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AN ASSESSMENT OF THE RUSSO-UKRAINIAN CONFLICT ON THE EUROPEAN CEREAL EXPORTS USING NETWORK THEORY

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Abstract

Cereal grains are basic nutrients in the human diet. Given the production capacity gap between countries, food security is subject to global challenges. The Russian invasion of Ukraine from February 2022 has inevitably raised concerns on the resilience of the agro-food system. In this paper, we use network theory to examine the export flows of the European producers of wheat, maize, and barley. Based on annual data from the United Nations Comtrade database, we build specific weighted and directed networks to comparatively assess the dynamics of cereal exporting patterns. We employ centrality metrics for network statistics and modularity for community detection. The central hub for all three cereals remained unchanged. Our results show the following core countries Russia for wheat, France for barley and Ukraine for maize. Their main export destination is also the same, from Russia to Türkiye, France to China and Ukraine to China respectively. Compared to the previous year, several destinations including low-income countries worldwide did not appear as recipients of the Ukrainian exports, but additional countries located in Europe and interconnected by land emerged as partners. This study provides a general assessment of the European exports to support a better understanding of the community structure under the Russo-Ukrainian conflict setting.

Keywords: Network analysis, Cereal trade, Centrality metrics, Conflict, Supply chain
JEL Classification: F51, D74, D85, Q17

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1. Introduction

Safeguarding food security is a worldwide challenge due to the existing gap between production capabilities and the actual consumption at country level. In agriculture, the geographical position holds a vital role given the influence of the weather conditions and the soil on the crops. Depending on their ability to self-suffice domestic demand, countries may choose to participate in international trade. Corroborated with the income levels and the available workforce, those countries that rely heavily on imports are more likely to experience food shortages. Globalization has enhanced trade worldwide but also increased the vulnerability of countries to disruptions in the supply chain, turning food security context into a constant preoccupation among scholars.

As internal production cannot always meet the domestic demand, international trade has been a contributor to balance the trade flows especially in agriculture. Cereal grains are essential components of the human diet due to their nutritional values and their absence can lead to malnutrition. Recent events have triggered insecurity on the global food market. Gradually recovering from the Covid-19 pandemic, the global agro-food system is again under pressure amid the Russo-Ukrainian conflict, as both countries are important producers and exporters of cereal grains.

On 24 February 2022, Russia launched a military invasion of Ukraine (Ellyatt, 2022). Subsequently, the Russian forces blocked the Ukrainian ports. As of June 2022, the Ukrainian president Volodymyr Zelenskyy declared that 22 to 25 million tonnes of grains were trapped inside the country underlining the importance of the maritime commercial activity (Abdülkerimov, 2022). The foreign policy chief of the European Union Josep Borrell publicly referred to the cereal blockade as a "real war crime" (Siebold and Van Campenhout, 2022). By the end of July 2022, both parties reached a 120-day valid agreement in Türkiye to restore the shipment of agricultural products (Drury, 2022). However, in October 2022, Russia suspended its participation in the grain deal that safely ensured the Ukrainian exports at the Black Sea (Walters et al., 2022). The conflict has developed with an alert evolution.

One of the affected areas derived from this conflict setting is the cereal trade. We aim to contribute to the existing trade literature by using network theory to comparatively assess the export flows of European producers to determine how the trade patterns have changed compared the pre-conflict year. Thus, motivated by Ukraine's role in the agricultural market, we identify the main cereals grown in Europe and their regional producers. We collect data on the European export flows for the latest two years and study the specific networks by acknowledging the existence of trade links between countries, finding the countries that hold a leading position in each network and detect their communities.

The purpose of this study is to provide a better understanding of updated European cereal flows. It can also be used as a complementary analysis to identify vulnerabilities and

opportunities in such situations of uncertainty generated by disruptions in the food supply chain.

Our paper is organized as follows: the next section covers a review of the relevant literature on food security related issues. Moving forward, we define the network theory concepts used in our analysis and describe the data collection process. The results are presented in section 4 and focus on the visual representation of the export networks and their metrics. We partition the networks to explore the communities, identify the core countries and comparatively assess the results. The conclusions are provided in the last section.

2. Literature review

One of the factors threatening the agricultural sector is the crisis. Green and Kirkpatrick (1982) investigated the food crisis from 1974 using cereal data at aggregate level for wheat, rice, and feedstuffs for 50 countries with food deficits. Their study drew attention on the global insecurity generated by an extreme climate resulting in poor crops and price increases which exposed the low-income countries to vulnerabilities mostly through malnutrition. The variability in food consumption depended on a cumulus of factors but most importantly on internal production capabilities, foreign exchange, and domestic food policies.

