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Agri-Food Supply and Retail Food Prices during the Russia–Ukraine Conflict's Early Stage: Implications for Food Security

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Abstract: The Russian–Ukrainian conflict has led to the disruption of global supply chains, thus posing a threat to food security. The study aimed to assess the short-term impact of the conflict on food supply and global retail food prices resulting from the disruption of agri-food exports from Ukraine after the war outbreak. To assess the impact of the conflict on retail prices worldwide, the actual food price level during the conflict period was compared with the counterfactual values obtained from the forecasting models. The research points to a significant decline in Ukraine's commodity exports at the beginning of the conflict leading to a supply gap for cereals in particular, affecting global access to staple foods. As a result, global food commodity prices rose sharply, however, the upsurge was short-lived, and as early as July 2022 price indices returned to their pre-war levels. On the other hand, in most regions worldwide the gradual and persistent increase in retail food prices was observed after the war outbreak. The study also found strong regional differentiation in the response of retail food prices to the conflict due to various specific factors that exacerbated or mitigated the impact of the war.

Keywords: agri-food prices; international trade; the Russia–Ukraine war; food security

Citation: Hamulczuk, M.; Pawlak, K.; Stefańczyk, J.; Gołębiewski, J. Agri-Food Supply and Retail Food Prices during the Russia–Ukraine Conflict's Early Stage: Implications for Food Security. *Agriculture* **2023**, *13*, 2154. https://doi.org/10.3390/agriculture13112154

Academic Editor: Tao Xiong

Received: 10 October 2023
Revised: 10 November 2023
Accepted: 13 November 2023
Published: 15 November 2023

1. Introduction

Ensuring food security is one of the main objectives of the country's economic policies. The food security concept initially referred only to physical access to food, then it was extended to the four-dimension approach (food availability, food access, utilization, and stability), most frequently referred to in numerous studies [1–4]. More recently, two additional dimensions of food security, i.e., agency and sustainability, have been proposed [5,6]. Ensuring unrestricted availability of a sufficient amount of reliable quality food, in view of limited natural resources, is undoubtedly one of the greatest challenges at all levels of food security, including global, national, local, household, and individual [7].

Food availability and accessibility may be limited by the reduction of agricultural production either due to climate change [8–10] or significant market disruptions resulting from political upheavals or armed conflicts [11,12]. The outbreak of war in Ukraine has already caused and will continue to cause a series of events with consequences at the global level, especially in the field of energy and food supply [11,12]. A restricted food supply results in food scarcity, which in turn leads to price hikes both within and outside of the conflict zone. High food prices are of significant importance, especially for low-income consumers, who struggle to buy enough food even when market prices are low. Therefore, the high level of local food prices aggravating economic access to food becomes the main cause of the deterioration of food security globally.

Ukraine and Russia are among the largest world exporters of staple food: cereals and vegetable oils. In 2021, the shares of Ukraine and Russia in the global exports of cereals were 7.5% and 9.2%, respectively, while their contribution to the global exports of vegetable oils amounted to 5.6% each [13]. At the same time, the importance of both countries in the world exports of oil seeds was slightly smaller. However, it should be emphasized that the share of Russia and Ukraine in the world exports of these commodities is steadily increasing. Therefore, it can be expected that the Russia–Ukraine conflict may have some negative consequences for global retail food prices and food security. From a short-term perspective, the conflict in Ukraine leads to market disruption through international trade reduction, especially in countries highly dependent on food imports from Ukraine [14–16]. As previously discussed, international trade has helped to reduce food insecurity in regions with limited agricultural potential and growing populations [17,18], while in more economically developed nations it has also supported more diversified diets. A decisive role of trade policies aimed at enhancing trade openness in order to ensure food security in low-income countries was discussed, e.g., by Bonuedi et al. [19] and Pawlak and Kołodziejczak [20]. Thus, trade-related factors along with soaring food prices appear to be increasingly important drivers of food insecurity during the Russia–Ukraine conflict. Such a way of thinking is supported by Ahn et al. [21], who found that in the first phase of the Russia–Ukraine conflict (between February and July 2022) grain and oilseed imports from Ukraine were almost 80% below the counterfactual. These authors also showed that global grain and oilseed trade adjustments were accomplished by price adjustments, which considerably varied across commodity groups.

The literature on the impact of the conflict in Ukraine on trade volumes, food prices, or food security is not extensive and refers to food availability rather than economic access to food. Grant et al. [22], Lin et al. [11], and Xu et al. [23] drew attention to the threatened food security worldwide, especially for countries heavily dependent on wheat imports from Ukraine. The Middle East and North Africa (MENA) countries, including Egypt, Sudan, and Yemen, are among them [16]. As Mottaleb and Govindan [24] assessed yearly per capita wheat consumption in the MENA region would be reduced by around 39%, assuming a 100% reduction of wheat export from Russia and Ukraine and the unavailability of alternative wheat import sources. In other regions, the decrease in wheat consumption would be between 19% in South Asia and 57% in Sub-Saharan Africa. According to Lin et al. [11], conflict-induced food insecurity could be considerably mitigated if major wheat producers increased their production by 2–3% between 2022 and 2023 and released unnecessary trade restrictions. De S. Nóia Júnior et al. [25] also stressed that food security is threatened in many countries worldwide without stabilizing wheat supplies through purposeful stock management and yield improvements. Mottaleb et al. [26] suggested two-way actions to lessen wheat import dependence, including enhancing domestic wheat production in major wheat-producing countries and substituting wheat with alternate crops. In turn, Zhou et al. [27] stressed that the involvement of global international organizations is required to meet global demand for energy and food, while more attention should be paid to the less economically developed countries in Africa and Asia to handle the risk.

The main aim of our paper is to assess the short-term impact of the conflict on the supply of agri-food commodities and global retail food prices resulting from the disruption of agri-food exports from Ukraine after the war outbreak. In the study, we try to answer the following questions:

- What were the food commodity supply implications of the Russia–Ukraine conflict resulting from blocking Ukrainian seaports and signing the Black Sea Grain Initiative (BSGI)?
- How much have global agricultural commodity prices risen as a result of the conflict?
- Have retail food prices in developing countries, particularly net importers of food and grains, increased more than in other countries?
- What are the key transmission mechanisms of the Russia–Ukraine conflict for food security?

The commonly accepted narrative assumes that as a result of the conflict, the supplies of agri-food raw materials to the developing countries, being net importers of grains and oilseed products from Ukraine, decreased significantly [14,24,28]. This should result in greater increases in food prices in these countries compared to other countries, thus leading to a greater food security deterioration. That issue was discussed, e.g., by Hatab [29]. On the other hand, humanitarian aid and activated tools of national socio-economic policy can mitigate the negative consequences of the war on food security [30]. Nevertheless, there appear to be other significant transmission channels for the conflict's impact on food prices—namely through energy and fertilizer prices [16,29]. Hence, it may turn out that in developed countries with relatively high shares of non-raw material costs (energy, labor), increases in food prices may be equally high. Such a case refers, e.g., to the European countries, where higher input prices created production difficulties for farmers, increased production costs, and, ultimately, inflation, which could affect poverty and worsen food affordability and access [31]. Alexander et al. [32] study showed that the impact of agricultural input costs on food prices was even stronger than that of food export curtailment from Russia and Ukraine. The higher vulnerability of agri-food systems to rising input prices was also proven for some developing countries by Arndt et al. [33].

