**Trends and Evolution of Global Imports in Food and Agriculture: Implications for Food Security and Nutrition**

**1. INTRODUCTION:**

The global food and agricultural trade network’s resilience, defined as its capacity to endure and recover from disruptions while adapting to risks and long-term changes to maintain stable food variety and quantity (Mena, Karatzas, and Hansen, 2022), has been significantly tested under various conditions. The COVID-19 pandemic in 2020 and 2021 led to widespread restrictions on movement and trade. Furthermore, since February 2022, the war in Ukraine has introduced localized shocks, affecting the agricultural production and export capabilities of key market players. These shocks can propagate through the network, causing further disruptions. The resilience of this trade network is influenced by the connectivity of countries within it, as well as the structure and distribution of that connectivity (Acemoglu, Ozdaglar, and Tahbaz-Salehi, 2015). While increased connectivity enhances the network’s ability to buffer against shocks, it also has the potential to transmit negative effects (Dellink, Dervisholli, and Nenci, 2020).

Fostered by the Agreement on Agriculture (AoA), the emergence of preferential and regional trade agreements (RTAs) and progress in transportation and communication technology, global food and agricultural trade expanded rapidly during the early 2000s, accompanied by an increasing share of low- and middle-income countries being active in global trade and the evolution of global value chains in the food and agriculture sector (Dellink, Dervisholli and Nenci, 2020; FAO. 2020.). This trend was interrupted by the 2008 financial crisis, followed by a slowdown of the expansion of global trade.

The greater Integration of countries into the trade network brings trade-offs for country- and global-level resilience to trade shocks (Karakoc and Konar, 2021).At the country level, individual countries can mitigate domestic food production shocks, such as those caused by extreme weather events, by adjusting trade quantities, thereby ensuring food security. At global level, the exchange of foods among countries can help offset specific shocks in the network, evening out supply fluctuations worldwide and reducing price volatility. However, there are concerns that increased import dependency and greater connectivity through trade may also increase vulnerability to shocks, rather than contributing to resilience. The transmission of shocks and vulnerability can be exacerbated if countries in the network respond to disruptions by imposing trade restrictions, leading to self-propagating trade disruptions and price spikes.

The vulnerability of countries to ”xter’al trade shocks depends on various factors, including the structure of the trade network. If a small number of dominant players control the network and many other countries are connected to these hubs without direct connections among each other, shocks affecting the dominant players can easily propagate throughout the network, potentially amplified by global value chains. Conversely, a shock to the system is more likely to dissipate when many countries in the network are connected to multiple trade partners, providing a greater degree of resilience (Acemoglu *et al.*, 2012a; Acemoglu, Ozdaglar and Tahbaz-Salehi, 2015; Lucas, 1977; UNCTAD. 2019)

Some argue that there is a trade-off between economic efficiency and resilience in the global network of food trade. While high specialization in line with comparative advantages increases economic efficiency, the dependence on few major exporters for specific goods may also induce vulnerabilities and reduce resilience of the global network (Karakoc and Konar, 2021).

Diversifying trade partners and imported products should be pursued to enhance resilience against shocks in domestic production and international trade. While pursuing regional trade integration, countries should proactively engage in multilateral negotiations to address the global dimensions and issues of food and agricultural trade. Recent developments raise concerns about the fragmentation of global food and agricultural trade and reduced network resilience to shocks, posing risks to countries’ food security and dietary diversity. Fragmentation into regional trading blocs may hinder countries from fully benefiting from trade gains and lead to less efficient outcomes in terms of production allocation and resource utilization. While regional trade agreements contribute to economic growth and regional value chains, deeper provisions in these agreements can address specific trade-offs between economic, environmental, and social interests.

Following this introduction, we delve into a comprehensive analysis structured around these main sections. First, we give a broad idea as to why the global food chains and the GAVC impact the nutritional security and food variability of countries and what are the factors affecting it. Next, we present our methodology for analyzing trade connectivity using extensive data from the FAOSTAT database, encompassing 175 countries from 1995 to 2021. We introduce measures of connectivity that assess both short-term shocks and long-term resilience in global trade networks. Subsequently, we detail our regression models, examining the effects of first and second-order trade links, trade intensity, and eigenvector centrality on various nutritional security indicators. Our findings reveal compelling insights into how trade connectivity shapes food security outcomes globally. For instance, we observe significant relationships between trade intensity and dietary energy requirements, alongside nuanced impacts on access to basic water and other essential nutritional variables. We conclude by discussing the results of these regressions and proposing a way ahead in further improving the food security and the role of agricultural and food trade in doing so.

**2. FOOD CHAINS AND NUTRITIONAL SECURITY:**

The triple burden of malnutrition—comprising undernutrition (stunting and wasting), overnutrition (overweight and obesity), and micronutrient deficiencies—remains a significant global challenge, particularly in developing nations. This issue has been worsened by the COVID-19 pandemic, which has been closely linked to increased food insecurity (FAO et al., 2023; Tabe-Ojong et al., 2023). Agrifood value chains are crucial in this context, as they directly impact the availability, affordability, and nutritional quality of food, as well as the complexities of supply chain operations.

