Contagion of Crisis, International Trade and Welfare

Thesis submitted in partial fulfillment of the requirements for the award of the Degree of Doctor of Philosophy in Arts at Jadavpur University, Kolkata

IMAN PAL

Centre for Studies in Social Sciences, Calcutta (CSSSC)
Jadavpur University
Kolkata 700032

2022

Certified that the thesis entitled "**Contagion of Crisis, International Trade and Welfare**" submitted by me for the award of the Degree of **Doctor of Philosophy** in Arts at **Jadavpur University** is based upon my work carried out under the supervision of **Dr. Saibal Kar**, Professor, Centre for Studies in Social Sciences, Calcutta.

And that neither this thesis nor any part of it has been submitted for any degree/diploma or any other academic award anywhere before.

Candidate: IMAN PAL
Signature : Iman Pal

Date : 25/2/2022

Countersigned by:

Supervisor: PROF. SAIBAL KAR
Signature : Professor CENTRE FOR STUDIES IN SOCIAL SCIENCES, CALCUTTA

Date : 28th February, 2022

ACKNOWLEDGEMENTS

The success and final outcome of this thesis required a lot of guidance and assistance from many people and I am extremely grateful and fortunate to receive this opportunity all along.

It is a matter of great pleasure for me to express my deepest respect and profound sense of gratitude and indebtedness to Prof. Dr. Saibal Kar, Professor, Centre for Studies in Social Sciences, Calcutta for his sincere exhortation, meticulous guidance and supervision, steadfast encouragement, painstaking efforts, caring parental affection during the entire course of investigation and preparation of the thesis.

I would also like to convey my regards and sincere thanks to all the other faculties of Economics in CSSSC, especially, Prof. Sugata Marjit, Dr. Pranab Kumar Das, Prof. Jyotsna Jalan, Dr. Indrajit Mallick, Dr. Rittwik Chatterjee and others for their valuable suggestions and encouragement.

Deepest thanks to our CSSSC library staff members for their kind co-operation and I would also like to thank our M Phil/PhD co-ordinator Kavita Bhowal for her constant support and motivation and also taking care of all the cumbersome official formalities.

I want to express my sincere thanks to the researchers of economics in the related field of contagion, crisis, international trade, and welfare. I gathered knowledge and experience from their work.

I express my deepest sense of gratitude to all of them, whether mentioned here or not, who have supported me in countless ways during the course of investigation and study.

Finally, I would like to convey my gratitude towards my parents, for their constant support and encouragement, along with their blessings and best wishes.

IMAN PAL

Contents

List of Tables

List of Figures

Chapter 1

Introduction and Literature Review

1.1 Background

Economic and financial crises is widely considered as an untoward event. Under most circumstances, it creates an unstable and dangerous situation in a system and affect an individual, group, community, or whole society. Crises occur either slowly (i.e., with warning) or abruptly (i.e., without warning) with negative changes in the security, economic, political, societal, or environmental affairs. When a crisis occurs abruptly, then this event is termed as "*emergency event*".

A financial crisis is a situation in a financial system where the value of financial assets is either dropping rapidly or bursting of a speculative financial bubble, a stock market crash, a sovereign default, or a currency crisis. This situation is often triggered by a panic or a run on banks.

The international financial crisis or global financial crisis (GFC) is a kind of financial crisis which is dealing with crises in a globalized world. It is a subset of financial crisis.

International trade is the exchange of capital, goods, and services across international borders or territories because there is a need or want of goods and/or services.

The system of international trade has helped to develop the world economy but, in combination with bilateral or multilateral agreements to achieve the following: (1) to lower tariffs, i.e., a tax or duty to be paid on a particular class of imports or exports, or (2) free trade, i.e., duty free for imports or exports.

Welfare is an indicator for assistance from national and international body or government to maintain the normal state of the nature as well as mankind. In economics, an assistance may be quantified in terms of finance. So the financial crisis will directly affect the welfare.

1.2 Motivation

In economics, the term '*contagion*' was first coined since July 1997, during that period of Asian financial market 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. Where 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 a 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 the beginning for the development of the world economy. So it is an integral part of international finance. Sometime an international trade will diversify risk in some domestic markets in different countries. In some situation an international trade may increase the transmission of crises across countries. In fact an international trade may increase a certain part of the degree of 'contagion' across countries.

The financial crisis will also directly affect 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 phenomenon dramatically increases the degree of 'contagion' across countries.

In welfare implications, mandatory disclosure of losses at financial institutions cannot raise welfare for small contagion. On the other hand, this mandatory disclosure can improve welfare for large contagion.

