Food connections: intended and unintended consequences of trade on food and nutrition security

PI

- Prof. Stefano SCHIAVO – University of Trento

Co-PI

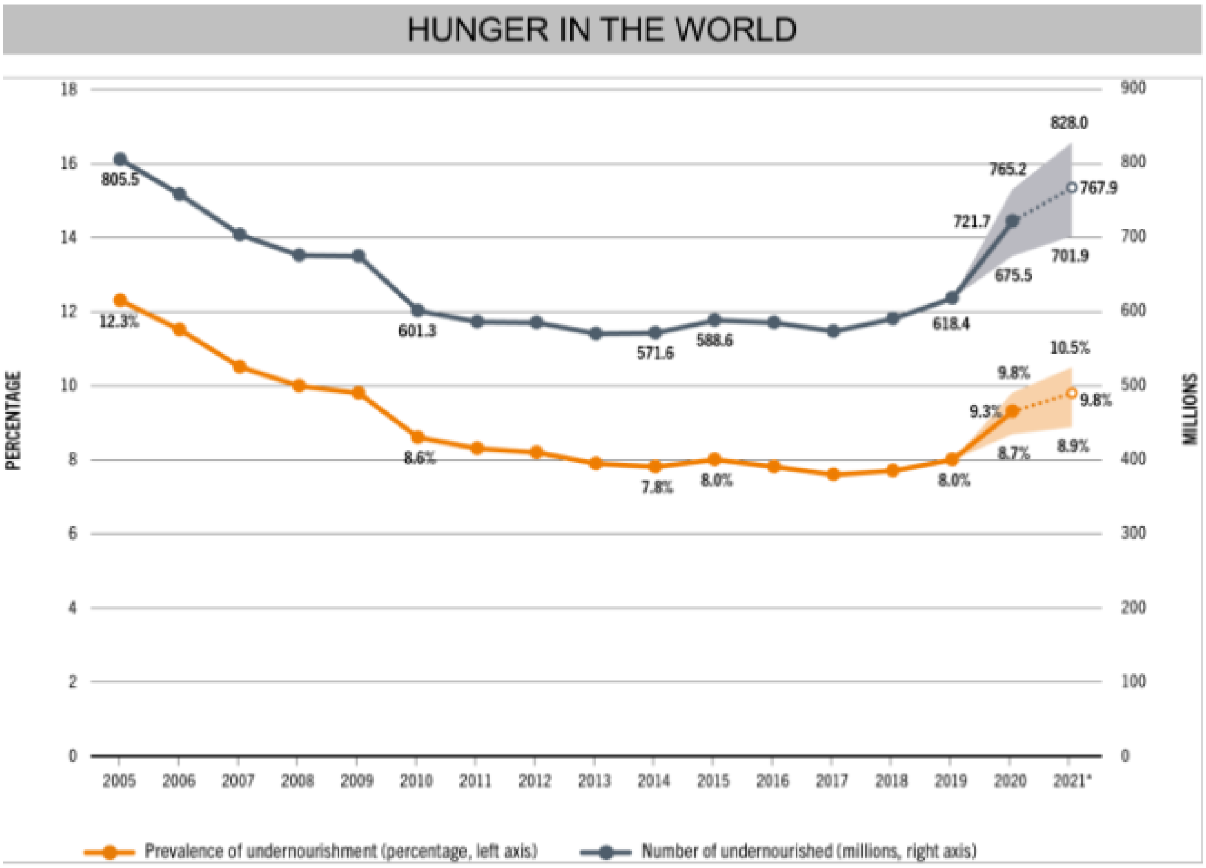
- Prof. Mariagrazia ALABRESE – Scuola Superiore Sant'Anna, Pisa
- Prof. Giuseppe MANGIONI – University of Catania

Duration

- 24 month

Abstract

Eradicating hunger and malnutrition while moving towards sustainable food systems is a central pillar of the Sustainable Development Goals. Yet, despite actions by the international community, food security is deteriorating and nutritional deficits as well as obesity are on the rise.