Our research will fill the research gap related to the link between global food security and the Russia–Ukraine war by attempting to quantify its impact on the food supply and overall level of food prices in different regions around the world. Apart from the regional-level analysis, our research's novelty includes using counterfactual prices derived from forecasting models as a baseline for the price implication analysis. Moreover, when analyzing regional import dependency, we used shares of imports from Ukraine and Russia in domestic consumption, which is a better measure than the commonly used share of imports from these countries in total imports. The more utilitarian contribution may provide a better understanding of the mechanism underlying the linkage between the conflict and food security, which may also be useful for policymakers.

2. Materials and Methods

The research focuses on the impact of Russia's aggression against Ukraine on international trade and retail food prices worldwide and its implications for food security. The general reasoning that constitutes the conceptual foundations and underpins the empirical research is contained in the Discussion section. According to this, changes in the supply of agricultural commodities and energy prices as a result of the war were key to changes in retail food prices and global food security during the initial period of the conflict (in 2022).

In our analyses, we focused on short-term price responses and agri-food supply in the world at a regional level, while the regions were extracted according to the Food and Agriculture Organization Corporate Statistical Database (FAOSTAT) methodology. We are aware of a certain heterogeneity of individual regions. Nevertheless, the problem of food security generally affects individual income groups, so even a country-level analysis will not fully account for the impact of conflict on food security.

The starting point for analysis was the overview of the supply factors. Firstly, we analyze the importance of Russia and Ukraine in world exports of such food commodities as cereals, oil seeds, and vegetable oils (based on the United Nations Conference on Trade and Development—UNCTAD [13] data). This was accompanied by the identification of the regions heavily dependent on imports of these goods from Russia and Ukraine. It was assumed that a region is heavily dependent on imports if the import dependency ratios account for at least 15%. Import dependency ratios in the pre-war period were calculated as 2-year averages for 2019–2020. Those data were the most recent available in the FAOSTAT database and due to the increasing importance of Russia and Ukraine in world exports showed the most reliable picture of import dependence. Moreover, food production and trade are affected by multiple factors; however, the demand for food, and in particular for staple food, is more stable than production. This results from the low price elasticity of demand for food, which is one of the basic human needs. This makes

the period 2019–2020 representative and allows us to draw objective conclusions. We also assessed the impact of the war on the physical access to staple agri-food commodities on the world market resulting from blocking Ukrainian seaports and signing the Black Sea Grain Initiative—BSGI (there is a lack of data on agri-food exports from Russia for 2022). The research was based on data from the UN Comtrade [34]. For this purpose, changes in exports of cereals and oilseeds due to the war were estimated, illustrating changes in the supply of these commodities in foreign markets compared to the corresponding months of previous years.

The main part of the research includes a regional analysis of retail food prices. We started with an analysis of the development of world agricultural commodity prices (based on the FAOSTAT commodity price indexes). Then, we assessed the impact of the war in Ukraine on the overall level of food prices paid by consumers (food inflation) in different regions around the world. The monthly food and non-alcoholic beverage price indexes (2015 = 100) from the FAOSTAT [35] database were used. The time range of the observations covers the period from January 2000 to December 2022. Studying the consequences of the war on food prices, we compared the actual level of food prices during the conflict period (from March 2022 to December 2022) with counterfactual values derived from forecasting models. The econometric models used to calculate forecasts were estimated on price series from January 2000 to February 2022 (as the pre-war period). This approach has the advantage of obtaining the pure impact of a structural change such as a war on prices by eliminating the influence of long-term inflationary trends or seasonality.

Considering that the forecasts obtained based on different models may differ (robustness reasons), the study used two types of models. The first is the seasonal autoregressive integrated moving average (SARIMA), while the second is the vector autoregressive model (VAR). The SARIMA model is a one-equation time series model, where the forecast depends only on the past values of the time series. The general notation of SARIMA(p,d,q)(P,D,Q)s model is [36]:

$$\varphi(B)\Phi\left(B^S\right)\left(1-B\right)^d\left(1-B^S\right)^D Y_t = \theta(B)\Theta\left(B^S\right)\varepsilon_t \quad (1)$$

where: Y_t refers to the original time series; d and D are the orders of non-seasonal and seasonal differentiation; p and P are the numbers of non-seasonal and seasonal autoregressive lags; q and Q are the numbers of non-seasonal and seasonal lags in the moving average; s is the number of seasons in a year; φ, Φ, θ and Θ are the model parameters, B is the backward shift operator and $(1 - B)$ is the difference operator.

The VAR model, in turn, is a multi-equation time series model, where the forecasts depend on the past values of all endogenous variables included in this model. VAR model is given by the following formula [37]:

$$Y_t = A_0 d_t + \sum_{i=1}^{r} A_i Y_{t-i} + \varepsilon_t, \quad (2)$$

where $Y_t = [Y_{1t}, \ldots, Y_{mt}]^{\mathrm{T}}$ is a vector of current observations of m endogenous time series; $d_t = [d_{0t}, \ldots, d_{kt}]^{\mathrm{T}}$ is a vector of $k + 1$ determinist components (constant, time variables, etc.); A_0 is a matrix of coefficients of the vector d_t; A_i is a matrix of coefficients for lagged variables in vector Y_t, where maximal lag order is r; $\varepsilon_t = [\varepsilon_{1t}, \ldots, \varepsilon_{mt}]^{\mathrm{T}}$ consists of a vector of residuals.

The estimation of those models was preceded by a unit root test (three series were I(2) whereas remaining I(1)), and the Akaike information criterion (AIC) was used for their specification (constants, number of lags). Both types of models were estimated on logarithm data. In the SARIMA model, seasonality is directly captured as appropriate seasonal lags. In contrast, in the VAR model, seasonality is captured using seasonal dummy variables. It is worth noting that VAR models were estimated separately for regions from each continent. The advantage of the VAR model is that it takes into account the potential relationships in price developments (inflation) between individual regions on a given continent due to the influence of common factors, as opposed to the SARIMA model, where the forecasts are independent of each other.

Having empirical information on food price indices P for i-regions and estimated ones in the base period t_0 = *February* 2022, as well as their forecasts F for the period $t_0 + T$ (t = 1, 2, . . ., T), forecast errors were calculated according to the following formula:

$$E_{i,t_0+T} = \log(P_{i,t_0+T}/F_{i,t_0+T}) \times 100. \quad (3)$$

Positive error values indicate that Russia's war against Ukraine positively impacted prices, whereas negative errors indicate a drop in food prices due to the conflict. The calculated forecast errors for individual regions were the starting point for further qualitative analyses. Based on the available data, we attempted to justify the differences in price responses across the regions and find market and regulatory determinants of retail food price formation. We also looked for the implications of the Russia–Ukraine conflict for food affordability and access.

3. Results

3.1. Agri-Food Supply under the Russia–Ukraine Conflict

The influence of the conflict between Russia and Ukraine on global food supply chains is multi-faceted [38]. Both countries are key producers and exporters of basic agricultural commodities in the world, while several regions depend heavily on their exports. At a regional scale, in 2021 Northern Africa and Western Asia were the major net importers of cereals and cereal preparations from Ukraine and Russia, while Eastern and Southeastern Asian regions were strongly dependent on imports from Ukraine. A similar trend was observed in the case of Southern Europe (Table A1 in Appendix A). The substantial cereal import dependency of those regions may be observed as expressed by the share of imports from Ukraine and Russia in their overall cereal imports (Table 1).