Value chains within the food and agriculture sectors are vital for transforming food systems and driving economic development. As more countries engage in global agrifood value chains (GAVCs), their importance grows. GAVCs connect countries and companies both horizontally and vertically, as well as link them to consumers (Swinnen and Maertens 2007; Sexton 2013; Balié et al. 2019). This integration can generate employment opportunities and boost household incomes. However, participating in these global value chains can also introduce competition to local and regional value chains, leading to welfare and distributional effects that might not benefit all households. Additionally, it can expose domestic economies to negative global shocks. Therefore, integration into global value chains has both advantageous and disadvantageous aspects, impacting food security and nutrition at both global and national levels.

Agrifood trade influences nutrition outcomes through various mechanisms. It is closely linked to economic growth, which impacts food security and nutrition by increasing per capita income and purchasing power. Higher incomes lead to better food security and improved nutrition. Agrifood trade also directly affects the four dimensions of food security: availability, access, utilization, and stability. As agrifood imports rise, food availability in a country increases, leading to lower food prices and improved access. Additionally, diverse food imports can result in more varied diets and better utilization of nutrients. Agrifood trade helps stabilize food supplies by buffering short-term fluctuations in domestic production caused by production shocks or seasonal patterns (Krivonos and Kuhn, 2019; Remans et al., 2014; Dithmer and Abdulai, 2017).

Higher agricultural productivity can enhance food availability, reduce food prices, and diversify production, all contributing to improved food security and nutrition. Moreover, greater participation in agrifood GVCs is linked to economic development and better employment opportunities, which positively impact per capita incomes and, consequently, food security and nutrition (Montalbano and Nenci, 2022; Lim and Kim, 2022).

Globally, about one-third of agrifood exports occur within global value chains (GVCs) (Nenci et al., 2022). Although the relationship between agrifood trade, food security, and nutrition has been explored in the literature, the specific characteristics of GVCs in this context have received limited attention. Research indicates that GVCs in the agrifood sector are generally associated with increased agricultural value added per worker, though this effect is geographically heterogenous (Montalbano and Nenci, 2022). The impacts on food security and nutrition can vary across countries based on their ability to generate value-added and create employment opportunities within the agriculture and food sectors (Jared, 2018). Due to differing comparative advantages, countries may integrate into various segments of the global value chain, experiencing distinct benefits and challenges (Jared, 2018). These outcomes are influenced by the level of competition between (sub)national value chains and global value chains.

The influence of global value chains (GVCs) in agriculture can vary significantly among households, depending on their primary income source and their access to employment opportunities. Households that rely on agriculture for income typically experience a more direct impact through the productivity and income channels, which are particularly significant. The extent of this impact is further shaped by factors such as education levels and gender composition within households, influencing their ability to engage with employment opportunities arising from GVC participation.

Moreover, the effects of income changes are most pronounced for households employed in sectors closely linked to agrifood GVCs. The implications of income increases on spending patterns, particularly on nutrient-rich products, also vary across households. Therefore, a one-dollar income increase can lead to different nutritional outcomes depending on factors such as the initial household income level, which affects their responsiveness to further income changes and price fluctuations. Additionally, household-specific characteristics, including dietary preferences and needs, further shape how income changes translate into dietary patterns and overall nutritional well-being.

The vulnerability of countries to external trade shocks depends on various factors, including the structure of the trade network. If a small number of dominant players control the network and many other countries are connected to these hubs without direct connections among each other, shocks affecting the dominant players can easily propagate throughout the network, potentially amplified by global value chains. Conversely, a shock to the system is more likely to dissipate when many countries in the network are connected to multiple trade partners, providing a greater degree of resilience (Acemoglu et al., 2012a; Acemoglu, Ozdaglar and Tahbaz-Salehi, 2015; Lucas, 1977; UNCTAD. 2019)

Some argue that there is a trade-off between economic efficiency and resilience in the global network of food trade. While high specialization in line with comparative advantages increases economic efficiency, the dependence on few major exporters for specific goods may also induce vulnerabilities and reduce resilience of the global network (Karakoc and Konar, 2021).

**3. DATA AND VARIABLE MEASUREMENT:**

**3a. Shocks and Resilience to those shocks through connectivity measures:**

Shocks in the trade network impact both exporters and importers. Exporters face a loss of export revenue, while importers encounter disruptions in their supply of final and intermediate products. The risks to food security from disruptions in food trade are generally considered higher for importers; hence, we analyze the resilience of the trade network from the importer's perspective. Effects on exporters are similar to those on importers and can be examined further in future studies. Trade shocks can be internal or external. From an importer’s viewpoint, an internal shock occurs when demand is disrupted, such as a significant income decline in importing countries. External shocks arise when exporting countries experience disruptions, such as extreme weather conditions, conflicts, or pest outbreaks affecting their production systems. Some shocks are bilateral, impacting both exporters and importers simultaneously. Sudden trade barriers are an example of bilateral shocks, disrupting both parties involved. The network of food and agricultural trade is vulnerable to various risks, and when a shock occurs in one country or region, it can have ripple effects on third countries or regions. Direct effects occur when trade partners are directly affected, while indirect effects impact third countries or regions and are transmitted through global value chains or other mechanisms. Shocks can impact individual countries either directly or indirectly, and a country's ability to withstand, adapt to, and recover from such disruptions—known as country-level resilience—depends on its connectivity within the trade network. Country-level resilience involves a country's capacity to maintain stable and functional food supplies by importing products in varying volumes and varieties from different sources. The individual capacity of countries to absorb shocks influences the global (network) level resilience, which is the ability of the entire network to collectively absorb, adapt to, and recover from disturbances. The concept of global level resilience considers the interdependencies and interactions between countries, examining how shocks or disruptions in one country can propagate and affect others within the network.