A conjunction of internal and external factors contributes to food insecurity. Diakosavvas (1989) considered such combination of factors to analyze their influence on less developed countries which are affected by crisis, recession, protectionism, or disruptions in the supply chain given that food imports hold a significant share of their overall imports. Following the cross-sectional analysis and regression, the most significant factor to explain the food consumption instability was food production as internal factor.

Apart from climate conditions, there are other factors that can trigger a food crisis. According to Devereux (2001), the disruptive effects of the war are materialized in production drops and labor shortages along with the disruptions of the ordinary trade routes and remittances. War can contribute to famine by reducing food stocks and increasing food prices in conflict-affected areas.

Countries become connected by trading to each other, and the trade flows can be represented as graphs to visualize the trade dependencies and build an entire network to identify structural characteristics. The empirical analysis of the world trade web within a network theory framework started with Serrano and Boguñá (2003) who showed that the trade links between countries shared the characteristics of a complex network. The trade links for the year 2000 revealed a hierarchical structure where the developed countries were highly connected whereas the less developed countries had poor interaction.

Wu and Guclu (2012) built a maize trade network with trade flows from 2000 to 2009. The countries with similar food policies formed different communities. The United States emerged as main global exporter of maize whereas Japan was the main importer. The European countries

were grouped into one community given their similar food regulations with France and Hungary leading the exports in the region. Ukraine was ranked on the eight-place based on the volume of maize exported during the reference period.

As emphasized by D'Odorico et al. (2014), trade is contributing to food security as some countries, mostly from Africa and the Middle East, are not able to self-suffice domestic demand. A strong trade dependency relationship leaves these countries at risk of food scarcity when the main exporting countries are facing extreme weather conditions. This affects crop production and the global food market dynamics by supply drops and price fluctuations.

By analyzing wheat and rice with data from 1992 to 2009, Puma et al. (2015) observed a significant increase in trade flows and their magnitude. Whereas a strongly interconnected global food network is robust to random shocks on minor nodes, it remains subject to systemic risk. There is a high dependency on imports for the less developed countries. During times of crisis, trade disruptions can appear due to protectionism manifested as trade restrictions and countries can switch from an exporting to a non-exporting status.

Bren d'Amour (2016) assessed the vulnerability of countries to supply shocks for wheat, maize, and rice. The main findings drawn from the average annual export data between 2007 and 2011 showed that trade disruptions mostly affect the Middle East for wheat, Central America for maize and Western Africa for rice. Considering poverty levels, the most vulnerable region is Africa with 33 countries at risk. Due to a geographic grouping pattern, supply shocks tend to affect a whole region rather than targeted countries only. For the selected crops, the dominance of some producing countries was observed in the world trade network. The suppliers of wheat are mainly Russia, Kazakhstan, Ukraine along with countries from North America and the Western Europe notably France. Maize exports mostly originate from the United States whereas Thailand and Vietnam are mostly exporting rice.

Distefano et al. (2018) evaluated the impact of food supply shocks on the international food trade network between 1986 and 2011 for wheat, maize, rice, and soybeans. Developing countries absorbed most of the negative effects. The income per capita exerted not only purchasing but also bargaining power. The latter did not depend entirely on the quantities imported. Poorer countries are exposed first to vulnerabilities experiencing larger food import drops. Moreover, in detecting trade shocks, price fluctuations should be accompanied by a quantity analysis of the trade flows to properly identify and assess its negative effects.

Under a multi-network approach, Torreggiani et al. (2018) considered the trade flows of the 16 most traded crops internationally to assess the community structure. The distribution of countries into the same community is influenced by their location and any existent trade agreements between them rather than the size of each individual economy. If countries with central positions in a community are subject to shocks, the expected results would be a decrease in the supply combined with increased prices. However, alternate trade partners from other communities might cover the import necessities.

Trade contributes to food security by allocating food surpluses towards food-deficit countries attempting to meet domestic demand through imports. Dupas et al. (2019) studied cereal trade flows between 1986 and 2013 from a network perspective to identify the distribution of countries. Three sub-networks emerged: a backbone sub-network comprising countries with a constant presence during the reference period, a transient sub-network formed by countries with a short time presence of two years or less and an intermediate sub-network for the remaining countries.