Table 1. Import dependency ratios by subregions in 2019–2020 (2-year average values, %). Source: authors' calculations from FAOSTAT [35].

Subregion	Ukraine						Russia						Ukraine + Russia					
	Cereals		Oil Crops		Vegetable Oils		Cereals		Oil Crops		Vegetable Oils		Cereals		Oil Crops		Vegetable Oils	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Eastern Africa	5.1	0.9	7.4	0.3	1.3	1.1	10.3	1.9	x	x	0.0	0.0	15.5	2.9	x	x	1.3	1.1
Middle Africa	0.3	0.1	x	x	0.3	0.1	13.6	4.1	x	x	0.0	0.0	13.9	4.2	x	x	0.3	0.1
Northern Africa	18.6	10.0	6.5	2.5	2.0	1.5	13.7	7.4	0.0	0.0	8.9	6.9	32.3	17.3	6.5	2.6	10.9	8.5
Southern Africa	1.3	0.4	0.1	0.0	1.1	0.7	10.6	3.3	x	x	0.0	0.0	11.9	3.7	x	x	1.1	0.8
Western Africa	1.3	0.3	0.1	0.0	0.7	0.3	8.7	2.3	1.6	0.0	0.1	0.0	9.9	2.6	1.6	0.0	0.7	0.3
Northern America	0.1	0.0	1.9	0.1	1.0	0.3	0.0	0.0	1.6	0.1	0.0	0.0	0.1	0.0	3.5	0.1	1.0	0.3
Central America	0.4	0.2	0.0	0.0	0.6	0.2	0.6	0.3	x	x	0.0	0.0	1.0	0.4	x	x	0.6	0.2
Caribbean	0.0	0.0	0.0	0.0	0.1	0.1	x	x	x	x	10.0	8.6	x	x	x	x	10.1	8.6
South America	0.1	0.0	0.0	0.0	0.4	0.1	0.5	0.1	0.0	0.0	0.0	0.0	0.6	0.1	0.0	0.0	0.4	0.1
Central Asia	0.0	0.0	0.0	0.0	0.0	0.0	9.7	2.3	31.3	3.4	19.3	10.6	9.7	2.3	31.3	3.4	19.3	10.6
Eastern Asia	10.8	1.2	0.0	0.0	7.3	2.9	0.7	0.1	0.9	0.6	5.6	2.2	11.5	1.3	1.0	0.6	12.9	5.1
Southern Asia	14.4	0.9	1.0	0.1	9.4	6.5	17.0	1.0	0.3	0.0	3.4	2.4	31.4	1.9	1.3	0.2	12.8	8.9
Southeastern Asia	8.9	1.9	0.0	0.0	1.9	0.3	3.7	0.8	0.0	0.0	0.6	0.1	12.6	2.7	0.1	0.0	2.5	0.4
Western Asia	10.7	6.3	13.5	7.2	6.3	5.3	24.0	14.1	7.6	4.1	14.8	12.3	34.6	20.4	21.1	11.3	21.1	17.5
Eastern Europe	3.2	0.2	10.9	1.6	9.6	4.3	3.6	0.2	9.3	1.3	2.3	1.0	6.8	0.5	20.2	2.9	12.0	5.4
Northern Europe	12.4	3.6	6.3	3.3	3.2	2.9	2.7	0.8	0.7	0.4	9.8	9.0	15.1	4.4	6.9	3.7	13.0	11.9
Southern Europe	14.9	7.3	4.1	1.5	9.6	8.2	1.0	0.5	0.5	0.2	0.1	0.1	15.9	7.8	4.6	1.7	9.8	8.3
Western Europe	10.4	4.8	9.9	9.2	5.3	5.5	0.1	0.1	0.2	0.2	0.1	0.1	10.5	4.8	10.1	9.4	5.4	5.6
Oceania	0.1	0.0	0.0	0.0	4.8	2.8	0.0	0.0	0.0	0.0	0.3	0.2	0.2	0.0	0.0	0.0	5.2	3.0

Notes: A—share of import from Ukraine and Russia in total imports, B—share of import from Ukraine and Russia in domestic use, x—no data available.

The share of cereals' import calculated for Northern Africa and Western Asia amounted to over 32% when taking into account imports from both countries jointly. A comparably high import dependency ratio was also noted for Southern Asia, while in Northern and Southern parts of Europe, similarly as in Eastern Africa, it was around 15%. This strong import dependence results from the fact that some countries in those regions are not self-sufficient in cereals due to the shortage of domestic production, while preferential trade agreements being in force support import from Ukraine and Russia (e.g., the Deep and Comprehensive Free Trade Area between the EU and Ukraine established in 2016). At the same time, in other countries of both Asia and Africa, consumption largely outpaces production, making these two regions net importers of cereals [39]. However, it should be emphasized that the share of imports from a given country might be a weak indicator of a food security risk if the imports constitute a small share of domestic consumption. A better

measure for assessing import dependence is the ratio of imports to domestic consumption. In view of the above, the most serious consequences of Russia's aggression against Ukraine, resulting in the suspension of grain deliveries might be experienced by Northern Africa and Western Asia, where the share of cereal imports from Russia and Ukraine in domestic use was over 17% and 20%, respectively (Table 1). In those regions, the supply of cereals imported from Russia and Ukraine plays a decisive role in ensuring food security and those are good examples of countries at risk.

As previously noted by Hellegers [15], Western Europe is among the greatest net importers of oil seeds and vegetable oils from Ukraine. The greater negative trade balance in trade in vegetable oils with Ukraine was recorded only in the case of Southern Asia, while in bilateral relations with Russia, high dependence on imports was observed in Western and Eastern Asia (Table A1 in Appendix A). Conclusions on the important role played by Russia and Ukraine in the total imports of oil crops and vegetable oils in the above-mentioned regions can also be drawn based on data from Table 1. Next to Western Asia, the highest contribution of the analyzed countries to the total import, although not accompanied by a significant trade deficit, was seen in Central Asia and Eastern Europe. Nevertheless, a particular threat to food security resulting from Russia's war with Ukraine concerns Western Asia, where more than 11% and 17.5% of domestic use of oil crops and vegetable oils are covered by imports from those two countries. Moreover, it can be noted that around 10% of domestic consumption of oil crops in Western Europe was covered by imports from Ukraine, while the same portion of domestic use of vegetable oils in Central Asia and Northern Europe was satisfied with imports from Russia.

Due to the difficulties in the operation of ports on the Black Sea and the Sea of Azov, being the main channels allowing the export of Ukrainian cereals, agri-food exports from Ukraine were more restricted than those from Russia. In general, it is estimated that there are 400 million people worldwide whose food security depends on Ukrainian grain exports [40]. According to Yarmak [41], the Russian invasion of Ukraine will significantly violate global food security, as the number of people who do not have access to a minimum set of calories may increase and reach even 1 billion. The threat to global food security resulting from the Russian–Ukrainian conflict was also discussed by Grant et al. [22], Lin et al. [11], Xu et al. [23], and Rabbi et al. [31]. Considering that fact, we will focus on the Ukraine case when analyzing the impact of the conflict between Russia and Ukraine on the food supply and prices.