Examining a country's direct connectivity reveals immediate spillover effects that directly impact trading partners. Higher-order connectivity, on the other hand, provides insights into the longer-term effects on a broader range of countries. When countries are connected through indirect or higher-order trade relationships, shocks originating from the network's core can propagate more easily, especially if global value chains are disrupted across multiple countries. The spread of these shocks throughout the network takes longer to manifest compared to the immediate effects felt by direct trading partners. However, higher levels of indirect connectivity allow alternative suppliers to more readily substitute disrupted imports, particularly if only specific countries are affected. In such cases, existing trade relationships can be leveraged to mitigate the impact.

The concept of the extensive margin of trade pertains to the diversity of trade, encompassing both the number of trading partners and the range of products exchanged. A higher level of diversity on the extensive margin indicates that a country engages with numerous trading partners and trades a wide array of products, thus expanding its trade network. Conversely, the intensive margin of trade focuses on the volume or value of goods exchanged between trading partners. An increase in the intensive margin signifies a larger value of goods being traded, reflecting a deeper level of trade integration between countries.

In general, having a greater diversity of trade partners and traded products helps avoid dependencies on a small number of partners or products traded at high intensity. However, there are trade-offs between efficiency gains from specialization and resilience gained through diversification (Karakoc and Konar, 2021).

We assess both direct connectivity between countries and their indirect connectivity, which is evaluated through second-order and eigenvector measures. Direct connectivity refers to a country's connections with its immediate trading partners. Second-order connectivity, on the other hand, involves a country's connections with the trading partners of its direct partners (the connections of its partners' partners). This measure reveals the extent to which a country's trade routes are diversified beyond its direct partners. A highly diversified trade network with strong second-order connections can serve as a buffer against disruptions in direct trade links. For instance, if a primary trade partner experiences economic or political instability, the country can still rely on the partners of its other trading partners, thereby reducing the risk of severe economic impact. Meanwhile, eigenvector connectivity assesses a country's connections within the entire network, acting as a measure of its influence within that network. It considers not just the quantity of direct connections but also their quality and influence. Eigenvector centrality assigns greater importance to countries that are connected to other highly central countries. Therefore, a country may have high centrality even if it has fewer direct trade partners, provided those partners are themselves major trading hubs.

Different orders of connectivity provide insights into the temporal dimension of resilience. The evolution of first-order connectivity, as observed through both its mean and distribution, reveals the immediate (short-term) spillover impact of shocks. In contrast, measures of second-order and eigenvector connectivity offer information on the longer-term resilience to shocks. These shocks may originate from countries not directly connected to a given country but still affect it, or from directly connected countries and then spill over to the given country through indirect linkages.

The following are the network indicators that we use in our analysis

1. First Order Node strength: refers to the total number of direct trade links (or relations) each country maintains with its trading partners within the context of international trade data. This metric is derived from aggregating the sum of trade relations reported by each country (Reporter Countries) for each specific year analyzed. For instance, in our analysis, we calculate the First Order Node strength by summing the reported trade relations between each country and its direct trading partners across various years from 1995 to 2021. This approach allows us to quantify the extent of direct connectivity or trade intensity for each country within the global trade network.
2. Second Order Node Strength : refers to the extended connectivity of each country within the global trade network beyond its direct trading partners. Specifically, it represents the cumulative trade links (or value) involving a country's second-degree connections, encompassing the trading partners of its immediate partners. This metric is computed by summing the total trade links of these second-degree connections for each country across the years 1995 to 2021.
3. Eigenvector Centrality : Eigenvector centrality is a fundamental measure in network analysis that assesses the importance of nodes based on their connectivity and the centrality of their neighbors. It operates on the principle that the centrality of a node is proportional to the sum of centralities of its neighboring nodes, reflecting the idea that connections from more central nodes contribute more to a node’s own centrality score.

In mathematical terms, for a network represented by an adjacency matrix A, eigenvector centrality C(eig) is computed as the principal eigenvector corresponding to the largest eigenvalue λ of the transpose of A. This relationship is formulated as: ATC(eig)=λC(eig). Here, AT denotes the transpose of the adjacency matrix A, and C(eig) represents the vector containing the centrality scores for all nodes in the network. The centrality Ci(eig) of each node iii is influenced by the centrality scores of its neighbors, weighted by the corresponding entries in A.

This weighted approach allows eigenvector centrality to account not only for the structural connectivity of the network but also for any additional weights associated with edges, such as the strength of trade relationships in economic networks. Consequently, nodes with higher eigenvector centrality are not only well-connected but are also connected to other nodes that themselves have high centrality, indicating their pivotal position within the network.