To study both direct and indirect trade dependencies, Burkholz and Schweitzer (2019) aimed to build a higher-order trade network with data on wheat, maize, rice, and soy for 176 countries from 1992 to 2013 by using a cascade model that integrates the export restrictions as a supply shock response. Rice is the crop with the highest exposure to cascades. The exogenous shocks experienced by the main suppliers propagate in the network and reveal several trade dependencies. Countries from South America and partially from Asia depend on the United States. The South African region depends on America and Asia while North Africa is mainly dependent on Europe. Countries in Europe act mostly as intermediaries.

Gutiérrez-Moya et al. (2021) built and analyzed a global wheat trade network with data from 2009 to 2013 to find a more resilient food network overtime with trade flows that tend to occur between countries from the same region. However, the vulnerability to production shortages still exists for countries in Africa, America, and Asia. The dependency on imports turns countries into being more sensitive to supply shocks. Major supply chain disruptions generate uncertainty and government responses can amplify these effects, as trade restrictions mostly affect the consumers and poor countries.

Duan et al. (2021) conducted a global analysis for a weighted grain network comprising 196 countries using the monetary values of the imports and exports between 2000 and 2018 to find a core-periphery structure with the United States positioned in the center as the main hub. Throughout time, the countries grouped closer to the core and dissipated on the periphery. Opposite to the gravity model, the geographical distance between countries positively impacted food trade. The same effect is held by economic development, the endowments of resources and regional free trade agreements while the cultural similarities and divergent politics negatively impacted the food trade.

Taking the import quantities for wheat, rice paddy, and maize from 1992 to 2018, Wang and Dai (2021) studied the food trade dynamics in a complex network analysis. Whereas the number of communities increased from four to six, the main exporting countries did not change their core positions. The United States was the hub for both the export and the import network with significant control on the food trade. As of 2018, Ukraine and Russia were placed in different communities dominating the second and third largest community. The core export countries showed more stability in time than the core import countries.

Recurring to network analysis tools Chen and Zhang (2022) examined the evolution of the cereal trade flows within the Belt and Road region to assess structural characteristics of the

network. Their findings placed India, Russia, and Ukraine at the core of the network being the most influential trade partners. The core-periphery structure was observed by having a few powerful exporters with significant market power and many countries heavily dependent on imports. Countries which are geographically close are inclined to form trade blocs.

Cereal trade is directly linked to food security. When consumption exceeds domestic production levels, the imports grow at a faster pace. Marson (2022) focused on cereal trade as the most connected agricultural sector to food supplies and nutrition to find that trade openness reduces the incidence of malnutrition in developing countries which are negatively affected by trade barriers because imports are a major component in these countries.

During the past year, the global agro-food markets has fallen under the pression of the Russian military invasion of Ukraine. to become the subject of various qualitative and quantitative research. As an important supplier of agricultural commodities to the international market, Ukraine has been facing the negative impact of war. Shubravska and Prokopenko (2022) discussed the losses occurred in terms of damages to agricultural land and forestry, food stocks, drops in production and increasing input costs along with the blockade of ports obstructing the Ukrainian trade flows. Khudaykulova et al (2022) reviewed the economic consequences of this military conflict. The concerns were oriented towards inflation and uncertainty on the financial markets, the dynamics of the oil and natural gas market in Europe and the vulnerability of developing countries in Europe and Central Asia.

Mottaleb et al. (2022) quantitatively assessed the conflict impact on food security through an econometric study using wheat-related data for 163 entities between 2016 and 2019. Recommendations were given in the context of the conflict between the Russian Federation and Ukraine for alternate wheat sources or substitutes. This can be done by increasing the domestic production of the countries that rely on imports, especially those located in Asia and Africa, and encouraging other wheat producers such as China, India, the United States or Argentina to engage in increasing their exports levels.

Among the vulnerabilities triggered by the conflictual relation between Russia and Ukraine, Hellegers (2022) expressed concerns mostly over increases in food prices globally and severe food insecurity in low-income countries that are highly dependent of cereal imports corroborated with their internal socio-economical struggles (i.e., Yemen, Lebanon, Egypt, Tunisia, or Türkiye). Other concerns include a decline in maize trade with indirect effect on the European Union and a workforce cut-off in the Ukrainian production process affecting harvesting periods due to the reallocation of people towards the war.

Network analysis is a versatile approach to study trade and conflict. Gönçer-Demiral and İnce-Yenilmez (2022) evaluated the trade flows for the biggest 50 countries by export volumes in 2019 and 2020 using social network analysis. At a continent-level, European countries intensively trade between each other. The geographic proximity pattern is also revealed for countries with low export levels. The Covid-19 pandemic did not change the primary trade relations in the short term.