From the short-term perspective, the suspension of port operations, which may not be easily substituted with other transportation modes, was the most important factor influencing world commodity prices. This period can be split into two phases: before introducing the Black Sea Grain Initiative—BSGI (March–July 2022) and after it (August–December 2022). During the first phase of the war period (March–July 2022), Ukrainian wheat exports accounted for only 19% of exports recorded in the corresponding months in 2020 and 26% of exports in 2021 (Figure 1, Table 2). Due to the fact that the main direction of Ukrainian wheat exports are the countries of North Africa and the Middle East (Table A1 in Appendix A), while the domestic consumption in those regions is heavily dependent on imports from Ukraine (Table 1), it should be recognized that they were at the highest risk of shortages. After signing the BSGI wheat exports constituted 71 and 75% of the exports in the analogical period in 2020 and 2021.

The war had an equally negative impact on the exports of fodder cereals (Table 2), including barley, which exports before the BSGI constituted only 12–17% of the level observed in the previous years. Exports of maize decreased by about 50%. This was due to the fact that its main recipient is the EU, while rail and road transport was less disrupted than that through the Black Sea ports. Ukraine is also a significant exporter of vegetable oils, particularly sunflower oil. Their exports from March to July 2022 accounted for 49% of exports in 2021 and 30% of the level in 2020 (in the analogous period). Interestingly, due to the difficulties with the export and refining of oils, sunflower seed exports increased markedly (mainly to the EU), which until now had practically no significance. This consid-

erably improved the supply situation in this market. In the rapeseed market, an opposite situation was observed. As the dominant direction of Ukrainian seed export is the EU, its decline in the first phase was noticeable. A significant percentage decrease in the export of rapeseed oil was noted; however, Ukraine does not play a significant role in the global supply.

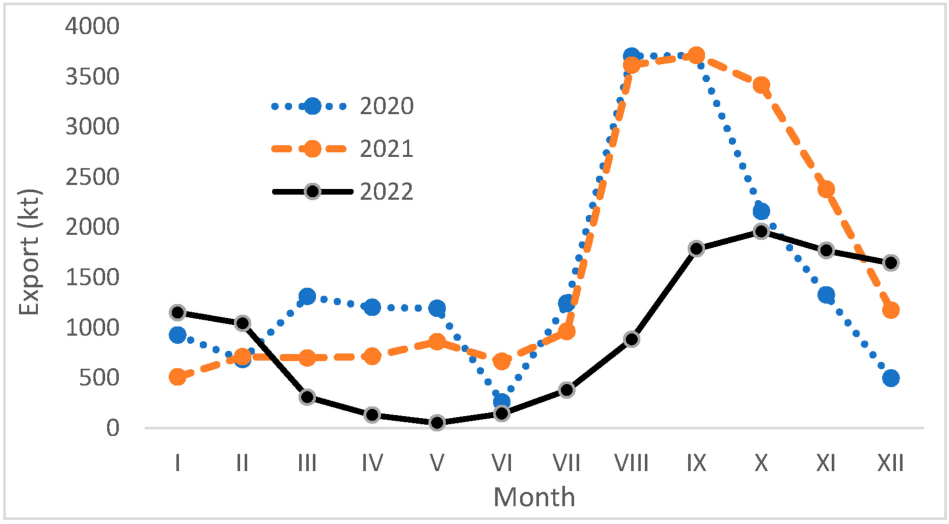


Figure 1. Wheat exports from Ukraine in 2020–2022. Source: authors' elaboration from UN Comtrade [34].

Table 2. Comparison of exports of grains, oilseed, and vegetable oils from Ukraine in 2022 with analogous periods in 2020 and 2021. Source: authors' calculations from FAOSTAT [35].

Commodity	Export Share		Export Change (1000 t)	
	2022 vs. 2020	2022 vs. 2021	2022 vs. 2020	2022 vs. 2021
March–July (Before the BSGI signing)				
Wheat	0.19	0.26	−4 195	−2 888
Corn	0.49	0.53	−5 573	−4 793
Barley	0.12	0.17	−1 602	−1 112
Sunflower oil	0.30	0.49	−1 985	−883
Sunflower seeds	50.58	155.98	1 382	1 401
Rape oil	0.37	0.63	−5	−2
Rapeseeds	0.79	2.26	−40	87
August–December (After the BSGI signing)				
Wheat	0.71	0.56	−3 356	−6 255
Corn	1.95	1.16	5 591	1 551
Barley	0.56	0.39	−1 150	−2 346
Sunflower oil	0.96	0.98	−78	−32
Sunflower seeds	3.98	15.23	492	614
Rape oil	0.61	0.45	−40	−74
Rapeseeds	1.27	1.22	588	489

Data on maritime transport confirm a huge decrease in exports of goods from Ukraine at the beginning of the conflict [42]. In January and February 2022, the number of ships loaded with goods in Ukrainian ports was more than a quarter higher than in the same months in 2021. From March to July 2022, it accounted for less than 23% (they came mainly from river ports). With the Black Sea Grain Initiative (BSGI) signing, this ratio increased to over 60% in September 2022. BSGI, guaranteeing safe sea corridors to three Ukrainian ports: Odessa, Chornomorsk, and Pivdenny, seems to be an effective tool to counter the global food crisis [32]. During its validity (from August to December 2022), about 15 million tons of cereals and oilseeds were exported by sea to 43 countries around the world. In real terms, the volume of exported cereals and oilseeds accounted for approximately 44%

of exports in the analogous period of 2021. Corn and sunflower seed exports were even higher than analogous months of 2020–2021 (Table 2). Around 48% of agricultural raw materials were exported to high-income countries, while less than 21%—to low-income and low-middle-income countries [43]. As Donaldson [44] pointed out, the flow of goods between surplus and deficit regions is of key importance for ensuring food security in import-dependent regions.

Due to the unavailability of statistical data, we do not know whether and what restrictions on food supply to world markets were in effect in Russia. The magnitude of theft of agricultural goods by Russia to sell them on world markets is not known. The relatively small price increases in North Africa and West Asia relative to those projected (see Section 3.2) may indicate that Russia has not reduced its grain exports and may have increased them. It is also likely that other countries have increased commodity exports to these regions, considering that export restrictions and high food prices lead to food riots in Asia and Africa regions [45].

3.2. Price Implications of the Conflict between Russia and Ukraine

As stated, disruption of supply chains resulting from the conflict in Ukraine could affect the prices of agri-food commodities in many regions of the world [26,28,46]. Indeed, global food prices rose sharply with the outbreak of the conflict, surpassing the speculative bubble's price levels of the so-called Arab Spring. However, this increase was only short-lived, and as early as July 2022 price indices returned to their levels at the beginning of 2022 or even below, as in the case of oil prices (Figure 2). This decline coincided with the signing of the BSGI agreement, which somewhat calmed commodity markets. In addition, upward trends in prices resulting from the economic recovery and the COVID-19 disruption of supply chains had already been observed. Thus, the medium-term impact of the conflict on world food commodity prices expressed in USD was not significant from a present-day perspective.