In our analysis, we apply the aforementioned measures to two perspectives of a trade network. The first perspective involves a network that quantifies the number of trade commodities exchanged between each pair of countries, providing insights into the diversity and breadth of trade relationships (network of country-product trade links). This perspective allows us to analyze the trade network along the extensive margin of trade, focusing on the variety and number of products exchanged. The second perspective utilizes a weighted trade network that reflects the monetary value of trade between any two countries (trade intensity matrix). This approach enables us to delve into trade dynamics along the intensive margin, emphasizing the volume and economic significance of trade transactions between countries.

**3b. Data for Network measures:**

For our analysis of network measures, we utilize data sourced from the FAOSTAT database on international bilateral trade of food and agricultural products. This dataset spans snapshots of global trade involving 175 countries from the years 1995 to 2021. It includes detailed records of both the import and export values of agricultural and food products exchanged between each pair of countries.

**3c. Data for Nutritional Variables:**

We have compiled a comprehensive dataset of nutritional variables spanning the years 2000 to 2021, sourced from various indicators available in the FAOSTAT database. This dataset comprises essential nutritional metrics such as average dietary energy requirements (measured in kcal), prevalence of undernourishment, access to basic drinking water, and other relevant factors. With a focus on key aspects of nutrition, particularly dietary energy requirements, undernourishment, obesity, and prevalence of stunting, this dataset also captures broader aspects of food consumption and security. These variables are instrumental in assessing food security and nutritional outcomes globally (Smith and Haddad, 2001). Additionally, we have also gathered the data of the Political Stability Index from the World Governance Indicators (WGI) provided by the World Bank Databank. The idea is to check whether the political situation of a country has a significant effect on different measures of nutritional security.

**4. EMPIRICAL IDENTIFICATION STRATEGY:**

This paper aims to examine the impact of global food chains and trade networks on food and nutritional security. Our analysis focuses on assessing both the extensive and intensive margins of trade. The intensive margin is measured by trade intensity or value, while the extensive margin is assessed by the number of trade links per country and product. Additionally, we explore the interaction between these two dimensions to understand how trade connectivity and diversity jointly influence nutritional security. Our regression model is specified as follows:

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Here, Nutrition Security\_it ​ represents the nutritional security of country iii at time ttt. IntConnectivity\_it and ExtConnectivity\_it​ denote the measures of intensive and extensive trade margins, respectively, while Interaction\_it captures their interaction effect. X represents a matrix of control variables, θ are their associated coefficients, FE\_i and FE\_t ​ represent country and time fixed effects isolate the effects of trade margins, and e\_it​ is the error term.

Specifically, we measure first-order connectivity, second-order connectivity, and eigenvector centrality for each margin of trade.

Hence, we can summarise the independent variables as follows:

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | **Trade network** | |
|  | **Connectivity measures** | **Trade links (per country and product)** | **Trade Intensity (per country)** |
| Order of connectivity | First order |  |  |
| Second order |  |  |
| Eigenvector |  |  |

For our analysis, we have included GDP per capita and the Political Stability Index as control variables in our regression models. This decision was made due to the presence of multicollinearity in the dataset, ensuring that our results are robust and interpretable. The objective of our analysis is to regress each measure of Nutritional Security against these independent variables and controls, examining for significant effects that shed light on the relationship between trade margins, economic indicators, political stability, and nutritional outcomes.

**4a. Method of Regression:**

Our analysis employs panel data, which is characterized by multiple observations over time for each unit of analysis, in our case, countries. This structure allows us to capture both cross-sectional and time-series variation, providing a robust framework to investigate the dynamics of trade networks and their impact on nutritional security from 1995 to 2021. Panel data inherently exhibits within-cluster correlation due to the repeated measurements of countries across time. This correlation arises from persistent factors such as economic policies, geographical proximity, and historical trade relationships. For example, trade values and connectivity measures for a country in consecutive years are likely to be correlated, reflecting ongoing economic ties and policy continuity. To address this issue, we utilize the Cluster Robust Standard Error (CRSE) method in our regression analysis. Heteroskedasticity, where the variance of error terms varies across countries, is another common feature of panel data. Larger economies, for instance, may exhibit greater variability in trade values and connectivity measures compared to smaller economies. This variation can lead to biased standard errors if not properly accounted for in statistical models.

To mitigate the biases introduced by within-cluster correlation and heteroskedasticity, we employ the CRSE method in our regression analysis. This method adjusts standard errors to accommodate the clustered structure of our panel data. By clustering standard errors at the country level, CRSE allows us to obtain robust estimates that accurately reflect the uncertainty in our regression coefficients. Specifically, CRSE corrects standard errors to ensure they are not underestimated, thereby providing reliable inference about the effects of trade networks on nutritional security.

