Bringing Order to the World Trade Network

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**Abstract.** The Social Network Analysis (SNA) tools are increasingly and intensively used to analyze the World Trade Network (WTN) in recent years. In this paper we present a graph-based ranking algorithm, called weighted-HITS (w-HITS) algorithm, using reinforcing equilibrium values to bring order to countries within the WTN based on their interdependencies and specific impacts on the whole network. The proposed algorithm is empirically studied on the real international trade dataset from 1962 to 2000. The results demonstrate that the proposed algorithm generates a reasonable ranking order within the WTN and shed essential light on consequent efforts on further investigating trade network.

**Keywords:** World trade network, social network analysis, international trade, weighted-HITS algorithm

1. **Introduction**

The ever-exploded international trade is becoming more and more critical for shaping the world social, economic, and political pattern in our globalizing era. The shift of global production and consumption has essentially resulted in an intricate network consisting of different countries and the economic partnership among them. Economists conceived the presence of such a multilateral trade network as early as the 1940s [1], and since then the World Trade Network (WTN) had gradually become a hotspot in many different disciplines. However, only until recent years have researchers started to go beyond graphical visualization and dig into the structure and dynamics of the WTN. Particularly, the Social Network Analysis (SNA) tools are intensively used to address issues arising during recent decades’ boom of globalization. The focus of these studies involves around graph theory and topological structure [2-3], network characteristics (e.g. scale-free, symmetry) [4-5], dynamic and evolution [6-7], and complement with other empirical analysis, in particular the gravity model and the relationship of trade network and GDP growth [8-9].

The current economic crisis illustrates that world economic systems are increasingly built on interdependencies [10]. Therefore there is a critical and emergent need to investigate the interdependencies of countries within the WTN and along the global supply chains. Many previous studies in this regard only consider typological relationship such as countries’ centrality (e.g., indegree, outdegree, betweenness) and thus cannot reflect the absolute weight of those links [11]; other endeavours either analyze the relatedness between products (the so-called “product space”) [12] or determine the dominant flows in a weighted WTN [13-14], so they do not provide explicit information on the rankings of involved countries.

In this paper, we aim at bringing orders to countries within the WTN based on their interdependencies and specific impacts on the whole network. Although the absolute amounts of import and export of a country to the world can be deemed as a straightforward indication of the country’s importance, they fail to reflect the country’s impact within the WTN and ignore dependencies among the complex links of countries (as visualized in Fig.1). Inspired by the HITS-like algorithms [15-17], we design a graph-based ranking algorithm, called weighted-HITS (w-HITS) algorithm, in a similar iterative process using reinforcing equilibrium values to capture the impact influence transmitted within the WTN (Section 2). The proposed algorithm is empirically studied on the real international trade dataset (Section 3).
2. The Proposed Approach

In this section, we first introduce a formal mathematic graph, called World Trade Network (WTN), to describe the connected trading relationships among countries. Then we formulate the proposed W-HITS algorithm to rank nodes/countries in the constructed WTN.

2.1. WTN Definition

Definition 1 (WTN). WTN stands for World Trade Network which is a weighted directed graph \( G(V, E, W) \). \( V \) is a set of vertices where each vertex represents a country in the international trade network. \( E \) is a set of directed edges between the vertices: \( E = \{(u, v) | u, v \in V \land u \neq v\} \). \( W \) is a set of weighted values, each of which, e.g., \( w_{uv} \), corresponds to a directed edge \((u, v)\) and denotes the total exports from the country \( u \) to the country \( v \).

With the above definition, import and export relationships among countries in a WTN can be depicted in a WTN graph. In the following of this section we propose the w-HITS algorithm to evaluate the impact of each node in a WTN.

2.2. The Proposed Algorithm

The purpose of the proposed w-HITS algorithm is to bring order to nodes in a complex WTN, taking nodes dependencies into consideration. Intuitively, we know that the impact of a country’s export/import is not only reflected by its trading amounts but also is related to other countries that trade with the country. Therefore, inspired by the HITS algorithms [15-17], we design a w-HITS algorithm in an iterative process using reinforcing equilibrium values to capture the impact influence transmitted among countries in the WTN. Different with the HITS algorithm that counts the weights of edges between nodes equally, the proposed w-HITS algorithm uses trade amounts as edge weights and takes these weights into calculation. Specifically, in the proposed w-HITS algorithm we associate each country \( u \) with an import attribute \( x^u \) and an export attribute \( y^u \) which respectively represent \( u \)’s import impact and export impact to the whole WTN. We further define two operations denoted by \( \alpha \) and \( \beta \) to respectively record import impact and export impact that \( u \) receives by trading with other countries:

- The \( \alpha \) operation updates the value of \( x^u \): \( x^u \leftarrow \sum_{v \in V, u \neq v} w_{uv} \times y^v \)
- The \( \beta \) operation updates the value of \( y^u \): \( y^u \leftarrow \sum_{v \in V, u \neq v} w_{uv} \times x^v \)
As presented in Algorithm 1, to calculate the reinforcing equilibrium values of the import impact $x^u$ and the export impact $y^u$, the proposed w-HITS algorithm performs a similar iterative process to HITS algorithm. After the iterative process of the Algorithm 1 is finished, each components of the vectors $x$ and $y$ will converge to their equilibrium values which serve as values of import impact and export impact of each country.

