

Key Food Exporters Detection: Network Analysis

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Abstract

Using network approach, we propose a new method of identifying key food exporters based on the Long-Range (LRIC) and Short-Range Interactions Indices (SRIC). These indices allow to detect groups of economies with direct and indirect influence on the routes of different levels in the food network.

Introduction

World food problem remains one of the global problems that have not been resolved by the humanity so far. According to the information published by World Food Programme, 1/9 of the Earth population is lacking access to sufficient amount of food.

"Food is a weapon," — claims an article devoted to Herbert Hoover, 31st President of the United States and the founder of American Relief Administration (Patenaude B., 2007). Food issues relate not only to socio-economic sphere; they have enormous influence on political sphere as well.

Even the smallest shortages in food supplies may cause significant political consequences in the form of strikes and riots. Thus food-exporting countries have considerable potential for influencing global socio-economic and political processes. Knowledge on actors controlling flows in the global food net allows to assess the balance of power more accurately and make more realistic forecasts.

The work focuses on assessing the mutual influence of exporting economies in the global food network. The majority of existing studies do not perceive food flows as a network (nodes — exporting economies, edges — volume of exports) and they use data in absolute terms (Schreier et al., 2014). As a rule, these studies are limited to an analysis of the existing distribution in global food production and do not try to assess the impact of any country on the entire food net. Other studies elaborate ratings of countries more exposed to the food problem — for instance, famous "Global Food Security Index" and "FAO Hunger Map" projects (Global Food Security Index, 2016; FAO, 2016) — but lack an objective of detecting influential players of the food market.

In this study we propose to apply new methods of network analysis — namely, Short-Range (SRIC) and Long-Range (LRIC) Interactions Indices, first presented in (Aleskerov et al., 2014; Aleskerov et al., 2016) — to identify key food exporters. In contrast to classical centrality indices,

SRIC and LRIC allow us to take into account parameters of economies (e.g. volume of food exported); their indirect individual and group influence on each other. LRIC permits to calculate indirect influence on the paths of higher levels (routes with 2 and more intermediary economies).

The research objective is to point out the economies with high influence on the global food network.

Key Definitions

Food security definition proposed by the Food and Agriculture Organization of the United Nations includes such aspects as sufficiency, safety and quality of the food, as well as existence of "*physical, social and economic access*" of people to it. Taking this definition into account, we interpret food security more narrowly, touching only the aspect of food accessibility (access to food) at the level of economies.

We use the term "economy" instead of a "state", for the reason that the analysis includes such territories as Hong Kong and Macao that are not sovereign states.

The paper is organized as follows. Section 2 provides short description of SRIC and LRIC. In Section 3 we describe the initial dataset and its analysis. Section 3 presents the results of SRIC and LRIC. Section 4 concludes.

2. Network Analysis

2.1. Short-Range Interactions

In contrast to classical centrality measures, short-range interactions index (SRIC), first proposed in (Aleskerov et al., 2014), permits us to take into account:

- parameters of economies: e.g. total amount of food imported;
- short indirect influence of economies in the net;
- group influence of several economies on the one under consideration.

The first reason why it is necessary to take indirect interactions into consideration — existence of indirect routes, when certain amount of food get into the importing economy via intermediary economies. An economy which generates food flows will possess some indirect influence in the network structure. The second reason — possibility that export-import flows between two economies will contribute to the emergence of flows between other economies.

Besides, the threshold q set at 15% level will allow SRIC to take into account the total amount of food imported by the partner economy. If the export of food from economy A to economy B exceeds 15% of the total volume of food imported by B , we can state that the economy B is dependent on the economy A in the food sector.

The group of economies, the total volume of exports from which to an economy B exceeds the threshold of 15%, is defined as **critical**. Economy A , without which the group ceases to be critical, is called the **pivotal** one. The intensity of interconnection between the economies A (exporting) and B (importing) can be calculated with the following formula:

$$f(a, w_b) = (p_{ab} + p'_{ab}) / (|w_b|),$$

where w_b — critical (towards the economy B) group of exporters with a pivotal economy A ; p_{ab} — volume of food exported from the economy A to the economy B directly; p'_{ab} — volume of food exported from the economy A to the economy B using an indirect route (via intermediaries).

Classical centrality measures are used to estimate direct route from A to B . **SRIC** is needed to estimate **indirect routes** of the type $A \rightarrow C \rightarrow B$, where C is an intermediary.

2.2. Long-Range Interactions

The difference between the Long-Range Interactions Index (LRIC) and the Short-Range Interactions Index (SRIC) consists in the ability of LRIC to take into account not only direct interactions on the routes of the 1st level and indirect interactions on the routes of the second level, but also more **distant types of interactions**.

An example of a distant interaction is a route $A \rightarrow C \rightarrow D \rightarrow B$, where both C and D — intermediary economies (route of the 3rd level).

There exist several versions of LRIC that depend on the approach (see Aleskerov et al., 2016):

1. **LRIC based on paths** — comprises several possible combinations of route aggregation methods and influence evaluation methods;
2. **LRIC based on simulations** — assumes analysis of each element and its combinations' influence on the network. Its advantage is the ability to track domino effect in the net.

In the research we will use one type of LRIC based on paths (MaxMin) and the one LRIC based on simulations.

3. Data Description

The research is based on the **United Nations Commodity Trade Statistics Database** on bilateral trade of 235 economies in food ("Food and Live Animals" section) for 2011-2014 years.

We have chosen data in accordance to Revision 4 of the Standard International Trade Classification (SITC), which is the latest and is used primarily for trade flows analysis.