**5. RESULTS AND DISCUSSION:**

**5a. First order connectivity:**

We begin by running the regression on different measures of nutritional security on the first order connectivity measured by the value of imports. We find that model with average dietary energy requirements as the dependent variable has a very high explainability with adjusted R squared as 0.977, with the first order tradelinks having a negative impact on the dependent variable at a 10 percent significance. We also note that political stability measured by the PSI has a significant (at 5%) impact on the average dietary energy supply over the years. This implies that countries with higher indices of Political stability have been able to better provide adequate dietary energy supply. The supply of protein have had a small insignificant effect by the first order tradelinks and intensity, however, with an increase in both tradelinks and intensity of imports, there is a small yet significant negative impact on the average protein supply. In case of animal protein supply, the FO intensity has a significant positive impact(2.96e^-07) showing that a higher import connectivity at the first order significantly ensures a better availability of animal protein supply, however a combined effect of tradelinks and intensity has a negative impact on its supply(-4.05e^-11), significant at the 1 percent level. A further look into the cereal import dependency ratio reveals that the intensive margins of import has a highly significant positive impact(1.036e^-06).

The nutritional variable “Obesity in Adult Population” showed to be very highly explained by the model with significant impacts of GDP per capita and political stability. However, the first order tradelinks and intensity along with their interaction terms had insignificant effects. Whereas, we also observed that a higher intensive import margin has a significantly negative impact on the number of people undernourished, and having higher extensive import margins significantly reduce undernourishment. The number of children stunted under the age of 5 years seemed to not be significantly affected by the first order connectivity of imports.

**Table 1: First Order Connectivity and Food Security and Nutrition**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** |
|  | **Energy Requirement** | **Animal Protein Supply** | **Obesity** | **Stunted** | **Undernourishment** | **Basic Drinking Water** |
|  |  |  |  |  |  |  |
| FO Tradelinks | -0.0026 | 1.78E-05 | -9.12E-05 | 6.08E-05 | -0.0006\*\* | -0.0002 |
| FO Intensity | -2.77E-07 | 2.96E-07\*\*\* | -2.49E-08 | -1.39E-07 | 2.89E-10 | 8.17E-09 |
| Constant | 1986.55\*\*\* | 12.7637\*\*\* | 2.9817\*\*\* | 1.9816\*\*\* | 21.1514\*\*\* | 49.1964\*\*\* |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
| *Model* |  |  |  |  |  |  |
| R-squared | 0.978 | 0.973 | 0.995 | 0.975 | 0.864 | 0.97 |
| Adjusted R-squared | 0.977 | 0.972 | 0.994 | 0.973 | 0.856 | 0.968 |
| No. of observations | 3469 | 2842 | 2627 | 2839 | 3011 | 3280 |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
| *Controls* |  |  |  |  |  |  |
| GDP per capita | Yes | Yes | Yes | Yes | Yes | Yes |
| PSI | Yes | Yes | Yes | Yes | Yes | Yes |
|  |  |  |  |  |  |  |
| *Fixed Effects* |  |  |  |  |  |  |
| Country | Yes | Yes | Yes | Yes | Yes | Yes |
| Time | Yes | Yes | Yes | Yes | Yes | Yes |

**5b. Second order connectivity:**

In our next step we conduct the regression analysis now with the second order tradelinks and second order trade intensity. In this regression, we have omitted the interaction term, because there exists multicollinearity of the independent variables. That is, the interaction between second order tradelinks and second order trade intensity may have a collinearity, thus reducing the degrees of freedom and hence decreasing the adjusted R-squared of the regression.

The regression with average dietary energy requirements showed a 97% Adjusted R^2 with both second order import links having a significant positive impact on the nutritional variable at the 5% level while second order import intensity having a significant negative impact on the same. The intensive margins of second order connectivity of imports significantly reduces the cereal dependency ratio(p-value 0.02). This implies that countries with higher second order intensity of imports have shown reduced dependency on cereal imports in the long term. Also it is important to note that the second order trade links and trade intensity have no real impact on the number of children overweight or stunted below 5 years of age. However, neither second order trade links nor intensity show significant impacts on the number of children overweight or stunted under the age of 5. Similarly, these variables do not significantly affect the number of food insecure people. Regarding obesity rates, countries with higher second order trade links tend to report fewer obese individuals, whereas higher import intensity is associated with higher obesity rates. Moreover, countries with higher second order import links demonstrate improved access to basic water (coefficient 2.017e-05) and basic sanitation (coefficient 2.07e-05). Conversely, higher trade intensity has a significantly negative effect on these basic amenities.