Due to the sanctions applied amid the Russo-Ukrainian conflict, Li et al. (2022) conducted an impact analysis of the economic system using complex networks and input–output analysis. One of the authors' main findings indicates that third parties, most notably China, Germany, United States and France, with strong links towards or from Russia are also subject to economic shocks.

Conflict impacts trade on a larger scale. It does not only affect the parties directly involved in a war but also the dynamics of their region and the trade system. Network theory applications in agro-food systems have increasingly populated the related literature during the last decade. In the next section, we present the key notions used for the cereal trade network.

3. Methodology

3.1. General concepts of network analysis

For the methodological framework, we use basic graph theory concepts to employ a network analysis approach. We define the agricultural trade network as a graph G where the countries are the node set $V(G)$ and the trade flows are the edge set $E(G)$. Conventionally, an edge $\{i, j\}$ is denoted as ij. Any two nodes i and j are adjacent, if $ij \in E$. The neighborhood of a node i is the adjacent node set:

$$N(i) = \{x \in V \mid ix \in E\} \quad (1)$$

The count of total nodes adjacent to a given node i is called degree and constitutes a basic centrality metric. By acknowledging the existence of the edges between nodes, we obtain an unweighted network. The network is represented as a N × N matrix with a binary adjacency matrix $A_N = \{a_{ij}\}$ where $a_{ij} = 1$, if nodes i and j are connected meaning country i trades with country j, and 0 otherwise.

In a network, not all nodes are of equal importance. The degree centrality reveals the position of a node and its involvement in a network. Nodes with high connectivity are called hubs. As highlighted by Freeman (1978), detecting central nodes is an essential step for network characterization. In an unweighted network, the degree of a node (k_i) is given by the total count of the adjacent links:

$$k_i = \sum_{j=1}^{N} a_{ij} \quad (2)$$

The trade links from country i to country j can be unidirectional or bidirectional. As they are not reciprocal, we need to consider their direction when assessing the overall network which becomes a directed trade network. In this case, the degree centrality differentiates between the in-degree (k_i^{in}) representing the number of incoming links or else the count of import trading partners and the out-degree (k_i^{out}) representing the number of outgoing links or the count of export trading partners. The average degree indicates the average number of links or trade partners for a country calculated as follows:

$$k^{avg} = \frac{1}{N}\sum_{i=1}^{N}(k_i^{in} + k_i^{out}) \quad (3)$$

The network density (d) is a measure calculated as the ratio of the actual number of edges (m) relative to the total number of possible edges. The value ranges from 0 in the case of a graph with no edges to 1 that corresponds to a complete graph. Denser networks have more connections while low-density networks are sparser. For a directed network with n nodes, the density can be expressed as:

$$d = \frac{m}{n(n-1)} \quad (4)$$

Based on the relationship between the nodes connected through the edges, communities emerge to group nodes considering their structural position. The community structure was early approached by Weiss and Jacobson (1955) who determined the structure of a complex system through a sociometric analysis applied to a government agency by separating work groups keeping no links between them to show the position of liaison individuals and the importance of connectors within the organizational structure. Thus, community detection can be used to identify the structural position of nodes.

Radicchi et al (2004) addressed the community structure as a topological property that identifies relevant subsets of nodes that are densely connected showing a strong cohesion while manifesting sparse connections with the other nodes in the network that fall outside their community. In a review conducted by Fortunato (2010), the nodes with a central position in their own community can have a controlling role in leading the flows and stabilizing the network. Communities are detected by partitioning the network. While each node is assigned to a community, it can also exchange links to nodes from other communities.

To find meaningful partitions, Newman and Girvan (2004) introduced the concept of modularity as a metric to quantify a relevant community structure. Modularity is a quality function, a method for community detection and for network visualization given the structural position of nodes. To detect communities, nodes are grouped based on their similarities.

Consider c_i the community assigned to node i. The function $\delta(c_i, c_j)$ equals 1 if $c_i = c_j$ and 0 otherwise. Let m be the total number of edges in the network with $m = 1/2\sum_{ij} A_{ij}$. Then $k_i k_j / 2m$ is the probability of an edge connecting two nodes i and j. As presented by Newman (2004), the modularity (Q) for unweighted networks can be written as:

$$Q = \frac{1}{2m}\sum_{ij}(A_{ij} - \frac{k_i k_j}{2m})\delta(c_i, c_j) \quad (5)$$

Beyond the link direction, trade flows are not usually symmetrical in volume or value and the edges may capture additional information through the weight (w_i). According to Granovetter (1973), the edge weight describes the frequency of the link between any two connected nodes reflecting its strength (s_i). Edges with different strengths compute a weighted network represented by a non-binary adjacency matrix.