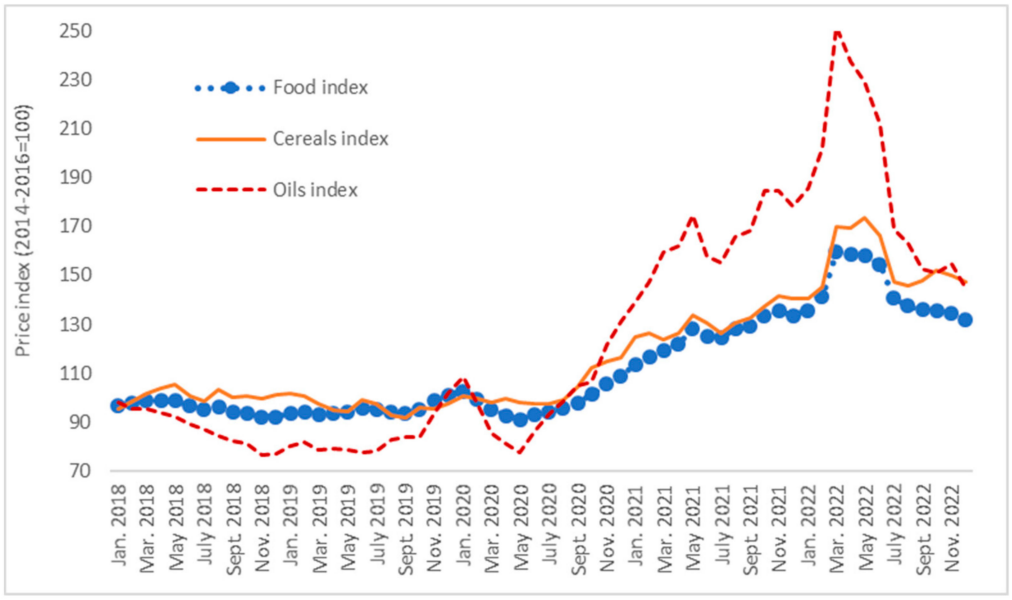
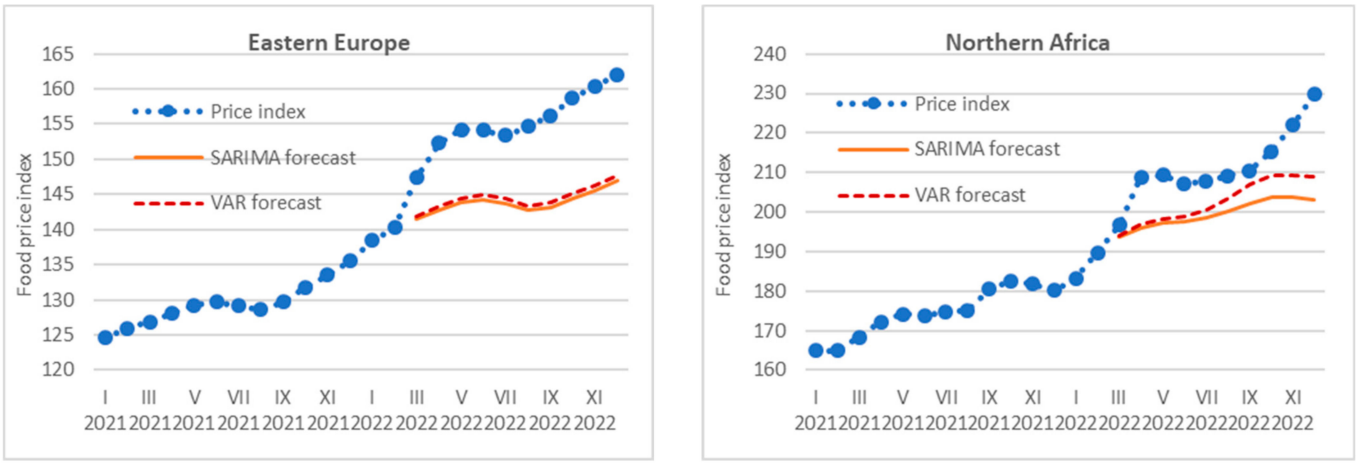


Figure 2. Food price indexes according to FAO (2014–2016 = 100). Source: authors' elaboration from FAOSTAT [35].

The threat to food security resulting from the war in Ukraine is manifested in domestic food price increases and world commodity prices are only one of the factors influencing retail food prices in individual countries or regions. Fluctuations in exchange rates, transportation costs, trade barriers, or inflationary trends mean that domestic prices for agricultural raw materials expressed in domestic currency are not necessarily correlated

with USD-indexed world prices. Also, there is a certain lag between changes in retail food prices and agricultural prices [47,48].

Many countries and regions experienced strong increases in retail food prices between February and December 2022 (Table 3). The strongest price rises were recorded in Western Asia (65.3%), South America (46.4%), and Southern Asia (28.6%). On the other hand, the least regionally significant increase in food prices over the period was recorded in Eastern Asia (2.2%), Southeastern Asia (6.3%) or Middle Africa (6.4%). A "purer" impact of the conflict on the prices can be obtained by comparing actual prices with counterfactual prices (forecasts) derived from SARIMA and VAR models. Average percentage forecast errors from both models for all the analyzed regions are provided in Table 3, while ex-post forecasts versus actual data for typical cases are shown in Figure 3. It is worth emphasizing the high consistency between the forecast errors obtained with both types of models (the linear correlation coefficient between the errors in each month exceeded 0.95), which confirms the high robustness of the results obtained.



(**a**) (**b**)

Figure 3. Examples of food price forecasts vs. actual data (indexes, 2015 = 100): (**a**) for Eastern Europe; (**b**) for Northern Africa. Source: authors' elaboration from FAOSTAT [35].

Table 3. Changes in retail food prices during the conflict in Ukraine and percentage differences between actual and predicted prices (average forecast errors obtained from SARIMA and VAR models). Source: authors' calculations based on FAOSTAT data [35].

Region	Price Change (%) from II 2022 till:				Forecast Errors (%) for the Period:			
	III 2022	VI 2022	IX 2022	XII 2022	III 2022	VI 2022	IX 2022	XII 2022
Eastern Africa	2.59	8.78	14.26	16.96	0.46	2.84	5.12	5.33
Middle Africa	1.00	2.81	4.35	6.37	−0.54	−2.67	−4.47	−5.47
Northern Africa	3.70	9.22	10.96	21.12	1.46	4.32	2.78	10.30
Southern Africa	0.58	4.90	8.32	10.43	−0.27	2.15	3.96	4.25
Western Africa	2.02	8.62	14.40	20.12	0.74	3.12	5.38	8.04
Northern America	1.46	5.08	7.91	8.94	0.82	2.88	4.58	4.80
Central America	1.22	5.32	9.46	11.09	0.40	3.52	5.28	4.73
Caribbean	0.91	4.58	7.74	13.51	0.08	1.29	2.05	5.30
South America	5.18	16.29	32.40	46.40	0.87	1.53	5.13	5.34
Central Asia	4.40	10.38	12.74	18.15	3.39	7.22	8.61	9.00
Eastern Asia	−0.57	−1.58	1.89	2.16	0.21	0.69	2.11	2.23
Southern Asia	1.52	18.71	26.70	28.58	−0.37	9.90	10.40	7.37
Southeastern Asia	0.67	3.82	4.78	6.31	1.08	2.95	3.11	3.18
Western Asia	5.33	27.78	45.07	65.27	1.30	2.60	−2.38	−7.50
Eastern Europe	5.07	9.89	11.39	15.47	3.81	6.19	8.14	9.01
Northern Europe	0.43	5.02	10.03	14.12	0.06	3.63	7.70	10.23
Southern Europe	1.11	6.21	8.41	12.42	0.69	4.61	6.62	9.17
Western Europe	0.92	5.91	10.18	13.66	0.58	4.59	8.67	11.00
Oceania	0.89	2.84	6.33	7.41	0.20	1.04	3.57	3.85

In most regions worldwide, the effect of the conflict in Ukraine was manifested in a gradual increase in food prices reflected in a regular increase in positive differences between the actual and forecasted prices. The median of the forecast errors for all analyzed regions were: 0.58% (III 2022), 2.95% (VI 2022), 5.12% (IX 2022), and 5.33% (XII 2022). This illustrates retail prices' lagged response to changes in agricultural commodity prices and rising marketing costs (wages, fuel, energy).

