the volume of agricultural imports from Ukraine. A 1% increase in GDP is associated with an approximate 0.65% increase in trade flows. However, an unusual positive coefficient (1.7760) ($p = 0.000$) was observed for ln_Distance. This suggests that the greater the distance between Ukraine and an EU country, the higher the exports from Ukraine. This could be attributed to the fact that wealthier EU countries (e.g., Germany, Spain, Italy) located farther from Ukraine have a greater capacity to absorb imports. Higher transport costs may be mitigated by the short distances within the EU and higher demand in countries with developed infrastructure (Persyn et al., 2022). However, this contradicts the classical assumptions of the theory concerning gravity models (Tinbergen, 1962). Nevertheless, it should be noted that under wartime conditions and constrained access to the Black Sea, geographic distance need not constitute an adequate proxy for trade costs, as the capacity of alternative transport corridors and importers' logistical capabilities become pivotal determinants of flows. Accordingly, the positive coefficient on ln_Distance may also reflect destination selection and the concentration of exports in countries able to effectively coordinate imports via the EU's transit and port infrastructure.

Variable	Model 1	Model 2
ln_GDP	0.6537*** (0.1201)	0.6495*** (0.1201)
ln_Distance	1.7760*** (0.4478)	1.7791*** (0.4462)
ban	-2.5848*** (0.3906)	-3.1787*** (0.3646)
TRQs	-0.8326 (1.1938)	-1.0227 (1.1999)
wardummy	0.6568** (0.264)	0.2752 (0.2821)
shared_border	2.2118*** (0.4787)	-0.1273 (0.6635)
TRQ_exceeded	0.9782 (1.1714)	1.1368 (1.1701)
int_war_border		3.0762*** (0.4681)
month_dummies2	-0.1393** (0.0542)	-0.1394** (0.0542)
month_dummies3	-0.5384*** (0.1156)	-0.5433*** (0.1124)
month_dummies4	-0.7385*** (0.1145)	-0.7443*** (0.1127)
month_dummies5	-0.7760*** (0.1087)	-0.7327*** (0.1019)
month_dummies6	-0.8645*** (0.1304)	-0.8265*** (0.1329)
month_dummies7	-0.8880*** (0.1636)	-0.8418*** (0.1687)
month_dummies8	-0.7295*** (0.2386)	-0.6916*** (0.243)
month_dummies9	-0.5006* (0.287)	-0.4627 (0.2901)
month_dummies10	-0.3367 (0.2254)	-0.2987 (0.2274)
month_dummies11	-0.0788 (0.1283)	-0.0411 (0.1308)
month_dummies12	-0.0887 (0.0939)	-0.0513 (0.0954)
_cons	-3.8665 (4.1228)	-3.6415 (4.1246)
Parameters	19	20
Observations	37 584	37 584
Country_Product clusters	783	783
Absorbed Product FE	Yes	Yes
Pseudo R-squared	0.6495	0.6723

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$ (robust standard errors in parentheses)
Source: own computation in the STATA 15, based on COMEX-T-Eurostat and World Bank data.

Table 3: Gravity model on Ukraine-EU selected agricultural products imports (PPML estimation with HDFE for products).

Variables such as TRQ (p = 0.486) and TRQ_exceeded (p = 0.404) were found to be not statistically significant in the model. The import ban on specific agricultural products from Ukraine to EU countries proved statistically significant. The coefficient for the ban is -2.5848 (p = 0.000), meaning that the ban has caused a significant reduction in imports from Ukraine. The model results also indicate a statistically significant impact of the war on the increase in the volume of agricultural imports to the EU (coefficient = 0.6568, p = 0.013). Additionally, the shared border was significant, with a coefficient of 2.2118 (p = 0.000), suggesting that being a neighbor of Ukraine positively influences imports of agricultural products.

On the one hand, our results show that the role of distance contradicts the assumptions of the theory on gravity models, indicating that the greater the distance between countries, the higher the trade volume. On the other hand, the coefficient for the shared bordered variable suggests that geographical proximity matters and increases trade. A particular dichotomy of our results becomes evident. A detailed analysis of the data revealed that the most significant inflow of agricultural products to countries neighboring Ukraine occurred in the first months following the outbreak of the war. Therefore, we decided to include an additional variable, int_war_border, into the model, which accounts for the interaction between war and a shared border. This resulted in the shared border variable no longer being statistically significant (p = 0.848). War is also no longer statistically significant (p = 0.329), whereas the interaction between the border and war became substantial and positively correlated with trade volume. The coefficient for int_war_border is 3.0762 (p = 0.000). The insignificance of wardummy and shared_border and the significance of the interaction term (int_war_border) indicate that the combined effect of war and proximity to Ukraine is more important than their individual effects. This finding highlights the conditional nature of the relationship, which is an essential insight for understanding trade dynamics in the context of war.

