

Contagion of Crisis, International Trade and Welfare

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SYNOPSIS

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1. Motivation

In economics, the term '*contagion*' was first coined since July 1997, during the period of Asian financial markets crisis. It is the spread of an economic crisis from one market or region to another country and can occur at both domestic or international level. An economic crisis is a situation which will occur in a business/financial system when an abrupt change takes place on the financial value of items such as assets, commodities or services. On the other hand, a contagion is the spread of an economic crisis from one market or region to another and can occur at both domestic or international level. Again the international financial integration is the first step to diversify risk but also may increase the transmission of crises across countries. This integration dramatically increases the degree of '*contagion*' across countries. So the financial market of a country appear to be vulnerable to contagion during the crisis period.

The system of international trade is at the core of the development of the world economy. Sometime international trade will diversify risk in some domestic markets in different

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countries. In some situation international trade may increase the transmission of crises across countries.

The financial crisis directly affects the welfare depending on the scale of macroeconomic risk. In particular, in a low risk environment, the increased leverage resulting from financial integration can reduce welfare of investors. This integration process dramatically increases the degree of 'contagion' across countries.

The causes of contagion can be viewed from different angles such as (1) Agency problems, (2) Asymmetric information, (3) Costly monitoring, (4) Coordination failures, (5) Strategic complementarities, (6) Risk shifting, (7) Heterogeneous beliefs and leverage, (8) Fragile institution of monetary and exchange rate arrangements, (9) Trade linkages, (10) Competitive devaluations, (11) Wake-up calls effect, (12) Common creditor effect, etc.

This thesis uses the standard trade linkages in exploring if contagion of financial crises can be estimated as outcomes of trade and financial flows across countries of the north and south.

2. Organization of the Thesis

This thesis consists of following five chapters. These are:

1. Introduction and Literature Review
2. Gravity Models in International Trade : An Exploration in Econo-Physics
3. Cross Country Analysis of Gravity Model in the Presence of FTAs
4. Radiation Theory in International Trade: Goods and Factor Mobility
5. Conclusions and Future Research

This thesis consists of five chapters as described below.

Chapter 1: Introduction and Literature Review

Review on Contagion of Crisis, International Trade and Welfare contains literature survey on related topics. These works are classified based on the topics like crisis, international trade, welfare and contagion; and then subdivided based on the theory and themes.

Here we made a survey on financial or currency crisis. This chapter summarize the generations of theoretical currency crisis models starting from first generation to fourth generation. Also we reviewed various empirical models of financial crisis. These are classified into two basic categories such as (1) currency crisis models on *early warning system* (EWS), and (2) Agent-based models of currency crisis. Again the early warning system (EWS) for currency crises can be studied into two main approaches:

- (a) *Signal Processing Approach*: It is a non-parametric approach to determine the risk of financial crisis. Here a variable is considered to be issuing a warning signal which if crosses a certain threshold level is considered potentially critical.
- (b) *Econometric Approach*: It is a multivariate one that allows testing of statistical significance of explanatory variables (such as exchange rates). This approach estimates a probability relationship among discrete dependent variables.

The model which is agent-based explains nonlinear behavior when compared to conventional equilibrium models. These are not well developed in economics, because of historical choices made to address the complexity of the economy and the importance of human reasoning and adaptability. The agent approach simulates complex and nonlinear behavior that are so far intractable in equilibrium models.

We feel that the recent development on economic crisis is based on advanced computing tools and techniques inspired from biology and/or from the nature. These are (1) neural network (NN), (2) fuzzy logic (FL), (3) genetic algorithm and (4) their hybridization such as (a) neuro-fuzzy, (b) neuro-genetic, (c) fuzzy-genetic or (d) neuro-fuzzy-genetic approaches.

We found few literatures based on these area of computation. In recent future these may lead to the next generation of economic crisis models. These intelligent system automatically generate the model as per requirement and it learns from the events and store the extracted *knowledge* into its *knowledge-base*. If necessary it may generate new rules or refine the existing rules stored into the *rule-base*.

A review on computational international trade based on most popular gravity model developed from Newton's law of gravitation in classical mechanics of physics is also given in this chapter.

A review of the applications of radiation theory of physics in economics is also presented.

Chapter 2: Gravity Models in International Trade : An Exploration in Econo-Physics

Gravity models are the computational tool in international trade. This gravity model is evolved based on Newton's law of gravitation in classical mechanics of physics. Thus the name, gravity models in international trade : an exploration in econo-physics. In an international trade network of economics, a bilateral trade strength is computed based on the economic masses of the partner countries in the network and the distance between them.

In this chapter we have discussed various computational model based the two key-terms (1) economic mass and (2) distance. In classical mechanics of physics, the distance between two bodies is well-defined, but in economics it is not. The geographical location of a country remains unchanged. In trade the distance influences mode of transport as well as volume of goods to be transport. In this chapter we have discussed various distances based on mode of transportation. These are as follows: (1) Shortest distance between two countries, (2) Geometric distance between two countries, (3) Air distance between two countries, (4) Shipping distance between two countries, (5) Road distance between two countries, (6) Geographical distance between two countries. The role of each distance have been explained with illustrations that includes maps and diagrams.