The strongest impact of the war in Ukraine on retail food prices was recorded in Europe, where forecast errors in December 2022 were 9–11% (Figure 3, Table 3). In Eastern Europe, located in immediate proximity to the conflict, one can see a fairly rapid and strong increase in the differences between actual food prices (indices) and forecasts. Already in June 2022 retail food prices were about 6.2% higher than the predicted ones. The errors also grew steadily and by September 2022 reached about 8.1%. Similar error patterns are observed in Central Asia. Retail food price reactions at the beginning of the conflict in other European regions were insignificant compared to Eastern Europe. However, later they started to upsurge and in December 2022 actual price levels were 9–11% higher than predicted. Non-commodity costs seem to play a key role in the formation of retail prices there. The energy crisis (the disruption of gas and oil supplies from Russia and the increase in prices) contributed to an unprecedented increase in food prices. These effects were further fuelled by increased demand due to migration from Ukraine and USD appreciation.

In Africa, we can see quite diversified retail food price reactions to the conflict (Table 3). In North Africa (Figure 3), there was initially a strong increase in retail prices in response to world price movement, but later the increase slowed. In April 2022, the forecast errors amounted to about 6% and decreased to 2.8% in September 2022. However, the food inflation accelerated at the end of 2022; in December 2022, it was over 10% higher than predicted. It might be caused by less strict food price control by the governments. A gradual increase in positive forecast errors is evidenced in the rest of the African regions (apart from Middle Africa). Middle Africa was the only region where counterfactual prices were higher than actual prices over the entire forecast horizon (negative forecast errors).

Retail price responses in Asia vary greatly between regions. In South Asia, forecast errors for September 2022 were 9.4–11.4%. However, price increases occurred only as of June 2022 and were due more to the drought in India rather than the military conflict itself. Of special note is the limited impact of the conflict on food prices in East and Southeast Asia where the share of grain import from Russia and Ukraine in domestic use was relatively low (Table 1). Interesting results were obtained for West Asia (Middle East countries). In 2022, this region experienced the highest increase in retail food prices in the world. However, the food price forecasts were even lower than the actual prices (Table 3). These results seem surprising since it was widely indicated that Middle Eastern countries were the most vulnerable to the war in Ukraine due to their high grain import dependency and high poverty levels [15].

Such diversified retail food price responses worldwide may be caused by the high Russian exports, the diversion of imports from other regions, or price control policies applied by some countries. Moreover, some regions consume relatively low-processed food, for which retail prices are more highly linked to agricultural prices. Therefore, the war-induced increases in fuel or energy prices did not play a significant role in retail food pricing as in developed countries.

4. Discussion: Linking Food Supply and Retail Price Responses with Food Security

As results from the analyses and the literature review show, there are many channels through which the conflict in Ukraine could affect global and local food security. These are summarized in Figure 4 and discussed in this section. Figure 4 describes the mechanism leading to the deterioration of food security in the analyzed period due to the conflict and factors that may exacerbate or mitigate the effects of the war depending on the country or region. The characteristics of individual countries and regions are crucial to understanding the strength of the conflict's impact. For example, the spatial proximity of the conflict, food

and energy import dependence, the share of marketing costs in the consumption value of food, internal and international policies, and the economic development of countries are among the factors determining the exposure of the population to supply and price shocks arising from the conflict or the ability to counteract the deterioration of food security.

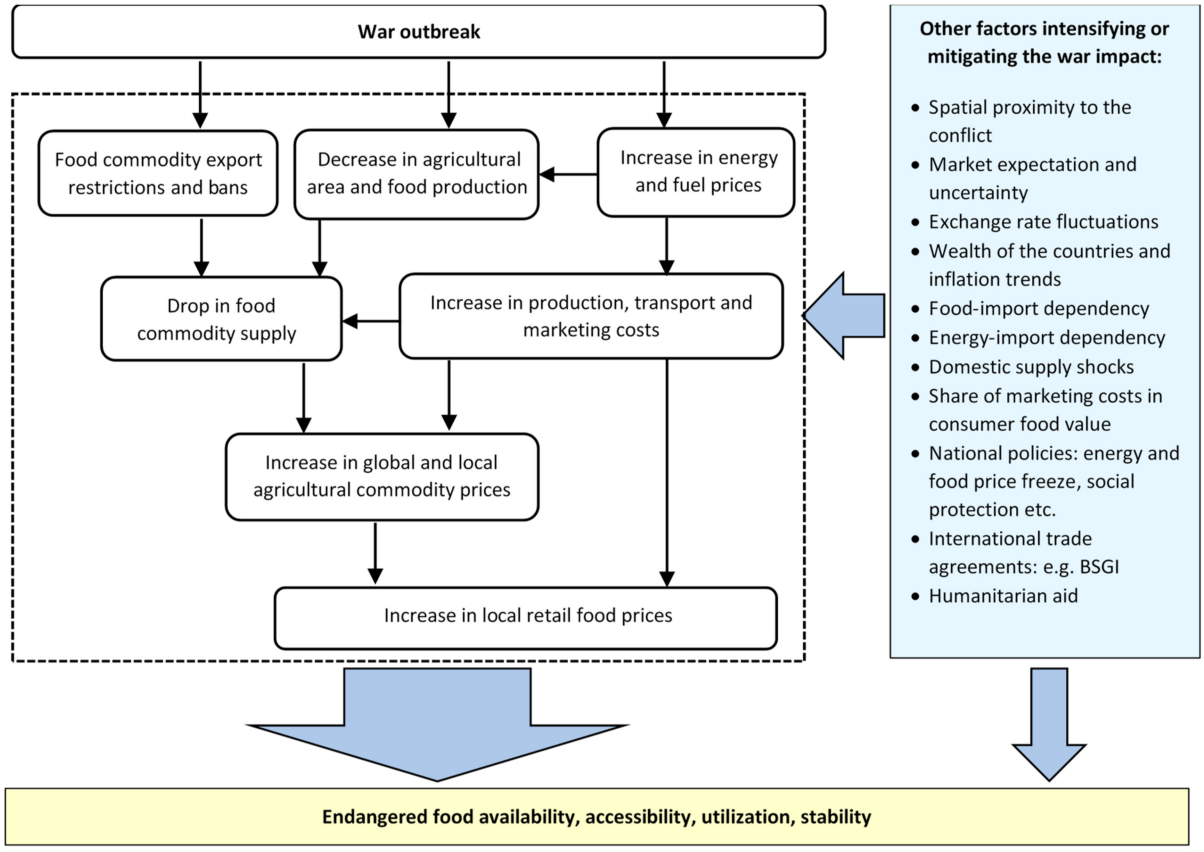


Figure 4. Short-run impact channels of the war in Ukraine for food security. Source: authors' own elaboration.