Algorithm 1 Iterative Process of w-HITS

\begin{algorithm}
\begin{algorithmic}
  \STATE \textbf{Iterate} ($\mathcal{V}$)
  \STATE \hspace{1em} 1: $\mathcal{V}$: a set of nodes in WTN
  \STATE \hspace{1em} 2: $\mathbf{x} = (x_1^u, x_2^u, \ldots, x_n^u)$ denotes a vector of import impacts of all countries in $\mathcal{V}$
  \STATE \hspace{1em} 3: $\mathbf{y} = (y_1^u, y_2^u, \ldots, y_n^u)$ denotes a vector of export impacts of all countries in $\mathcal{V}$
  \STATE \hspace{1em} 4: Initialize $\mathbf{x}$ and $\mathbf{y}$ to be the vector $(1, 1, \ldots, 1)$
  \STATE \hspace{1em} 5: While $\mathbf{x}$ and $\mathbf{y}$ not converge Do
  \STATE \hspace{1em} 6: For $i = 1, 2, \ldots, n$ Do
  \STATE \hspace{1em} 7: Apply the $\alpha$ operation to $x_i^u$
  \STATE \hspace{1em} 8: Apply the $\beta$ operation to $y_i^u$
  \STATE \hspace{1em} 9: Endfor
  \STATE \hspace{1em} 10: Normalize the vector $\mathbf{x}$
  \STATE \hspace{1em} 11: Normalize the vector $\mathbf{y}$
  \STATE \hspace{1em} 12: Endwhile
  \STATE \hspace{1em} Return $\mathbf{x}$ and $\mathbf{y}$
\end{algorithmic}
\end{algorithm}

3. Evaluation and Discussion

3.1. Data set

The international trade data we used in this study are taken from a constructed database by a National Bureau of Economic Research (NBER) project lead by R. Feenstra [18]. This dataset was built, cleaned, and made compatible based on the United Nations Comtrade Database [19] which consists of imports and exports both by country of origin and by destination. We take only the monetary data from the datasets for all the countries (some are actually territories, regions or country groups based on [18]; hereafter simplified as “countries”) for the time period of 1962 to 2000.

3.2. Experimental Results and Discussion

The experimental results for the rankings of export and import in the WTN for five representative years (1962, 1970, 1980, 1990, and 2000) are summarized in Tab. 1 and Tab.2. Only the top 20 are shown for the convenience of visualization. It can be observed that most of the countries with high “absolute amount ranking” also show high “WTN impact ranking” in general. However, the two rankings show interesting differences as well. For example, the first three important exporting countries in 2000 based on the “amount ranking” are USA, Germany, and Japan, while they rank 6th, 5th, and 2nd, respectively based on the “impact ranking”. These differences demonstrate that a country that has significant total import or export does not necessarily show the same significance if interdependencies of countries are considered within the WTN, and visa versa. Thus the proposed algorithm provides a new perspective to interpret and consider international economics and trade relationship. Further investigations (e.g., further break-down of product categories in the trade) are necessary to explicitly understand the reasons of the differences. For example, two types of countries always show higher “impact ranking” than their “amount ranking”: resource rich countries, e.g., Canada, and trading hub countries/territories, e.g., China HK SAR.
Both rankings for some important countries (China, U.S., Japan, and U.K.) are presented in Fig 2. Although US is ranked the first for both import and export from 1962 to 2000, its “impact ranking” are decreasing since the 1980s. Similar patterns could be observed for the U.K. On the contrary, Japan and
especially China show a clear increasing for both rankings, which reflect the growing influence of these two countries in the world economic system and the WTN.

4. Conclusions

The Social Network Analysis (SNA) tools are increasingly and intensively used to analyze the World Trade Network (WTN) in recent years. In this paper we present a graph-based ranking algorithm, called weighted-HITS (w-HITS) algorithm, using reinforcing equilibrium values to bring orders to countries within the WTN based on their interdependencies and specific impacts on the whole network. The proposed algorithm is empirically studied on the real international trade dataset from 1962 to 2000. The results demonstrate that the proposed algorithm generates a reasonable ranking order within the WTN. Our consequent work will further explore the critical factors influencing the impact ranking, for example further break-down of product categories in the trade.

5. References