**Table 2: Second Order Connectivity and Food Security and Nutrition**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** |
|  | **Energy Requirement** | **Animal Protein Supply** | **Number of Obese Adults** | **Stunted** | **Undernourishment** | **Basic Drinking Water** |
|  |  |  |  |  |  |  |
| SO Tradelinks | 9.12E-05\*\*\* | 6.07E-06 | -3.81E-06\*\*\* | 8.88E-07 | -0.0000196 | 2.01E-05\*\*\* |
| SO Intensity | -2.47E-08\*\*\* | -9.37E-10 | 1.07E-09\*\*\* | -1.78E-10 | 5.66E-09 | -5.49E-09\*\*\* |
| Constant | 1984.02\*\*\* | 12.5213\*\*\* | 4.28E-01 | 1.7855\*\*\* | 21.3614\*\*\* | 48.6405\*\*\* |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
| *Model* |  |  |  |  |  |  |
| R-squared | 0.978 | 0.973 | 0.995 | 0.973 | 0.865 | 0.97 |
| Adjusted R-squared | 0.976 | 0.971 | 0.994 | 0.971 | 0.857 | 0.968 |
| No. of observations | 3469 | 2842 | 2627 | 2839 | 3011 | 3280 |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
| *Controls* |  |  |  |  |  |  |
| GDP per capita | Yes | Yes | Yes | Yes | Yes | Yes |
| PSI | Yes | Yes | Yes | Yes | Yes | Yes |
|  |  |  |  |  |  |  |
| *Fixed Effects* |  |  |  |  |  |  |
| Country | Yes | Yes | Yes | Yes | Yes | Yes |
| Time | Yes | Yes | Yes | Yes | Yes | Yes |

**5c. Eigenvector Centrality:**

With respect to the eigenvector value of the countries for each year, we observe a significant positive impact (coeff 921.62) of the eigenvector of trade intensity on the supply of animal proteins. This implies that the countries which have higher importance to imports with respect to the volume of trade have shown a long term improvement in their average supply of animal protein over the years. Coefficient of variation of the calorie distribution is higher in countries with a higher eigenvector intensity values. This implies that, a country with higher long term import relevance have a more diverse calorie consumption over time. It is also important to note that eigen vector centrality both in terms of the weighted average of the trade network as well as the trade intensity have had insignificant impacts on obesity, undernourishment and prevalence of anemia among women. However consistent with the variation in the calorie consumption, the per-capita food supply variability is significantly lower for countries with higher eigen vector trade links. This might indicate that the countries with higher trade relevance have lower per capita food supply variability, thus providing the families a better all round nutritional security where they can vary their calorie consumption to suit their respective needs.

**Table 3: Eigenvector Centrality and Food Security and Nutrition**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** |
|  | **Energy Requirement** | **Animal Protein Supply** | **CV Calorie Dist.** | **Stunted** | **Undernourishment** | **Per capita food supply variability** |
|  |  |  |  |  |  |  |
| EC Tradelinks | -2909.0714 | -917.02\* | -2.8689\* | -167.2265 | 435.9002 | -9450.211\*\*\* |
| EC Intensity | 2374.8988 | 921.62\* | 3.1386\*\* | 163.2273 | -366.2102 | 10100\*\*\* |
| Constant | 1994.17\*\*\* | 12.2897\*\*\* | 0.2663\*\*\* | 1.8506\*\*\* | 20.7509\*\*\* | 14.0064 |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
| *Model* |  |  |  |  |  |  |
| R-squared | 0.978 | 0.973 | 0.935 | 0.973 | 0.865 | 0.359 |
| Adjusted R-squared | 0.977 | 0.971 | 0.931 | 0.971 | 0.857 | 0.32 |
| No. of observations | 3469 | 2842 | 3469 | 2839 | 3011 | 3187 |
|  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
| *Controls* |  |  |  |  |  |  |
| GDP per capita | Yes | Yes | Yes | Yes | Yes | Yes |
| PSI | Yes | Yes | Yes | Yes | Yes | Yes |
|  |  |  |  |  |  |  |
| *Fixed Effects* |  |  |  |  |  |  |
| Country | Yes | Yes | Yes | Yes | Yes | Yes |
| Time | Yes | Yes | Yes | Yes | Yes | Yes |

**5d. Evolution of the Orders of Connectivity:**

At the outset of this analysis we show the trend of the total imports all over the world. Total imports across all countries have significantly increased from 1995 to 2021 as can be seen very clearly from figure 1.

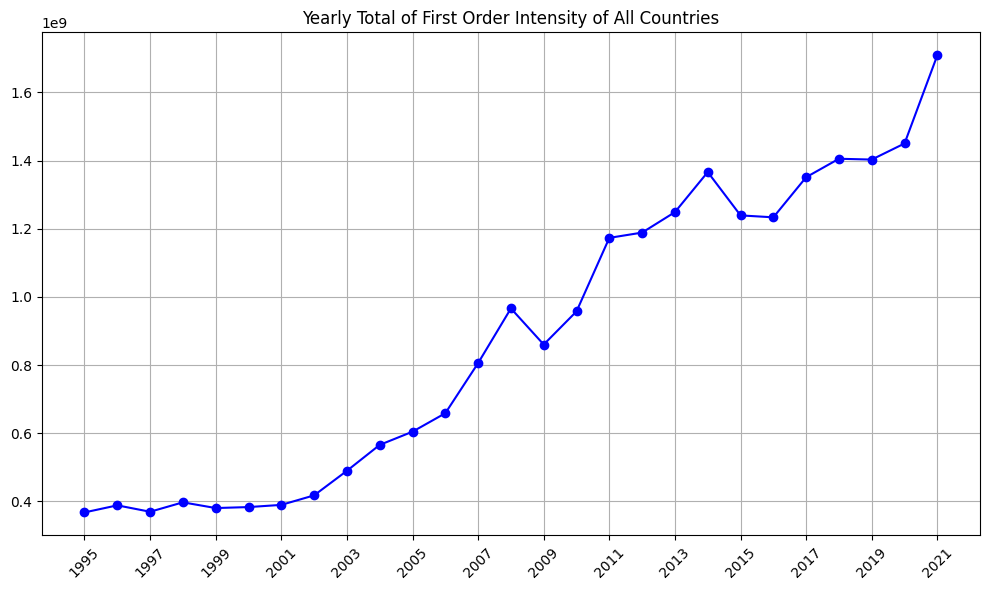


Figure 1: Trend of total imports across all countries from 1995 to 2021.