$$s_i = \sum_{j=1}^{N} w_{ij} \quad (6)$$

We obtain a weighted and directed trade network where the strength is given by the cumulative volume of the trade flow. As direction matters, we distinguish between the weighted out-degree (s_i^{out}) which is the quantity traded from country i or the export flow and the weighted in-degree (s_i^{in}) which is the quantity traded to country i or the import flow. Both components contribute to the average weighted degree of the overall network reflecting the average volume of the trade flow calculated as follows:

$$s^{avg} = \frac{1}{N}\sum_{i=1}^{N}(s_i^{in} + s_i^{out}) \quad (7)$$

According to Newman (2004), standard techniques in unweighted networks can be extended to weighted ones. By replacing the degree (k) with the strength (s) of a node and the number of edges (m) with the sum of all weights (W), the calculation of modularity in weighted networks is written as follows:

$$Q = \frac{1}{W}\sum_{ij}(W_{ij} - \frac{s_i s_j}{2W})\delta(c_i c_j) \quad (8)$$

In our analysis, we recur to a combination of both unweighted and weighted centrality metrics to identify patterns. To characterize the trade network, it is essential to consider the popularity of trade partners along with the trade volumes to determine the position of countries and assess the role of hubs within the communities to evaluate their importance and trace any trade dependencies to evaluate the potential impact of trade disruptions.

3.2.Data processing

We select three commodities: wheat and meslin, barley, and maize (corn) as provided by the publicly available UN Comtrade database[1]. We focus on the export trade flows from a country to all its trade partners. For the cases in which the reporting country has missing values in the exported quantities, we calculate the same based on the imports declared by its trade partners. We use annual data collected as the net weight (kg) for the years 2021 and 2022 respectively. Beyond relaxing the Covid-19 pandemic restriction, this time span is particularly interesting because it also captures the Russian military invasion of Ukraine that started in early 2022. This allows us to review the impact of the conflict on the trade flows and to comparatively assess the situation with the previous period to detect any positional changes.

We use the open-source software Gephi 0.10 to build the weighted and directed cereal trade networks, visualize the data, and run basic network metrics. The trade links are represented as "source – target" pairs and the export quantities from a country towards each trade partner are collected as weights during the reference period. The communities are distinctively represented in the network and the nodes scaled based on exports.

[1] UN Comtrade Database commodity codes: wheat and meslin (HS 1001), maize (corn) (HS1003) and barley (HS 1003).

4. Results

Wheat, maize, and barley are among the top cereals produced in Europe. Based on FAOSTAST data for 2021 (table no. 1), the European production was around 269.18 million tonnes for wheat, 141.85 million tonnes for maize and 89.39 million tonnes for barley. Russia was the leading European producer of wheat with approximately 34.70% of the regional production followed by France (16.22%) and Ukraine (14.68%), but also of barley (20.13%) followed by France (12.66%) and Germany (11.66%). For maize, Ukraine is the main regional producer with a share of 29.69% of the European production followed by France (10.83%) and Russia (10.74%).

Table no. 1: Production Quantity (million tonnes) in 2021

Country	Wheat	Country	Maize (corn)	Country	Barley
Russia	76.06	Ukraine	42.11	Russia	18.00
France	36.56	France	15.36	France	11.32
Ukraine	32.18	Russia	15.24	Germany	10.41
Germany	21.46	Romania	14.82	Ukraine	9.44
United Kingdom	13.99	Poland	7.32	Spain	9.28
Poland	11.89	Hungary	6.42	United Kingdom	6.96
Romania	10.43	Italy	6.08	Denmark	3.46
Spain	8.56	Serbia	6.03	Poland	2.96
Bulgaria	7.34	Spain	4.60	Romania	1.98
Italy	7.29	Germany	4.46	Czechia	1.75
Others	43.41	Others	19.41	Others	13.83

Source: Authors' calculation based on FAOSTAT data

For the European producing countries, we consider the overall net weight of their export flow to each of their trade partners for 2021 and 2022 to build specific networks for the selected cereals. From this data, we draw the main network metrics (table no. 2). The total nodes denote the number of overall countries engaged in the network and the edges correspond to an unique trade pair. The trade flow is directed from country A (as European producer) to country B (as export destination). Thus, the out-degree is showing the number of export trade partners and the weighted out-degree is capturing the export volumes (million tonnes).