To assess volumes of trade between countries, we used data on gross exports and gross imports, which include re-export (re-import) as well as export (import) data. We chose gross export/import data in order to take into account all the existing flows and evade possible errors due to inaccurate reporting of some countries which may have included re-export/re-import into export/import, increasing the flow. Initial number of flows was equal to **77628**:

| Number of flows | | | | |
|------------------------------|-------|-------|-------|-------|
| Year | 2011 | 2012 | 2013 | 2014 |
| Total number of flows | 18859 | 19345 | 19627 | 19797 |

40451 flows with both exporter & importer information contained inconsistencies. Partly they can be explained by publishing FOB- (by exporter) and CIF-type values (by importer), that differ in calculation of freight costs. According to the UNSD 2006 Survey, 96,2% of importing economies and 92,4% of importing economies follow this recommendation on reporting (UNSD, 2006).

However, there remained at least 23455 flows which discrepancies cannot be explained with this reasoning — their export values are greater than the import ones. To aggregate the diverging flows we developed an algorithm of dealing with the inconsistencies depending on the flow data characteristics (mainly difference in absolute terms and ratio of the maximal and minimal values). In the majority of cases with little discrepancies an average of gross export and gross import data was calculated. Flows with large discrepancies were analyzed separately with national statistics.

After that we analyzed the internal consistency of the flows. Those with suspicious dynamics (change rate by year higher than 2) were analyzed separately, some of them corrected. In the result we obtained 24952 flows. Section 4 presents the results of network analysis conducted on them.

4. Results

4.1. SRIC Results

Having conducted all the necessary steps of the research, we obtained the following results.

1. According to SRIC, **United States** are the economy with highest direct and indirect influence on the net on the routes of the 1st and 2nd levels for all years under consideration.
2. With a significant gap, it is followed by **Canada** and **Mexico**.
3. Netherlands, Germany, China, France, Argentina & Brazil are stably included in TOP-10.
4. The influence of Russian Federation, according to SRIC, was ranked 15th — higher than that of Denmark, United Kingdom, Italy, Belarus, Norway, Turkey, Saudi Arabia, Ukraine, etc.
5. SRIC results agree with that of classical centrality measures (Weighted Out-Degree, Betweenness, PageRank and Eigenvector) towards the USA as the top influential exporter.
6. In relation to the other top-3 economies results of classical centrality measures vary, ascribing the 2nd and the 3rd place to Germany and Netherlands (Weighted Out-Degree and Eigenvector), France and Germany or Canada (Betweenness 2011 or 2014), Germany or Canada and France (PageRank 2011 or 2014) respectively.
7. Classical centrality measures significantly underestimate several influential economies:
 - a) Canada and Mexico, according to some of classical centrality measures, may not be included even in top-10 (PageRank with 16th place for Canada and 24–27th for Mexico) or top-30 (for Mexico in Betweenness rating).
 - b) The influence of several economies with relatively high direct and indirect influence (Russian Federation, Argentina, India, Brazil, etc.) can be seriously underestimated due to the inability of classical centralities to measure indirect influence on the network.
8. During 2011-2014 the net remained rather stable and the majority of key food exporters (except for Belgium and New Zealand that rotated) didn't experience any shift in their positions.

4.2. LRIC Results

After calculating Long-Range Interactions Indices, we found out the following.

1. On the routes of higher levels (with two intermediary economies) United States lose the indisputable leadership. Depending on the version of LRIC, either **Canada, New Zealand** (2011) or **Mexico** (2011-2014) become the most influential exporting economy.

2. United States take the 3rd place (MaxMin 2011 and the majority of LRICs for 2014) or are even not included in top-10 (with 13th place in Sim rating in 2011-2014). It can be concluded that the indirect influence of the US and its potential to generate domino effect decrease on the routes of higher levels.

3. Germany and Netherlands remain in top-3 influential economies in 2011, but in 2014 lose their positions. In 2014 Netherlands remains in top-5, while Germany shifts downwards.

4. The influence of economies may experience change on the routes of the higher levels compared to those of the 1st and the 2nd level:

a) such economies as Brazil and Argentina increase their influence on long routes;

b) in contrast, the influence of Russia, Belarus, France, Germany and India decreases on the routes with two intermediary economies.

5. Long-range interactions net is more dynamic during 2011-2014 than the short-range net.

6. There exist countries with sustainable influence on the net whose positions remain almost unchangeable independently of the LRIC: among them are Argentina and Brazil (in 2011); Mexico, Canada and the Netherlands (in 2014).

5. Conclusion

The problem of food security remains acute for the international community and the knowledge on actors with high potential of influence on it is crucial for understanding distribution of power and vulnerabilities in the global food network. The work answers the question: which economies have high both direct and indirect influence on the food network.

We have found out the following.

1. On the routes of the 1st and 2nd level United States, Canada and Mexico exert the highest influence on the network.

2. TOP-10 influential exporters include the Netherlands, Germany, China, France, Argentina and Brazil. However, their influence is underestimated by the classical centrality measures.

3. On the routes of higher levels (with two intermediaries) the influence of economies mentioned above changes. The influence of such economies as Mexico and Canada increases significantly, making them the most influential actors in the net. In contrast, the US, France and several other economies lose their leadership on the routes of higher levels.

4. Short-range interactions net is more stable during 2011-2014 than the long-range interactions net.

5. It can be concluded that the influence of economies is to a large extent determined not by the absolute amount of exported food, but by the structure of the routes of export.

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