Source: Authors visualization based on FAOSTAT data.

Here we hypothise that the first order intensity of trade imports is actually the total value of imports, which makes sense because the total first order intensity is calculated by summing all the import values of the direct connections of each country. When comparing this with the first order tradelinks, that is comparing the intensive with the extensive margin of trade we can get a picture about the diversity of the import scenario across all countries over time.

A graph with a line going up

Description automatically generated

Figure 2: Evolution of first order import tradelinks across all countries from 1995 to 2021.

Source: Authors visualisations based on FAOSTAT data.

It is interesting to note that while the import intensity has increased from 350m to 1.7b from 1995 to 2021, the tradelinks per item has fallen from 1.48m to 1.39m. The decrease in the number of tradelinks implies that countries are reducing the number of direct trade connections they maintain. The combination of these trends suggests a reduction in trade diversity. As countries maintain fewer trade connections, they are likely concentrating their trade activities with a select group of key partners. This can lead to a more polarized trade network, where major trade flows are concentrated among fewer nodes.

This analysis is backed by a similar trend in the second order(indirect) connectivity for both extensive and intensive margins of trade as shown in figure 3.

A graph showing the growth of the second order

Description automatically generatedA graph with a line going up

Description automatically generated

Figure 3: Evolution of second order import tradelinks and intensity across all countries from 1995 to 2021.

Source: Authours visualization based on FAOSTAT data

Increasing import intensity alongside decreasing trade links indicates that certain countries are becoming increasingly important hubs of trade, characterized by higher eigenvector centrality in the global trade network. This means that these key countries not only have numerous direct connections but also are highly influential in facilitating indirect trade routes. As trade becomes more concentrated, these central hubs gain greater significance, handling a larger volume of trade and acting as critical nodes that support the flow of goods and services globally. Their elevated importance enhances their negotiation power and economic influence but also underscores the vulnerability of the entire network to disruptions affecting these hubs.

**5e. Evolution of the Nutritional Security Variables:**

We move on to the analysis of the evolution of the nutritional variables over time to substantiate our analysis. At first we examine the overall trend of the nutritional variables over time, as follows in figure 4.

A graph with a line

Description automatically generated A graph with a line going up

Description automatically generated

1. Dietary Energy Requirements b) Average Supply of Animal Protein

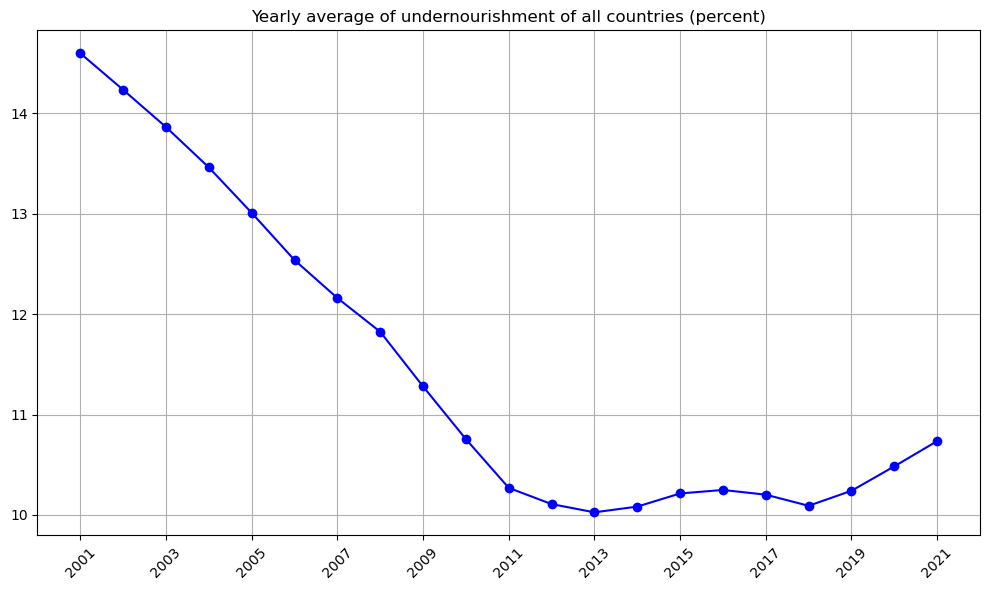
A graph with a line

Description automatically generated A graph with a line going up

Description automatically generated

1. Children stunted below 5years(percent) d) People using basic drinking water(percent)

A graph with a line

Description automatically generated 

e) Obese adults(percent) f) Undernourishment(percent)

Figure 4: Evolution trends of Nutritional Security Variables

The average dietary energy requirements increased from 2320 kcal per day to 2370 kcal per day over the course of 20 years. We also document a mere 7 percent increase in the percentage of the population across all countries using basic drinking water from just below 81% in 2001 to just above 88% in 2020. Similarly, a very minor reduction in the instances of stunted children below the age of 5 could be observed, a reduction from 26% to 18% over the course of 20 years.