Table no. 2: Network overview

Indicator	Wheat and meslin		Barley		Maize (corn)	
Year	2021	2022	2021	2022	2021	2022
Nodes	143	124	113	100	118	123
Edges	959	844	673	622	909	923
Density	0.047	0.055	0.053	0.063	0.066	0.062
Average out-degree	27	24	19	18	30	31
Average weighted out-degree	2.9	2.11	0.74	0.47	1.69	1.66
Number of communities	5	5	4	6	3	6

Source: Authors' calculation based on UN Comtrade data

The structure of the network explains the low-density values. Our purpose is to visualize the worldwide export flows of the European producers which are a part of a wider global trade network. The average exported volumes are higher for wheat and meslin and increased in 2022. The average European exports of both barley and maize decreased compared to 2021 but with a more notable reduction on the former. On average, a European producer has more trade links in the maize network.

The following sub-sections comparatively assess the composition of each cereal network for 2021 and 2022. The dimensions of the nodes are scaled by their weighted out-degree so that the size of the country name reflects the total export net weight to easily identify the hubs within the reference period. The width of the edges is scaled by the total net weight exported from a country to any trade partner. By running modularity, the network is divided into optimal number communities that have been assigned a distinctive colour for network visualization purposes.

4.1. Wheat and meslin network

In 2021, the overall wheat and meslin network had approximately 144 countries with 35 European producers and their export trade partners creating 959 distinct country pairs. The hubs representing the main exporters by net weight are: Russia, Ukraine, France, Germany, Romania, Bulgaria, Poland, Lithuania, Czechia and Latvia. The highest export flows have been registered from Russia to Türkiye, Russia to Egypt and Ukraine to Egypt.

In 2022, the participation of countries decreased to around 124 countries with 33 European producers that have exported wheat and meslin through 844 trade links. Although the hubs remained unchanged, their order had been slightly changed, as France has surpassed Russia and Ukraine while Latvia positioned itself ahead of Lithuania, and Czechia. The highest export flows have been registered from Russia to Türkiye, Russia to Egypt and France to Morocco.

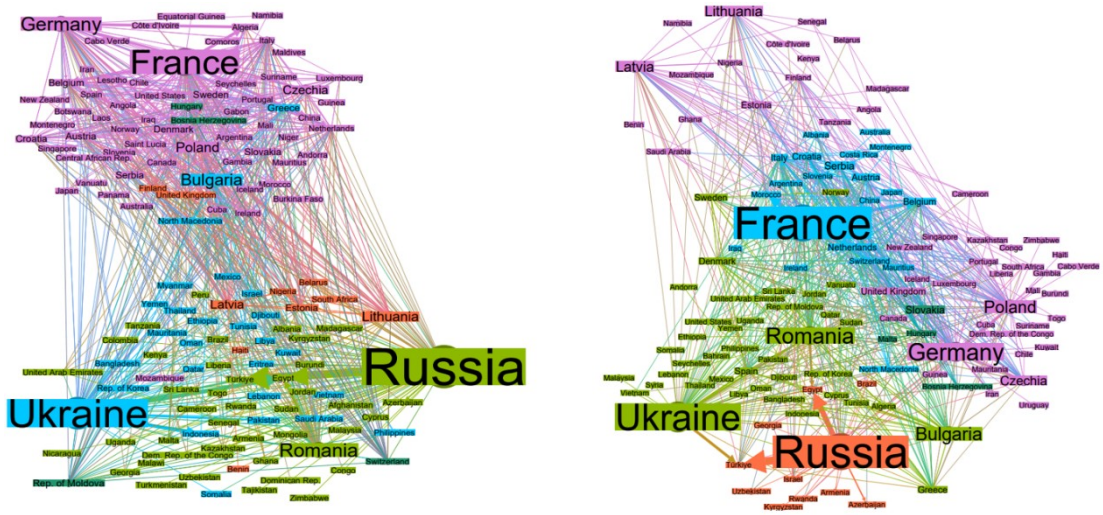


Figure no. 1: Wheat and meslin trade network 2021 (left) and 2022 (right)

Source: Authors' representation based on UN Comtrade data

There are five communities with the following leading countries per community: Russia, Ukraine, France, Lithuania, and Serbia in 2021 and Russia, France, Ukraine, Germany, and Slovakia in 2022 (figure no. 1). Ukraine was placed in the same community as Russia in 2021 but they have no trade links with each other in 2022.

The recipient countries of Russian wheat and meslin exports have significantly decreased in 2022. More than 50 countries, most notably African (i.e., Nigeria, Sudan, Kenya, Libya, Ethiopia, Ghana, Senegal, Uganda etc.) and Asian (i.e., Kazakhstan, Bangladesh, Saudi Arabia etc.) countries are not present in 2022. For Ukraine, the number of export trade is comparable, however, with several substitutions. Most notably, Romania came in as one of the major export destinations. Other European countries also appeared as trade partners for Ukraine in 2022 such as Slovakia, Bulgaria, Latvia, Portugal, or Estonia.