Source: FAO. 2022. *The State of Food Security and Nutrition in the World*

Against this backdrop, what is the role played by agricultural and food trade at global, national and individual levels? On the one hand, international trade is considered a key determinant of food and nutrition security, as both the pandemic and the war in Ukraine have forcefully shown. In fact, during the last four decades, trade in agricultural goods has increased six-fold, determining the emergence of a truly global food system in which 25% of agricultural production is traded. On the other hand, global connections play a critical role in the transmission of shocks, both natural and man-made. Indeed, there is a long-standing debate on the merits of international integration versus food “sovereignity/self-sufficiency”, and export restrictions are a common -albeit often ineffective- tool to address shocks to domestic food supply, since events such as food shortages or increasing prices can fuel social unrest. The potential disruptions to food supply caused by climate change (linked to soil aridification or extreme weather events) further complicate the challenge of feeding humanity without putting additional pressure on the environment and add complexity. Trade allows countries to decouple food consumption from the availability of natural resources and promotes a more efficient use of their natural endowments. In addition, it can contribute to the mitigation of the risks associated with idiosyncratic shocks to domestic food supply. Yet, interconnected markets facilitate the transmission of climate shocks, and worsen the vulnerability of countries to disruptions originating abroad. Moreover, global sourcing from fragile areas can increase environmental pressures and feed a negative loop. Similar tensions emerge also from a nutritional perspective: food imports promote dietary diversity, but the lower prices determined by trade may boost consumption of unhealthy foods rich in sugar and saturated fats. The project addresses the role of international trade as an adaptation strategy to lower the global impact of climate change on the food system, and weighs it against the possibility that increased connectivity facilitates the diffusion of external shocks. In fact, network analysis has shown that the same factors that contribute to resilience under certain conditions, may function as significant sources of systemic risk under others. Combining insights from economics, law and computer science the project provides an illustration of the various channels through which trade and trade regulations can affect food and nutrition security, as well as a quantitative assessment of the role played by global connectivity in magnifying or dampening the effects of climate shocks.

Objectives and Methods

The main objective of the proposal is to bring together competences from economics, law and computer science to enhance our understanding of the role played by international trade, and by the rules that govern it, in linking two crucial societal challenges, namely environmental sustainability, and food and nutrition security.

The proposal combines insights from economics, law and network analysis to unravel the complex set of interlinkages that connect international trade with food and nutrition security.
A large body of literature has shown that the topology of the trade network plays a critical role in determining the resilience of the food system, while the position of single countries within the web of bilateral exchanges contributes to affect local vulnerabilities above and beyond individual characteristics such as reliance on food imports, per capita GDP or domestic agricultural production. Hence, countries with similar features may be affected very differently by external shocks depending on their position within the international trade network. Accounting for direct and indirect effects is therefore necessary to fully understand the role of international exchanges in the transmission of shocks that may affect food production and food availability, triggered, for instance, by extreme weather events or policy actions.

The proposal integrates an analysis of the legal and policy framework relevant to agricultural and food trade into a simple network model that simulates the diffusion of shocks across the global food system.
In fact, international and bilateral legal rules related to trade as well as regulations disciplining requirements (such as safety and environmental conditions) for food to be imported or exported have a very significant impact on trade flows and on how they change in reaction to external disturbances. It is therefore necessary to combine the legal and policy framework with economic analysis to build a modeling framework that allows us to simulate the effect of various kinds of shocks on food and nutrition security.

More specifically, the analysis simulates the diffusion dynamics of shocks to the food system through a network, which is calibrated on the basis of actual food trade data. Network nodes represent countries while edges are bilateral flows of agricultural goods (either a specific good, such as a wheat or rice, or a food basket)

and the weight of the generic edge from the country *i* to country *j* can be the total quantity (or, alternatively, the caloric or nutritional content) of agricultural goods exported from the former to the latter.
In formal terms, we will run simulations on a weighted directed graph G = (V, E, W), where V={c_i: i∈{1,...,N}} is a set of nodes, E={(c_i,c_j): i,j ∈ {1,...,N}} is a set of directed edges between pairs of nodes, and W ={Wc_ic_j :i,j ∈ {1,...,N}} is the set of the weights associated with the edges (in terms of quantity, kcals, or nutritional content).
We model the diffusion of shocks building on Grassia et al (2022). First, we define the equilibrium domestic demand (i.e., before the shock) of the generic county c_i as:

(eq 1)
$$dem_{c_i}(t) = prod_{c_i}(t) + imp_{c_i}(t) - exp_{c_i}(t)$$

in which $prod_{ci}$, exp_{ci}, and imp_{ci} indicate domestic production, export and import respectively. In network terms they can be expressed as:

(eq 2)
$$exp_{c_i}(t) = \sum_{j=1}^{N} W_{c_i c_j}(t)$$

(eq 3)
$$imp_{c_i}(t) = \sum_{j=1}^{N} W_{c_j c_i}(t).$$

By using Eq. (1) we compute the initial demand of each country at time t = 0.
In the baseline version of the model, when a country c_s is hit by a $shock_{cs}$ in period t=1 that reduces domestic supply, a deficit dd_{cs}(t = 1) = $shock_{cs}$ results, as the available quantity of food falls short of demand. Country c_s can compensate for this shock by reducing its exports and/or by increasing its imports to make up for lower domestic production. Formally:

$$\begin{aligned} exp_{c_s}(t=1) &= exp_{c_s}(t=0) - \alpha \cdot shock_{c_s} \\ imp_{c_s}(t=1) &= imp_{c_s}(t=0) + (1-\alpha) \cdot shock_{c_s} \end{aligned}$$

where α ∈ [0, 1] is a parameter used to distribute the shock between import and export flows. For example, a value of α = 0.2 means that the 20% of shocks is compensated by reducing exports while the remaining 80% is compensated through an increase of imports.
Shock compensation by country c_s induces a cascading effect on those countries that import/export from/ to c_s. In fact, after the initial step, the shock propagates across the trade network producing deficits in any generic country c_i (at time step t) given by:

$$dd_{c_i}(t) = dem_{c_i}(t=0) - prod_{c_i}(t) - imp_{c_i}(t) + exp_{c_i}(t).$$

To face this demand deficit country c_i will in turn reduce its exports (or increase its imports) to:

$$exp_{c_i}(t+1) = max\{exp_{c_i}(t) - dd_{c_i}(t),\ 0\}.$$

Variations in exports and/or imports are, in network terms, implemented by changing the weights associated with the edges connecting countries, as detailed in Eqs. (2) and (3).
The model assumes two different dynamics for adjustment via imports and exports. Namely, any increase in imports is distributed across trade partners in proportion to the quantity supplied to country c_i in the baseline scenario (t = 0). On the other hand, when it comes to export flows, we posit that export shocks are transmitted in a way that is inversely proportional to the GDP of trade partners. This is to say that larger and/or richer countries will face smaller reductions in their imports, as they are likely to have stronger bargaining power.

This is consistent with the evidence suggesting that poor countries are likely to be disproportionately affected by global food shortages.
The diffusion process stops when no country facing a positive demand deficit can further reduce its exports. While there are no specific assumptions regarding the length of each step of the diffusion mechanism, it is assumed that the whole propagation process stops in a relatively short period of time, that is between a few months and a year.
Building on this basic setup, the proposal aims at extending and improving the diffusion model by including additional elements that allow us to capture important mechanisms at play. The first extension is the introduction of reserves stocks, which allow each country to absorb part of the shock, so that trade no longer represents the sole instrument to face supply deficits. The second extension integrates price effects into the picture, so that reduction in global supply (likely to occur when a production shock hits a country with a significant market share, as in the case of wheat and sunflower oil in the context of the war in Ukraine) triggers a change in prices, and this in turn affects demand. Third, we plan to model a degree of "network elasticity", that is the ability of the network to change its topology as a consequence of the shock. This will allow new bilateral links to emerge as importing countries scramble to find new sources of supply, producers see new market opportunities, and bilateral/regional agreements allow for new sourcing patterns to develop. Last, we propose to extend the standard network representation to account for the fact that countries often interact multiple ways, for instance exchanging multiple products, and that goods feature some degree of correlation (due for instance to their substitutability). As a consequence, shocks hitting a specific market (e.g. maize production in Brazil) not only travel across the maize-trade network but can also percolate to other products because of complementarities or substitution effects, or because countries facing market turbulence implement generalized export restrictions. The use of a multilayer network representation allows the model to integrate an additional degree of complexity and better capture the multiple interactions mediated by international trade, that span the global food system.

Structure of the Project

The project is organized in four work packages (WPs), each one further broken down in a series of specific tasks entrusted to a RU that acts as task leader, with the PI guaranteeing the coordination of the overall project and respect of the project timeline.

WP0 Project Management and Dissemination Activities
- 0.1 Project meetings
- 0.2 Webpage
- 0.3 Scientific dissemination
- 0.4 Beyond academia

WP1 Data and Preliminary Information
- 1.1 Review of relevant regulation (SSSA)
- 1.2 Data collection
- 1.3 State of the art

WP2 Simulation Model
- 2.1 Model setup
- 2.2 Simulation scenarios
- 2.3 Nutritional aspects
- 2.4 Shock propagations in multilayer networks
- 2.5 Simulation results
- 2.6 Model validation

WP3 Policy Implications
- 3.1 Policy implications
- 3.2 Early warning system