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 institutional of monetary and exchange rate arrangements, (9) Trade linkages, (10) Competitive devaluations, (11) Wake-up calls effect, (12) Common creditor effect, etc.

1.3 Review on Economic Crisis

In 1978 Salant and Henderson [266] explained the concept of currency crisis. Krugman (1979) [187] was inspired by their work [266] and developed a framework for the analysis of currency crisis. This framework is the beginning of first-generation models on currency crises. This model is also termed as models of *balance of payment crises*. Later the first-generation models on currency crises were improved by different researchers (Flood & Garber (1984) [129]; Connoly and Taylor (1984) [79]; Calvo (1987) [61]; Edwards (1989) [109]; Agenor, Bhandari, and Flood (1991) [7]; Krugman and Rotemberg (1992) [188]; Blackburn and Sola (1993) [44]; Esquivel and Larrain (1998) [123]; Guimaraes (2007) [146]; Tularam & Subramanian (2013) [291]).

In the literature of economics, we observed that the economic crisis phenomenon is developed and propagated via international trade and welfare based on different factors such as (1) currency, (2) assets, (3) credit frictions, (4) management, (5) environment and so on. This phenomenon is also evident in contagion of crisis. People have faced many different crisis in the history of mankind, some are: (1) twin crisis (both currency and banking crisis) (late 1990), (2) Asian Flu (end of 1997), (3) Russian Cold (Aug 1998), (4) Brazilian Sneeze (Jan 1999), (5) Nasdaq Rush (April 2000), (6) Mexican Crisis, (7) East Asian Crisis, (8) Russian crises, (9) Long Term Capital Management (LTCM) near collapse, (10) East Asian Financial Crises of 1997 - 1998, (11) ERM (European Exchange Rate Mechanism) crises (1992 - 1993), etc.

1.3.1 Theoretical Models of Currency Crisis

Financial crisis can manifest in different ways such as follows: (1) currency crisis, (2) banking crisis, (3) credit frictions, (4) liquidity crisis, (5) Eurozone crisis, (6) balance of payment crisis.

Various models of currency crisis are available in economic literature. Currency crisis models are classified into four different generations – starting from first generation to fourth generation. All these four generations of crisis models are designed based on traditional mathematical models.

First-generation to fourth-generation of currency crises models are theoretical models. Also a theoretical model is designed and mathematically formulated based on a set of assumptions. Each of these currency crisis models is grounded on some underlying mechanism such as:

(1) Fundamentals,
(2) Speculation,
(3) Contagion and moral hazard driven investment, and
(4) Institutions and others.

FIRST GENERATION : The first generation currency crises models explain that a currency crisis will result if the government has huge deficits and there is a fixed exchange rate. If expectations start to build that government will be unable to finance the deficit and could monetize the deficit, the monetization could result in high inflation. This could lead to foreign outflows and a speculative attack on the domestic currency. The attack could initially be defended by forex reserves. But if the attack grows and central bank is unable to defend the currency and does not have adequate reserves, it could result in devaluation. A sudden devaluation of a fixed exchange rate leads to collapse of the exchange rate system and leads to a crisis.

This branch of models, the so-called first generation models of currency attacks was motivated by a series of events where fixed exchange rate regimes collapsed following speculative attacks, for example, the early 1970s breakdown of the Bretton Wood global system. The first paper here is the one by Krugman (1979) [187] encouraged from the work by Salant and Henderson (1978) [266]. Krugman describes a government that tries to maintain a fixed exchange rate regime, but is subject to a constant loss of reserves, due to the need of monetizing government budget deficits. These two features of the policy are inconsistent with each other, and lead to an eventual attack on the reserves of the central bank, that culminate in a collapse of the fixed exchange rate regime.

Flood and Garber (1984)[129] extended and clarified the basic mechanism, suggested by Krugman (1979) [187], generating the formulation that was widely used since then.

First generation currency crisis model identifies the causes of a currency crisis. The possible causes are

(1) the fundamental inconsistency of the policy measures,

(2) expansionary fiscal and monetary policies, and
(3) foreign exchange reserves at the central bank.

This model can indicate the antecedents of currency attacks where the possible indicators are

(1) a growing decline in international reserves,
(2) a growing current account deficit,
(3) a growing budget deficit,
(4) a growing domestic credit, and
(5) an exchange rate overvaluation.

Important Factors: Some important factors are listed below.

(1) It focuses on long run, unique equilibrium, fiscal deficits and monetary policies.
(2) Crises arise as a result of an inconsistency between an excessive public sector deficit that becomes monetized and the exchange rate system.
(3) Abandonment of a fixed exchange rate regime is largely due to unsustainable credit expansion and unsound economic fundamentals. A country with weak economic fundamentals is more vulnerable to speculative attack. It emphasizes the relationship between speculation attack in foreign exchange market and macroeconomic variables.