The immediate cause of food security deterioration in the short term was the decrease in the supply of staple food resulting from the limitation of Ukrainian exports. The blockade of ports at the Black Sea and the Sea of Azov, Ukraine's major food distribution channels, worsens physical food access in import-dependent regions such as Northern Africa, Western Asia, and Southern and Western Europe. It can be noted that this problem has affected not only low-income countries but also developed ones. Deterioration of food security in developing countries, including those located in Asia and Africa regions, is a consequence of the Russia–Ukraine conflict that has been previously discussed, e.g., by Arndt et al. [33], Grant et al. [22], Lin et al. [11], and Xu et al. [23]. Rabbi et al. [31] addressed this issue based on the developed European countries. In the early weeks of the war, these effects were reinforced by the short-lived export restrictions imposed by both Russia and Ukraine. In the case of Russia, the export restriction was a kind of reaction to sanctions imposed by Western European countries [49], while in the case of Ukraine, the restriction of food supplies was motivated by the strengthening of national food security policies. The possible, but significantly limited by logistic constraints, export opportunities via Poland or Romania do not improve the situation considerably [14]. It is worth noting that Ukraine's grain supply is much smaller than in previous years also due to the smaller area under cultivation, the lack of harvesting opportunities in war-affected areas, and the simultaneous theft of agricultural crops from storage facilities by the aggressor. The effect of food supply constraints led to an increase in global food prices in 2022, which

contributed to a decline in economic access to food. This finding is in line with the study by Arndt et al. [33], while Legrand [50] found that crop prices started to rise even before the outbreak of the Russia–Ukraine conflict due to the previous COVID-19 pandemic, droughts, and poor harvests in key producing areas. Very strong commodity export restrictions and uncertainty about the future supply prevailed until the BSGI was signed, which is an international trade agreement. Due to the blockade of Ukrainian seaports and the threat to global food security the European Commission at the beginning of the conflict decided to suspend all import duties and quotas on Ukrainian agricultural exports to the European Union. Booth agreements have somewhat calmed the situation in this regard, as evidenced by the decline in world agricultural commodity prices.

The second factor, apart from the decrease in the supply of agricultural raw materials, which resulted from the war and affected agri-food markets, was the increase in energy and fuel prices. As found by Hatab [29], Abay et al. [16], and Rabbi et al. [31], it mainly influenced: an increase in production costs in agriculture, as well as an increase in processing costs and transport costs. In addition, high prices of energy and fuels for households weakened their purchasing power and the ability to purchase food (see, e.g., [33]). In developing countries, rising agricultural input prices simply limit their usage, making yields lower and causing a drop in domestic production at a time of falling global supply and spiking prices. High input prices in some developed countries pushed farmers to make decisions on substituting high fertilizer-requiring crops, such as wheat or maize, with those with lower requirements; however, this trend may not be of key importance in population feeding [51]. Rising energy and transportation prices contributed to the increased food manufacturing costs, especially where the production processes are energy-intensive. This was evident in the significant increase in food prices in developed countries, where the share of agricultural raw materials in the price of the final product is relatively small. On the other hand, the consumption of less processed food in developing countries meant that the increase in world energy prices was less reflected in food prices than in developed countries. It is worth noting that the impact of this factor was not immediate, but over time the increases in fuel and energy prices became increasingly important in shaping food prices. Alexander et al. [32] proved this for the European countries.

It is worth emphasizing here that the power of changes in supply and production and transport costs, pushing the prices up, depended on at least a few other factors. On the one hand, the supply gap was more remarkable in countries strongly dependent on food imports from Ukraine while at the same time experiencing a high level of market uncertainty or depreciation of the domestic currency [14]. The supply related effects of the war in Ukraine were also exacerbated by domestic supply shocks, e.g., droughts in India, Ethiopia, Kenya, Somalia, and Sudan. On the other hand, the supply and price-related effects of the war could have been mitigated by international agreements concluded (e.g., the BSGI) or humanitarian assistance, including food aid through the World Food Programme (WFP) and other relevant organizations. Humanitarian aid efforts reduced the impact of supply disruptions on food security in developing countries by shifting food deliveries away from developed nations and to developing nations. World Trade Organization Member States agreed to exempt WFP humanitarian food purchases from export restrictions [30]. Also, many governments and other entities have offered humanitarian assistance to Ukraine.

The national governments also took some specific policies determined by the budgetary possibilities of individual countries. Extensive social protection and food aid programs were also launched to support anti-inflation policies. As reported by the FAO [52], most policy responses to soaring food prices in 2022 have consisted of subsidies to consumers and producers (food, fuel, and fertilizer subsidies). Among others, such steps were taken in countries most dependent on food imports from Ukraine, including Egypt, Somalia, the Dominican Republic, Pakistan, and Indonesia [53]. It is also worth noting here that in some countries, e.g., Germany, the non-governmental organizations were also financially supported to encourage their efforts aiming at improving access to staple foods, as well as protecting and restoring productive livelihoods in drought-affected communities in Ethiopia, Kenya, Somalia,

and Sudan [54]. In many developed countries, a large variety of classic tools such as reliefs for fuels, food, fertilizers, and other selected means used in agricultural production were in force. For example, in Hungary, the number of products available to citizens at guaranteed prices has increased while, among other things, indexation of pensions and a pension bonus were planned. Strengthening supply activities aimed at reducing costs and increasing the availability of goods were noticed in Germany. In turn, the French government prioritized the distribution of food stamps to citizens with the lowest income.

The results of our analysis, however, did not confirm the hypothesis that food prices in developing countries increased more than in developed countries due to the war in Ukraine. This does not mean that economic food accessibility deteriorates equally in developed countries and in developing ones in response to the same increase in food prices (e.g., 5%). There is a regularity: the more developed a country is, the smaller the percentage of their income the households spend on food. It is worth emphasizing that in countries such as the United States, Great Britain or Switzerland, among others, where food expenditures account for less than 15% of household expenditure, and sometimes even less than 10%, a 5% increase in food prices will not be as noticeable as in countries where food accounts for more than 40% of the budget, as, e.g., in Kenya (55%), Senegal (52%), Sierra Leone (40%), or South Sudan (89%) in 2019 [55].

Other issues, which, however, were outside the scope of our research, include the worsening of dietary diversity and the lack of high-quality food decisive to the health dimension of food security. Malnutrition may increase as a result of the deteriorated quality of the diet. All the phenomena discussed above can be observed in the short-term perspective, while a prolonged conflict will affect the availability, accessibility, and utilization of food in the long run.

In the long term, the prolonged conflict between Russia and Ukraine will inevitably force changes in the global grain trade system. Countries will be able to minimize disruptions and ensure the continued proper functioning of international markets by reconfiguring and diversifying supply networks [56]. Hence, meeting the demand of importing countries will depend on the ability of major grain producers and exporters such as Australia, North American countries, and Europe to increase production and export volumes. In particular, this will require sustainable intensification of production to feed the world's growing population with minimal risk to natural ecosystems. Concerted efforts are needed at global, regional, national, and local levels to fulfill the mission of global food security through policymaking, increased consumer awareness, knowledge of food markets, and investment in scientific research using advanced biotechnological tools to improve crop productivity [57]. It also seems that in the long term, limiting grain supplies from Ukraine may change consumer behavior, including accelerating the process of reducing food losses and waste. A significant proportion of all food produced in the world is lost in the production chain or wasted in households. Improvements in harvesting and storage methods and rationalization of consumption can potentially reduce losses and thus increase the availability of food for those in need. In conditions of supply shocks, national governments often use trade policy interventions in an attempt to stabilize domestic food prices and prevent the negative effects of volatile global agricultural commodity prices. Such a policy may exacerbate the volatility of global food prices, which will then adversely affect other countries. Farmers and producers in countries with export bans and restrictions may be unable to respond with increased production due to limited access to the global market and distorted price signals resulting in worsening supply shortages [58]. In addition to disruptions directly related to the grain market in the longer term, producers may have to deal with limited supplies of fuel and inputs, which could reduce potential sowings and yields. It seems that the impact of changes in energy and input prices on food security may be greater in the future than restrictions in grain supplies and increases in their prices. Losses and destruction of the agricultural production potential of Ukraine are also important consequences of the war. Its reconstruction in the future will require significant investment outlays.