The other important term of gravity model is economic mass of a country. Popularly we use GDP of the country or volumes of import/export in terms of money. But in international trade GDP, import, export must be important but they do not represent the complete picture of economic mass of a country while computing trade force. In this context we have considered various group of features. The main group of these features or variables are:

(1) Country-specific Geographical Features: This includes (a) Surface area of land, (b) number of islands, (c) landlocked, (d) border type (sea, land, common border, etc.), (e) road length, (f) Number of ports, (g) border length (perimeter), (h) country type (e.g., Baltic sea country, Central European country, Mediterranean country), etc.

(2) Country-specific Demographical Features: This includes (a) Population, (b) Language, (c) Religion, (d) Culture, (e) Nation, (f) Colonizer, (g) Internal political tension, (h) War, (i) Car driving pattern, etc.

(3) Country-specific Economic Features: This includes (a) Gross domestic product (GDP), (b) national income, (c) currency, (common currency, currency union, etc.), (d) exchange rates, (bilateral exchange rate, real exchange rate, volatility of exchange rate,

etc.) (e) tariffs, (f) trade barrier – (i) natural barriers, e.g., distance (geographical feature) and language, (ii) tariff barriers, or taxes on imported goods, (iii) non-tariff barriers, e.g., import quotas, embargoes, buy-national regulations, exchange controls) (demographical feature), (g) trade agreements (e.g. free-trade, ANZCER, ASEAN, CEFTA, CFA, COMESA, ECCAS, ECOWAS, EFTA, EU, FTA, MERCOSUR, NAFTA, RTA, etc.), (h) imports and exports (Past exports, Trade law, Economic status, etc.), (i) economically developed/developing country, (j) Shadow related features, (k) Currency crisis, etc.

(4) Country-Specific Ratio Features : (a) GDP per capita, (b) Road length per capita, (c) capital-labor ratio, (d) high and low skilled labor ratio, (e) telephones per capita, (f) trade complementarity, (g) transportation cost as a function of weight to value ratio, etc.

(5) Country-Specific Dynamic Dependent Features: (a) Remoteness, (b) Nearness, (c) Similarity (similarity in country size, measure of similarity between countries, similarity in income, similarity in economic sizes, etc.) (d) Relative factor endowments ((i) Average tariffs for new and used cars, (ii) Differences in per capita income, (iii) Trade orientation, trade imbalance, economies of scale (iv) Level of infrastructure, (v) Multilateral trade resistance, (vi) Information costs, etc.)

We have defined these features and tried to explain with illustrations. The nearness parameter is defined and viewed as analogous to electrical network. The result is presented in a theorem and proved by using the concepts of **Ohm's law** and **Kirchhoff's law** of current electricity.

Also we define the *Proximity Measures between Two Countries* with various kinds of feature vectors that represents a country. also we define the measure of Similarity in Country Size.

Concepts of Multi-Channel Gravity Model of a Trading Network in the International Trade is described.

At the end of this chapter a unified gravity model is described. Also we have described the Estimation of Model Parameters.

Chapter 3: Cross Country Analysis of Gravity Model in the Presence of FTAs

In this chapter we will emphasize on the empirical part of the work with the help of gravity model. One of the objectives is to describe the concept of free trade. Another objective is to analyze the trade relations of India with its top trade partners, focusing on the last few years. The extant literature review on the Gravity Model used for the estimation of trade flows has been analyzed in Chapter 2 so as to be able to identify the variables which form the backbone of the model. Additionally, it will be used to estimate the Gravity Model for India's trade flows by deriving quantitative conclusions on the effect of the selected explanatory variables and the trade agreements.

Gravity Model has become widely popular to rate the potential of trade between countries. Though research has been done on the model but its effect on commodity trade only has not been tested with India at its center. The first part of this chapter explains the concept of free trade and makes an analysis of benefits and threats as two contradictory approaches based on the economic thought over the years. The second part includes an overview of the Gravity Model and the variables used in similar work, leading to that of data and estimation of Gravity Model.

The data for this analysis have been collected from different sources. All the data collected are secondary data from various online sources. The import and export data from and to different countries, as explained by variables, $Export_{ij}$ and $Import_{ij}$; is collected from COMTRADE database of UN. CEPII, France have been used for 'distance between countries' data ($Distance_{ij}$), real effective exchange rate (Real Effective Exchange Rate $_{ij}$), previous colonial history among countries ($Colony_{ij}$) and similar language between countries ($Language_{ij}$). Population of both countries, inflation and GDP of both countries are collected from World Bank Open data source. The rest of the variables, such as common border ($Border_{ij}$), common currency ($Currency_{ij}$), common religion ($Religion_{ij}$) among the pair of countries have been taken from various open sources. The data for presence of FTAs among pairs of countries (FTA_{ij}) has been taken from WITS (World Integrated Trade Solution) maintained by the IMF, UNCTAD and the WTO.