Our regression analysis can also be verified by examining the KDEs of the nutritional measures with the KDEs of the orders of connectivity. As observed in our regression analysis, an increase in the first order intensity of imports significantly increases the supply of animal protein in the countries. Similarly countries with higher trade relevance(i.e, higher eigenvector values) have shown a significantly high supply of animal protein over the years. This can be substantiated by figure 5, showing the KDE of the supply of animal protein for the years 2001, 2010 and 2019. As we know from our previous analysis that the first order intensity has increased over time, we notice a rightward shift in the KDEs.

A graph of a number of animals

Description automatically generated

Figure 5: KDE of the average supply of animal protein for the years 2001, 2010 and 2019

Further, our regression also suggested that a long-term increase in the trade intensity, i.e, as the second order trade intensity rises, there is an increased percentage of population recording obesity. Figure 6 compares the evolution of the second order intensity to the evolution of the percentage of obese adults for years 2001, 2010 and 2016. We can observe a clear shift of observations to the right implying that as countries have increased their long term trade intensities, their percentage of obese population has also increased. This validates the findings of our regression analysis as well.

A graph with orange lines

Description automatically generated A graph of a graph showing the amount of obesity

Description automatically generated with medium confidence

1. Evolution of second order import intensity b) Evolution of obsese adult population(percent)

Figure 6: Comparing the evolution of percent of obese adults to the evolution of second order import intensity

We also observe a significant reduction in undernourishment in countries over the years, as observed by figure 4f. This shift is consistent with the regression analysis that with an increase in direct import intensity, there is a significant reduction in the prevalence of undernourishment in the countries over the years. The following figure 7, showing the KDE of the prevalence of undernourishment for the years 2001, 2010 and 2020.

A graph with numbers and lines

Description automatically generated A graph of a number of individuals

Description automatically generated

1. Evolution of first order import intensity b) Evolution of prevalence of undernourishment(percent)

Figure 7: Comparing the evolution of undernourishment to the evolution of first order import intensity

In figure 7a, a higher peak in a leptokurtic distribution for 2001 indicates that most of the countries had a similar first order intensity of imports. In later years, we can observe that the density of first order intensity gets spread out indicating that more and more countries are having a high variation of first order intensity. A heavier tail on the right indicates that the first order intensity has slightly increased. Comparing this to the evolution of the prevalence of undernourishment in figure 7b, we can observe that as the years have gone by, more countries have lower percentages of undernourishment. This validates the findings from our regression analysis.

**6. CONCLUSION:**

In conclusion, this paper has explored the resilience of the global food and agricultural trade network in the face of various challenges, including the COVID-19 pandemic and geopolitical shocks such as the conflict in Ukraine. The analysis underscores the critical role of trade connectivity and network structure in shaping resilience. Enhanced connectivity can bolster the network's ability to mitigate local production shocks and stabilize global food supplies. However, it also introduces vulnerabilities, particularly when concentrated among a few dominant players. The trade-off between economic efficiency and resilience emerges as a central theme, highlighting the need for diversified trade partnerships and products to enhance overall network resilience. Furthermore, the integration of countries into global value chains has profound implications for food security and nutrition, influencing availability, affordability, and dietary diversity worldwide.

This study investigates the intricate relationship between global trade networks and nutritional security across 175 countries from 1995 to 2021. By analyzing both the extensive and intensive margins of trade—measured by trade links, product diversity, and trade intensity—we have uncovered significant insights into how trade connectivity influences various dimensions of nutritional security in the shprt term and the long term.

Our findings highlight that higher trade connectivity, particularly through diverse trade links and intensive trade relationships, plays a crucial role in improving access to dietary energy and protein supplies across countries, both in the short and long run. Political stability also emerges as a key determinant in ensuring robust nutritional outcomes, underscoring its importance alongside trade dynamics.

Moreover, eigenvector centrality in trade networks reveals nuanced impacts, enhancing animal protein supply and reducing variability in calorie consumption, thereby contributing to improved nutritional stability over time. However, while trade connectivity shows positive effects on certain nutritional indicators, such as food supply stability, its impact on obesity and undernourishment appears limited.

Overall, this research underscores the multifaceted impacts of trade networks on nutritional security, providing valuable insights for policymakers aiming to enhance food systems resilience and nutritional outcomes globally. Moving forward, policymakers should prioritize diversifying trade partnerships and products to mitigate vulnerabilities and enhance resilience against global shocks. Promoting inclusive global value chains and multilateral trade agreements can foster more robust and sustainable food systems globally. Balancing economic efficiency with resilience-building measures is crucial to ensuring equitable access to diverse and nutritious food supplies worldwide.

In conclusion, understanding the dynamics of global food trade networks and their impacts on nutrition is essential for addressing global food security challenges in an interconnected world.