5. Conclusions

Russia and Ukraine play a significant role in the world's supply of staple foods. Before the conflict, they accounted for around 18% of the world's cereal exports and 11% of the world's vegetable oil exports. Some regions are heavily dependent on imports of Ukrainian and Russian agri-food commodities. Northern Africa and Western Asia are among them. In 2019–2020, around 20% of domestic cereal consumption in both regions was satisfied with the supplies from the countries at war. In the latter region, more than 11% of domestic use of oil crops and 17.5% of domestic consumption of vegetable oils was also covered by imports from Russia and Ukraine. Regarding oil crops and oils, a relatively high dependency of domestic use on import was also observed in Central Asia, Western and Northern Europe. Those regions seem to be most at risk of deterioration in food security in the case of a possible reduction in supplies from Russia and Ukraine as a result of a prolonged conflict.

The conflict in Ukraine has led to the deepening of disruptions in global agricultural and energy commodity markets. The effects were both short- and long-term. Long-term effects from increased input prices or reduced production potential in Ukraine were not fully analyzed here. The short-term effect was a practical halt in the export of agricultural commodities from Ukrainian seaports (from March to July 2022), the effect of which was a strong increase in world grain and oil prices. After signing the BSGI from August to December 2022, almost 16 million tons of grains and oilseeds were exported by sea, which was about 44% of the exports in the same period of 2021. The signing of the BSGI led to a calming of the market situation and a drop in world prices. Nevertheless, only 21% of total agricultural commodity exports under the BSGI were directed to low-income and low-middle-income countries.

The strongest impact of the conflict on the reduction in export volumes from Ukraine was observed in the case of wheat, corn, and barley. For wheat, which is crucial for food security, this shortage resulting from limited Ukrainian exports accounted for about 4% of global wheat exports in 2021. Due to the high import volumes, North Africa and the Middle East were most at risk of shortage. The lack of data on exports from Russia does not permit a reliable assessment of the magnitude of the disturbance in exports of grains and oilseeds from that country. However, in light of the price response, it seems that the disruption was not significant.

The price analysis showed that there had already been upward trends in retail food prices in most regions around the world before the conflict, which only intensified after the outbreak of the war. In light of the estimated ex-post forecast errors, the war has contributed to a significant increase in food inflation worldwide. The strongest impact of the war on prices in 2022 was recorded in Europe, Central Asia, and South Asia. The research showed that in North Africa and the Middle East (West Asia), which have a relatively significant share of their imports of agricultural commodities from Russia and Ukraine in domestic consumption and imports, the impact of the war on price increases was less than anticipated. The observed varied price responses seem to be determined by the region's distance from the area of the military conflict, the share of agricultural commodities and non-commodity costs (energy and fuels) in the price of food, or the post-conflict policies pursued by countries. No correlation was found between the increase in food inflation due to the conflict and the region's degree of economic development.

Our study also has some limitations related to the data and methodology used. It should be noted that, in addition to the war, the level of consumer prices in each region was influenced by several other specific factors, which may cause a bias in the obtained estimates of forecasts and errors. In future research, it seems advisable to quantify the relationship between price changes during the war and the variable determining the level of food security. It would also be advisable to study the impact of conflict on food security at the national level or by different income groups due to the possible heterogeneity of FAO regions.

The Russia–Ukraine conflict has highlighted the vulnerability of global food security and, in the long term, underlined the critical need to achieve food resilience through the transformation and diversification of agri-food systems. Diversification of food, production,

crop, and technology markets is needed to secure global food supplies and build resilience to future shocks. Considering this, more detailed analyses of the long-term impacts of the Russian–Ukrainian conflict on global food security would also be valuable in the course of further research.

Author Contributions: Conceptualization, K.P., M.H., J.S. and J.G.; methodology, M.H. and K.P.; software, M.H. and K.P.; validation, M.H. and K.P.; formal analysis, M.H. and K.P.; resources, K.P., M.H., J.S. and J.G.; writing—original draft preparation, K.P., M.H., J.S. and J.G.; writing—review and editing, K.P., M.H., J.S. and J.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Data Availability Statement: The data presented in this study are publicly available in FAOSTAT, UNCTAD and UN Comtrade Databases.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Balance of trade in cereals and cereal preparations, oil seeds, and vegetable oils with Ukraine and Russia by world regions in 2021 (million USD). Source: authors' calculations from UNCTAD [13].

Region	Cereals and Cereal Preparations		Oil Seeds		Vegetable Oils	
	Ukraine	Russia	Ukraine	Russia	Ukraine	Russia
World	−12,775.0	−10,232.8	−2306.6	103.8	−6802.4	−3015.7
Africa	−3104.2	−3423.4	−38.9	−9.2	−292.4	−231.1
Eastern Africa	−343.0	−441.1	0.0	x	−61.7	−19.7
Middle Africa	x	x	x	x	x	x
Northern Africa	−2472.8	−1978.2	−38.3	−10.8	−199.5	−206.9
Southern Africa	−9.3	x	x	0.0	−5.0	−0.3
Western Africa	−254.8	−550.7	−0.4	1.6	−23.9	−3.9
Americas	−52.7	−155.8	14.0	927.3	−136.5	−22.7
Northern America	−14.8	−6.3	−37.7	−27.7	−102.5	0.1
Latin America and the Caribbean	−37.9	−149.6	51.7	955.0	−34.0	−22.8
Central America	−33.3	−38.7	0.3	8.2	−11.7	−2.2
Caribbean	−0.1	−10.2	x	x	−0.7	−20.1
South America	−4.6	−100.6	51.5	946.8	−21.6	−0.4
Asia	−7493.6	−6278.2	−590.7	−467.0	−3662.5	−2632.5
Central Asia	−17.8	−324.7	0.5	−25.3	−1.6	−470.3
Eastern Asia	−3473.7	−379.7	−39.2	−420.6	−1079.5	−1005.3
Southern Asia	−747.0	−756.2	−250.2	7.2	−2159.4	−707.0
Southeastern Asia	−1236.8	−495.9	−0.7	−3.1	242.1	794.4
Western Asia	−2018.3	−4321.7	−301.2	−25.2	−664.1	−1244.3
Europe	−2123.5	−375.3	−1724.4	−347.3	−2670.5	−129.4
Eastern Europe	4.6	−232.3	−274.0	−353.6	−434.3	19.4
Northern Europe	−243.2	−32.6	−177.9	−11.9	−228.2	−231.6
Southern Europe	−1061.8	−254.5	−104.9	61.7	−889.9	99.3
Western Europe	−823.2	144.2	−1167.6	−43.6	−1118.1	−16.5
Oceania	−0.9	0.0	33.4	x	x	0.0

Note: x—no data available.

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