Issues : Some issues are given below.

(1) These models require agents to increase their estimates of the likelihood of devaluation.
(2) It does not explain why the currency crises spread to other countries.
(3) From the literature of first generation models it is difficult to understand why the government tries to keep the exchange rate fixed and conducts a policy which the government knows will ultimately lead to a currency crisis.

SECOND GENERATION : First generation currency crises model could not explain the contagious currency crisis. For instance, we saw South East Asian crisis becoming a contagious crisis spreading from one region to the other. The second generation currency crises model explains these events via trade channel or via neighboring trade partners or via having similar macroeconomic attributes or via financial channel.

Following the collapse of the ERM (European Exchange Rate Mechanism) in the early 1990s, which was characterized by the tradeoff between the declining activity level and abandoning the exchange rate management system, the so-called first-generation model of currency attacks did not seem suitable any more to explain the ongoing crisis phenomena. This led to the development of the so-called second generation model of currency attacks, pioneered by Obstfeld (1994, 1996) [233, 235]. A basic idea here is that the government's policy is not just on automatic pilot like in Krugman (1979) [187] above, but rather that the government is setting the policy endogenously, trying to maximize a well-specified objective function, without being able to fully commit to a given policy. In this group of models, there are usually self-fulfilling multiple equilibria, where the expectation of a collapse of the fixed exchange rate regime leads the government to abandon the regime. This is related to the Diamond and Dybvig (1983)[91] model of bank runs, creating a link between these two strands of the literature.

Obstfeld (1996) [235] discusses various mechanisms that can create the multiplicity of equilibria in a currency-crisis model.

Second generation currency crisis models suggest that a government continuously measure the following:

(1) the cost and benefits of defending the currency,
(2) adding that one possible trigger,
(3) the event of an intermediate economic situation, and
(4) peoples expectation.

It indicates in the macro economy it may affect the governments decision based on the following indicators:

(1) high unemployment,
(2) inflation,
(3) a large fiscal deficit, and
(4) possible stability of the financial sector.

This generation may have a unique equilibrium or multiple equilibria.

Important Factors: Some important factors are listed below.

(1) It focuses on short run, multiple equilibrium, government policies and speculation expectations.
(2) It explains the relationship between economic fundamentals and speculative attack period.

(3) The government is an active agent that maximizes an objective function.
(4) Circular process exists, leading to multiple equilibrium.
(5) It suggests that crises are not affected by the position of the fundamentals. Instead, they may simply occur as a consequence of pure speculation against the currency.
(6) Self-fulfilling speculative attacks brought about by the governments time inconsistent policy goals appear to be the main cause of crisis.

Issues : Some issues are given below.

(1) The shift from one equilibrium to another is unexplained.
(2) Economists described only quite lightly the role of financial markets in the run-up crises.
(3) It did not attempt to review the Asia currency crisis, which was financial crisis and then led to financial collapse.

THIRD GENERATION : First and second generation currency crises models did not provide policy prescriptions.

While the first and second generation currency crisis literature focused on the government alone, the third-generation models connect currency crises to models of banking crises and credit frictions.

In the late 1990s, a wave of crises hit the emerging economies in Asia, including Thailand, South Korea, Indonesia, Philippines, and Malaysia. A clear feature of these crises was the combination of the collapse of fixed exchange rate regimes, capital flows, financial institutions, and credit. This led to extensive research on the interplay between currency and banking crises, sometimes referred to as the twin crises, and balance sheet effects of depreciations. The importance of capital flows was anticipated by Calvo (1995) [62].

Third generation currency crises model says that a currency crisis leads to a number of problems in the economy and higher interest rates would create more damage to the economy. It suggests to keep real interest rates low and keep financial system functioning in the crisis. These crisis models concern with:

(1) the issue of contagion, and
(2) moral hazard driven investments.

These models involve the following variables:

(1) labour,

(2) interest rates,
(3) growth rate of output and/or current account of other neighboring countries or countries that have trade and financial linkages

It indicates some of the following:

(1) a currency crisis is occurring elsewhere and could put pressure on the home currency,
(2) the moral hazard driven investment mechanism,
(3) information regarding the financial fragility,
(4) excessive build up of debt in the balance sheets of entities in the economy,
(5) balance sheet mismatches,
(6) under regulated financial intermediaries, etc.

Important Factors: Some important factors are listed below.