4.2. Maize (corn) network

In 2021, the maize (corn) network included around 118 countries comprising 30 European producers and their export trade partners which have established 909 distinct country pairs. It is divided into three communities led by Ukraine, Russia and France (figure no. 2). Romania is the second hub by exported quantity after Ukraine and they pertain to the same community. Other significant European exporters are Serbia, Poland, Bulgaria, Croatia, Germany, and Slovakia. Ukraine has the highest exports flows from the network, the largest quantity being exported to China, followed by Spain, Netherlands, Egypt, and Iran.

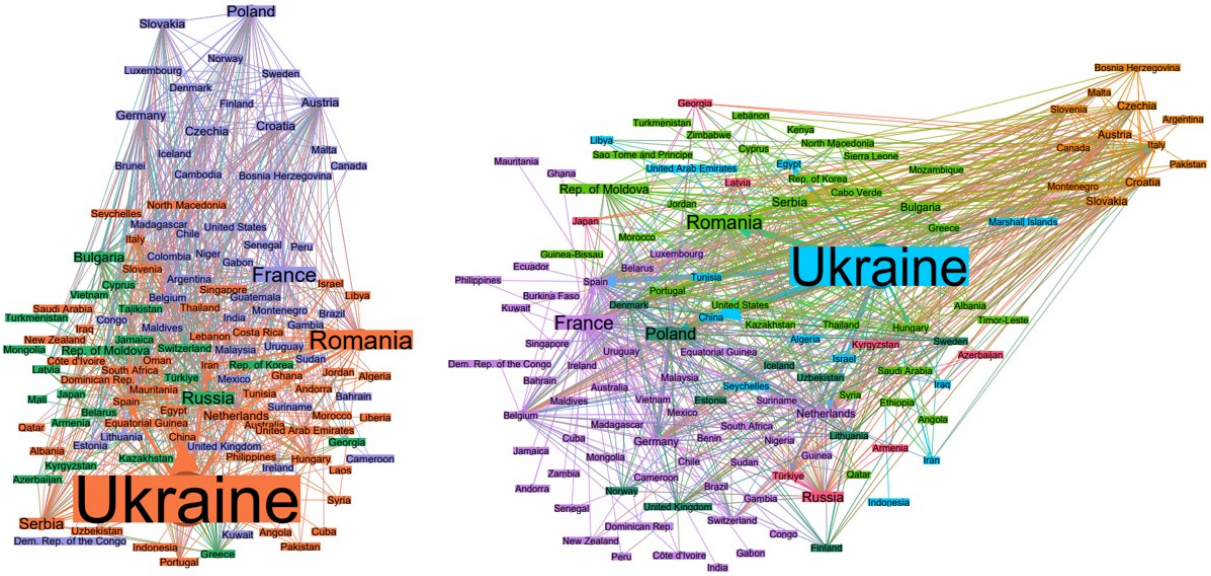


Figure no. 2: Maize trade network 2021 (left) and 2022 (right)

Source: Authors' representation based on UN Comtrade data

In 2022, the maize network expanded to 123 countries and 923 trade links between 31 European producers and their export partners. Six communities have emerged led by Ukraine,

Romania, France, Poland, Russia, and Slovakia. The highest trade flows are coming from Ukraine to China, Romania, Spain, and Poland. Türkiye is the main recipient of Russian exports but also the first export destination outside Europe for Ukraine. The Ukrainian maize exports have been comparable to the previous year accounting for the largest trade flows. In this network, 31 countries have one European producer as trade partner, and they are located worldwide (i.e., Ukraine – Indonesia, Ukraine – Marshall Islands, or Portugal – Cabo Verde).

Regardless of their volume, trade links also tend to appear between countries that are geographically close or share similarities in their cultural or linguistic heritage as in the case of Spain with Latin American countries or Portugal with former Portuguese colonies in Africa (i.e., Mozambique, São Tomé and Príncipe, Guinea-Bissau).

4.3.Barley network

The barley network is the sparsest network from our analysis. In 2021, it had 113 countries comprising 36 European producers and their export trade partners amounting to 673 distinct trade pairs. The hubs of the overall network and the communities are easily identifiable (figure no. 3). Top European exporters were France, Ukraine, Russia, Germany, and Romania. France and Ukraine are part of the same community with the largest trade links towards China. The main recipients of Russian exports are Türkiye, Saudi Arabia, Libya, and Tunisia.

