Dynamics of financial crises in the world trade network

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ABSTRACT

A simple dynamical model is introduced to simulate the spreading of financial crises in the world trade network. In this model a directed network is constructed in which a weighted and directed link indicates the export value between two countries. The weights are subject to the change by a simple dynamical rule. The process begins with a crisis, *i.e.* a sudden decrease in the export value of a certain country and spreads throughout the whole network. We compare our results with the real values corresponding to the global financial crisis of 2008 and show that the results of our model are in good agreement with reality.

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1. Introduction

Financial institutions have increased exponentially in the last 20 years. Financial institutions form a system in which institutions are in close relationships with each other and the failure of one institution has significant exposures to the other actors in the market. The financial system has become more complex and risky as a result of the considerable numbers of actors in the market and the creation of the new financial instruments such as derivatives. The complexity of new financial instruments and the weakness of regulations can create layers of opacity in financial markets. This opacity was experienced in the global financial crisis and it amplified an initial shock and imposed losses that were far from greater than the originally estimated [1].

Financial Crises can be defined as substantial changes in credit volume and asset prices or intense disruption in the supply of external financing to various actors in the economy [2]. They are among the most challenging phenomena that appear every few years in the world economy and they have rocked the most part of the world in recent decades. Financial crisis can affect only a country (e.g. the Russian financial crisis in 1998), a region (e.g. the Asian financial crisis in 1997) or the entire world (e.g. the financial crisis of 2007–2008). A poor understanding of the transmission of financial crisis and the negative effect of financial crisis of 2008 on many countries have stimulated a surge of interest in studying dynamics and contagion effects of the crisis.

Financial institutions such as banks are the main players of the recent crisis and in many studies; the vulnerability of the financial system to contagion has been modeled by the interconnections among these institutions [3,4].

Financial crisis can be transmitted from a country to another through a direct trade linkage as well [5–7]. Nevertheless, only a few researchers have focused on the bilateral effect of international trade and financial crises. Theoretically, three different channels influence on trade: a crisis causes exchange rate movements and thereby changing the relative prices of goods in countries. Moreover, it can affect income within the crisis country and can change the export and import expenditure. Furthermore, competitiveness of a country might be influenced as a result of exchange rate movements of crisis countries [8].

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In empirical studies, different methods have been applied in order to describe the contagion of a financial crisis. In some studies an econometric method has been applied [8,9]. By using a structural Vector Auto Regression (VAR) model, Abeysinghe and Forbes [6], showed that even weak bilateral trade flows can transmit shocks across the countries. In the econometric method, different variables are generally considered in a complex set of equations. A network approach is another method which has been used more recently [5,10]. Kali and Reyes [5] considered the global trading system as a network. They found that the position of countries in the network is vital to transmit shocks toward other countries. In comparison with the economic methods, the network approach is a simpler method in which results and information can be derived from only export or import flows of countries. Besides, dissimilar from econometric models in which a specific model is used for each country, the effect of a financial crisis on every country included in the network can be extracted from only a simple general model.

The world economy is an interconnected system of heterogeneous countries which have dozens of global trading relationships [11]. As many social and financial systems, the international trade system displays a power law like behavior and it follows complex dynamics.

The international trade system can be considered as a complex network [12–15]. The properties of the world trade network such as degree distribution, degree correlations, and hierarchy are found to be obtained by exploiting GDP values of countries [14]. In addition, the gravity model of trade can excellently reproduce the main features of the real world trade network [11].

In the World Trade Network (WTN) countries are defined as nodes and trade relationships as links. WTN can be transformed into the weighted network if bilateral trade flows are assigned to countries. Since countries are connected through trade linkages, when a shock occurs in a node (country), it could spread to the entire network and influence the trade relationship of other countries indirectly. For example, according to the data available in UN Comtrade database, the direct and indirect effects of financial crisis of 2008, known as a global financial crisis, on the United State and other countries caused the total volume of trade to decline 22 percent internationally [16].

Developing a model that can explain the decline in exports as a result of a financial crisis can provide significant information for studying financial crises and its dynamics and their effect on different countries. To get a better insight into the mechanisms of crisis spreading in the whole network, we propose a simple model in which weights of links are not constant in time. Here weights of links show the values of export or imports of countries (see below). In this model a crisis begins from a certain country (say USA) and spreads through the whole network according to a certain dynamics which is explained below. The dynamics here means the change of weights of links with time.

2. The model

Based on the real export flows of the countries for the year 2008, a weighted directed network with N countries was built. In this network, nodes and weighted links indicate countries and export values respectively. The export value from country i to j is indicated by W_{ij}. Two important quantities can be defined using W_{ij}s as below:

$$S_i^{ex}(t) = \sum_{j=1}^{N-1} W_{ij}, \tag{1}$$

$$S_i^{im}(t) = \sum_{j=1}^{N-1} W_{ji}, \tag{2}$$

where $S_i^{ex}(t)$ and $S_i^{im}(t)$ indicate the whole exports and imports of country i, at time step t, respectively.

To model the effect of a crisis on the world trade network, we consider a dynamical process in which the export values of countries (the weights of outgoing links of a node in our network) change with time due to the change of import values of the same node (the weights of incoming links). Clearly, export values of countries may be affected by many other parameters. In this paper we are going to study the spreading of a crisis through the world trade network using a simple network model. Therefore we just consider the change of export values due to the change of import values.

The process starts by selecting one country as a starter of the crisis. The total export value of this country is decreased by a certain amount. This clearly affects the import values of its neighbors. For each neighbor i, we define a fractional decrease r_i as:

$$r_i = \frac{S_i^{im}(t^-) - S_i^{im}(t^0)}{S_i^{im}(t^0)}, \tag{3}$$

where t^0 and t^- show the present step and the previous steps, respectively. Import reduction of this node leads to decreasing of its export in the next time step according to the following rule:

$$S_i^{ex}(t^+) = S_i^{ex}(t^0)(1 - r_i). \tag{4}$$

This means that the fractional decrease of export values between time steps t^0 and t^+ is equal to fractional decrease of import values between time steps t^- and t^0. The process continues for all nodes affected by the import decrease and spreads through