The estimation techniques such as (1) Between Effect (BE) estimation and (2) GMM estimation are performed by STATA software. The main source of contagion, which we have argued as of prime interest to this thesis comes in the form of joint movements in some of

the variables that are significantly influenced by international trade. In this set up, we use the gravity model as discussed in the previous chapter to see if contagion is more dominant within countries closely linked via trade or could also be influenced by other factors chosen as covariates in this empirical specification.

Chapter 4: Radiation Theory in International Trade: Goods and Factor Mobility

In this chapter we have proposed a mathematical model for the analysis of international trade by radiation theory in physics. Also we have proved that this theory is related with gravity model of international trade where we have considered that economic masses such as GDP of the countries are statistically distributed as (1) uniformly distributed, (2) exponentially distributed, and (3) power-law distributed. These results are summarized in tabular form.

Chapter 5: Conclusions and Future Research

In this chapter we have summarized the outcome of each chapters and stated a set of extensions in future.

In this thesis, each items and terminology is explained with illustrations. Theoretical models of crisis starting from first generation to fourth generation is explained. Empirical models of currency crisis are divided into two basic categories: (a) currency crisis models on early warning system (EWS), (b) economic data with time is the signal and that can be processed by signal processing techniques. Also we introduced the application of biologically inspired advanced computing techniques such as *softcomputing* (SC) and/or *computational intelligence* (CI) tools and techniques (e.g., Neural Network, Fuzzy Logic, genetic algorithm, genetic programming, etc.) for the analysis of economic data. This biological and natural computing tools introduce a next generation of crisis model. This might be a proposal of the fifth generation of crisis model – here the model is intelligently and automatically designed that learns from the environment as it changes based on the available economic data. This model is an intelligent model designed using the techniques of artificial intelligence (AI). So its knowledge-base is upgrading with time as human experts of the domain. For example a neural network can do the following task:

- (1) It can extract knowledge from the economic data.
- (2) It can design a function as a black-box between input-output data of an economic system.
- (3) It can select the important features from input-output relation.
- (4) Each neural network can act as an expert for an expert decision.
- (5) A group of neural network can form a single neural network known as committee network for an expert committee.
- (6) Neural network can perform regression task known support-vector regression (SVR) or support vector machine (SVM).
- (7) Neural network can combine score by the method of network fusion.
- (8) Neural network can update its knowledge from the dynamic environment
- (9) Neural network can hybridize with Fuzzy Logic or Genetic Algorithm or Genetic Programming where (a) Fuzzy Logic can be used to process nonnumeric data, (b) Genetic algorithm can be used for optimization problem (may be constraint-satisfaction problem), (c) Genetic Programming (GP) can be used to generate decision-tree for a rule-based expert system.
etc.

A fifth generation crisis model can be proposed after exploiting these properties of the computational intelligence tools.

In international trade of gravity model we explained various distances such as shortest distance, geometric distance, air distance, shipping distance, road distance, geographical distance between two countries with illustrations on geographical map. Various parameters related to international trade are classified as (1) country-specific geographical features, (2) country-specific demographical features, (3) country-specific economic features, (4) country-specific ratio features, (5) country-specific dynamic dependent features. Also these parameters are described in a mathematical form.

Also we proposed a feature termed as *nearness*. This is defined mathematically and illustrated numerically. The computational procedure is presented in a theorem and proved mathematically using *harmonic mean* as well as *Ohms' law* and *Kirchhoff's law* of current electricity. Also we introduce the concept of *multi-channel model* of international trade using gravity equation. An unified gravity model is presented by considering all these discussed features. We applied the *radiation theory* in physics to international trade. The pro-

posed model is analyzed and a relation established with the gravity model of international trade. This analysis is studied with various cases and with various distributions such as (1) uniform, (2) exponential, and (3) power-law distributions of economic masses of the partner countries in the trade network.

There is a possibility of the application of the theory of bubble dynamics in reacting fluid in the study of contagion of financial crisis. Theory of bubble dynamics in reacting fluid means liquid oxygen is injected in the liquid impure (e.g., carbon and silicon) iron. and that liquid oxygen is converted to gaseous oxygen bubble inside impure liquid iron due to high temperature difference. Then oxygen particle of outer layers of oxygen bubble start reacting with carbon to form gases (carbon di-oxide, carbon mono-oxide and that will be inside the oxygen bubble. At the same time oxygen is reacting with silicon too for slag which is floating up, and not staying inside the bubble. The gas particles (both oxygen, oxides of carbon) move inside the bubble as per Brownian motion. Volume of the bubble keeps changing with time and also density of oxygen particle decreases. This philosophy can be used for the study of contagion of financial crisis.

Economic data is a time series data. Contagion depends also on other factors starting from geographical, political, demographical, etc. So contagion depends on multichannel signals. Information theory is very rich area that can be exploited to improve contagion models.

Pattern recognition is also a very rich area, so its tools and techniques will improve output quality.

Publications

1. Iman Pal and Saibal Kar, (2021) Gravity Model in International Trade: An Exploration in Ecno-Physics. *South Asian Journal of Macroeconomics and Public Finance*, pp. 1-33, SAGE. DOI:10.1177/2277978721989922
2. Iman Pal, Saibal Kar and Srimanta Pal, "The Theory of Radiation and Bilateral Trade Between Regions" (*Communicated*)

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