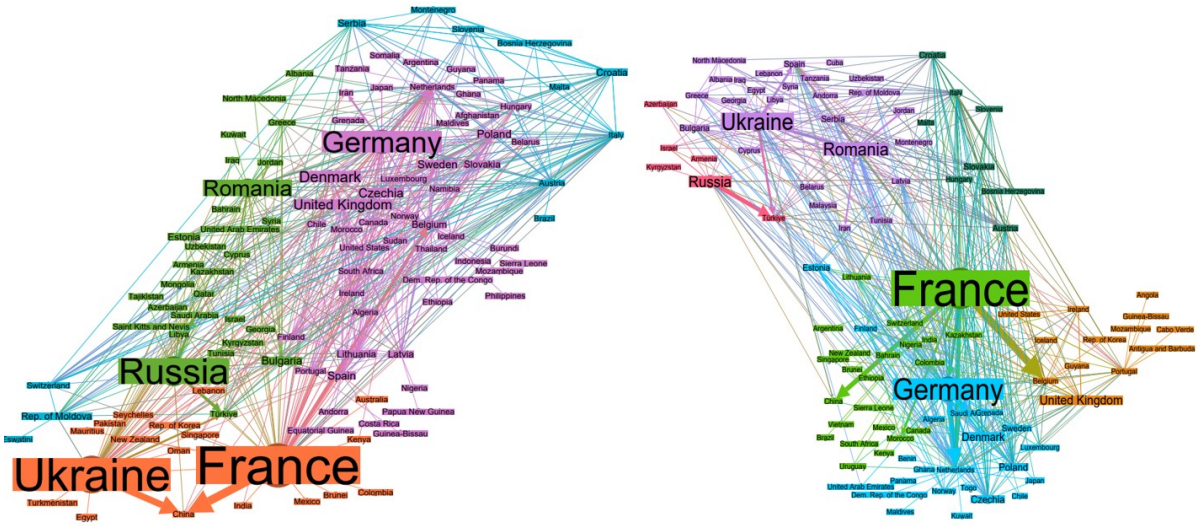


Figure no. 3: Barley trade network 2021 (left) and 2022 (right)

Source: Authors' representation based on UN Comtrade data

In 2022, there was a slight decrease to 100 countries and 622 trade links. The main European exporter were France, Germany, Ukraine, Romania, Russia, United Kingdom. The trade partners have been divided into six communities led by France, Germany, Ukraine,

Russia, United Kingdom, and Austria. The largest export flows were from France to Belgium and from Germany to the Netherlands.

5. Conclusions

Food security has been extensively studied from the perspective of developing countries which lack resources to satisfy internal demand and therefore rely on imports. Broadly, trade openness is enhancing the connections between countries by stimulating trade flows. But the positive impact exerted on countries by allocating commodities on the international agricultural market does not eliminate the vulnerability against supply shocks.

Wheat, maize, and barley are among the major cereals grown in Europe. Most of the producers are also exporters contributing to a more sustainable food system. After experiencing a large-scale pandemic, the agro-food system has come again under pressure following the Russian invasion of Ukraine who is a key agricultural producer and exporter.

In this paper, we have built the export network of the European producers based on annual data to identify trade patterns. We have opted for a network analysis approach because it allows us to rank and visually represent the most influential nodes.

In the wheat and meslin network, Russia, Ukraine, and France have secured their positions. Ukraine is dominating the maize network as the top exporter with comparable volumes to the previous year. Several European countries connected by land with Ukraine emerged as new export destinations for 2022 replacing former countries worldwide having less trade barriers. In the barley network, both Ukraine and France have decreased their participation. France is the main hub while Germany has a better position as exporter in 2022.

For visualization purposes, we partitioned each network and used modularity to detect the communities. We scaled the elements of the network by the export net weight to easily identify the focal points in each community and have the countries gravitate around their main suppliers. Countries placed in the same community have dense intra-group trade links and opportunity can arise for substituting trade flows subject to their internal production capabilities. Although the cohesion is stronger intra-community, we also detected several strong export links inter-communities. We observed that the countries tend to create trade links with partners located in their proximity or with their former colonies.

We have therefore conducted a general assessment of the export patterns of the European producers to provide a complementary analysis on the distribution of the trade links combined with a comparative view but limited in scope on the variation of the net weight values and major changes in the distribution of recipient countries.

Further research can explore the trade diversion effect with an emphasis on both vulnerabilities for the countries directly affected by conflict and opportunities for other not-conflicting countries to build resilience against disruptions in the global supply chain.

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