The impact of conflicts on trade flows has attracted the attention of scholars for decades; however, the research results remain ambiguous. Karlsson & Hedberg (2021) showed that in the nineteenth century, the negative influence of war on trade was noted only in relations between war-involved economies, while trade between war-embroiled countries and third countries was either unaffected or even increased during wartime. As far as twentieth-century wars were concerned, they reduced trade between the parties to the conflict and between countries directly involved in it and countries neutral to the conflict. The war-related impacts on trade in third countries were also confirmed by Krpec and Hodulak (2019). A valuable analysis of the effects of conflicts on trade in 1979-2000 was delivered by Marano et al. (2013). Similarly to the studies mentioned above, they proved that conflicts negatively affect both countries that directly experience war disruptions and neighboring countries. Moreover, their findings indicate that trade is more negatively impacted by conflict in the exporter's territory than in the importer's territory. Using the gravity approach, Kamin (2022) also found that the conflict types and their unique characteristics are essential in determining the extent and direction of their impact on trade. It means that the war-related trade impact on a specific economy depends on whether the conflict is interstate or intrastate and whether both trading partners are in conflict. Similarly to our study, Kamin (2022) proved that the distance between trading partners does not have a leading impact on bilateral trade during the war. This clearly shows that the assumptions of classical gravity theory indicating that trade intensifies between countries close to each other could remain invalid in the face of sudden and exceptional circumstances, such as armed conflicts, including the war between Russia and Ukraine, and its impact on EU-Ukraine agri-food trade.

The results for other variables, such as ln_GDP, ln_Distance, and ban, are consistent with the baseline model (Table 3), indicating their stability as determinants of trade. In the case of the ban, the coefficient decreased to -3.1787, suggesting an even more negative impact on the volume of trade. The presence of seasonality in trade, represented by the month_dummies variables, is also consistent across both models, which is a standard phenomenon for agricultural products. However, the extended model provides a better understanding of trade mechanisms during the war and the structure and significance of traditional determinants of international trade.

Conclusions

In the presence of war and trade liberalization, which changed the trade situation between Ukraine and the EU, the study found that neighboring countries became a natural center for absorbing Ukrainian products due to their geographical proximity and the availability of transportation infrastructure. Nevertheless, the excessive inflow of these products created tensions in local markets, necessitating protectionist measures. At the same time, the visible growth in imports to distant countries suggests that the EU has the potential for further diversification and internal trade development in response to potential future crises.

The analysis results indicate that distance does not always act as a limiting factor for trade, contrary to the assumptions of the classical gravity model. The findings suggest that geographical proximity plays a particularly significant role in the initial phase of a crisis. However, the negative impact of distance on trade may diminish in the case of countries with high GDP and well-developed trade infrastructure. The EU countries that do not share a border with Ukraine and are located farther away increased their share in importing Ukrainian products. From 2023 onward, the increased inflow of Ukrainian goods to more distant EU countries was also influenced by the import bans introduced by some of Ukraine’s neighboring Member States. Simultaneously, the pivotal role of border countries in handling Ukrainian exports highlights the importance of a shared border under crisis conditions. The study found that the traditional relationship between distance and trade volume can be disrupted in crises, especially when other factors, such as trade regulations and infrastructure, play a significant role.

In addition to the dynamic growth in trade, the war introduced significant challenges, such as the need to create new transport routes, which affected costs and the direction of trade flows. The study's findings emphasize the necessity of EU actions to support an even distribution of the import burden among member states, which could reduce economic and social tensions. In the long term, the EU faces the challenge of developing mechanisms that ensure the effective distribution of agricultural products within the Union.

The development of logistical infrastructure, particularly in regions bordering Ukraine, could help minimize economic tensions. Investments in efficient transportation systems and initiatives to strengthen local markets could help mitigate inequalities and support long-term stability at both regional and EU levels. We recommend introducing joint management systems for surplus goods, such as shared warehouses. Additionally, it would be essential to undertake investments to expand logistical infrastructure and support the flow of goods to reduce pressure on local markets.

The study addresses a research gap concerning the simultaneous impact of distance and armed conflicts on international trade. Previous literature has examined these factors separately, whereas the conducted analysis integrates their cumulative effects, highlighting the conditional nature of their influence on trade. The results indicating atypical behavior in the gravity model suggest the need for further research on the impact of conflicts and crises on international trade and the resilience of markets to these crises. Future studies should also include an analysis of transport cost structures and preferred transport routes. These analyses could help better adapt trade policies to potential crises.

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