(1) It explains the relationship between financial fragility and currency crisis.
(2) It focuses on the role of foreign currency denominated debt and its adverse balance sheet effects.
(3) It helps fundamentals driven, self-fulfilling prophecies and banking sector to analyze the Asian crisis.
(4) It suggests that asset market prices may an be useful indicator of crisis.
(5) It emphasizes scope of macroeconomic analysis of exchange rate mechanism, monetary policy, fiscal policy, and public policy.
(6) It focuses on financial intermediaries, change in asset prices.
(7) It analyzes investments affected by moral hazard, bankruptcy, and balance-sheet implications of currency depreciation

Issues : Solutions to currency crises are too radical to be executed in practice and measures are to fail.
The third-generation models together tell us the following factors that lead to a currency crisis:

(1) Domestic Public and Private debt,
(2) Expectations,
(3) State of financial markets, and
(4) Pegged exchange rate

FOURTH GENERATION : In 2001, Krugman [190] conjectured fourth generation crisis model. He also stated that it may be a more general financial crisis model in which other asset prices also play the major role. Fourth generation models extend the earlier models by identifying features of institutional environment that set the stage for the build-up of macroeconomic imbalances, which subsequently give rise to banking problems. The models also relate to some work in which political indicators play a significant role in crisis forecasting (Bussiere & Mulder, 2000) [57]. Breuer (2004) [50] defined fourth-generation (institutional) models as a model that determines important economic outcomes such as ethic tension, politics (voting, checks, and, balances, etc.), civil order including rule of law, trust, culture, social norms, property rights, legal origin and types of governance, be it over the financial sector or the trade sector. Poor institutional factors appear to be the underlying cause for unsustainable policies, excessive borrowing and lending, hyperinflation, among others. It appears that institutional factors set the conditions for economic outcomes. In contrast, Ghosh (2002) [137] understood the fourth generation as those models in which currency crises are created and accentuated by unexpected financial panic from different players in the market and governments. Bonin & Wachtel (2003) [47] and De Nicolo, et al. (2003) [86] showed that institutional infrastructure affects the level of financial development, depositor trust in the financial system, and the level of credit risk. In the fourth generation models (Agenor & Aizeman, 1999; Alesina et al., 2002; Das et al., 2004), [8, 10, 84] explanatory variables include variables such as politics, trust, ethic, tensions, culture property rights, legal origin, types of governance and quality of financial policies. These variables are important given they have an impact on information and uncertainty, and can affect the efficiency of decision-making. These models highlight the roles of rule of law and contract enforcement, protection of shareholder and creditor rights, regulatory frameworks, and the socioeconomic environment (Buch & De Long, 2008; Das et al., 2004; Demirguc-Kunt & Detragiache, 1998, 2005; Eichengreen & Arteta, 2000; Hutchinson, 2002; Hutchinson & McDill, 1999) [55, 84, 88, 89, 116, 162, 161]. The advantage of fourth generation currency crisis models is that they build upon forward looking information, contained in market prices.

Fourth generation currency crisis models are loosely concerned with

(1) the issue of institutions, and

(2) some other mechanisms

(a) coordination failures
(b) agency issues,
(c) information asymmetries,
(d) possible policy intervention effects, etc.

As institutions tend to have an impact and correlate on the health of the economy and are informative in the sense that they can signal market agents about the future of economic fundamentals, and thereby shape market expectations, they may be an important component that may help anticipate a currency crises.

It indicates some of the following:

(1) recent turnover in the government,
(2) presence of divided government,
(3) level of corruption,
(4) government instability,
(5) weak law and order and level of democracy,
(6) weakness of the legal institutions for corporate governance

Important Factors: Some important factors are listed below.

(1) It emphasizes on economic and financial rules and regulations, shareholder rights, transparency and supervision over the financial system, and government distortions.
(2) It explains relationship between financial institutions and financial systems.
(3) It builds upon forward looking information contained in market prices.

Issues : Its reliance on market prices derived from liquid markets, limits its applicability when such markets do not exist.

1.3.2 Empirical Models of Currency Crisis

A number of empirical models on currency crisis have been made in literature. These empirical models can be classified into two major categories such as
(1) Early Warning System (EWS): The output of a currency crisis model on early warning system (EWS) (Berg & Patillo, 1999; Demirguc-Kunt & Detragiache, 1998; Eichengreen et al., 1996; Furman & Stiglitz, 1998; Gavin & Hausman, 1996; Goldstein et al., 2000;

Honohan, 1997; Kaminsky & Reinhart, 1999) [39, 88, 115, 135, 136, 140, 158, 171] is an indicator of financial status of the country. The selection of early warning indicators was based on the portfolio balance model which was first introduced by Kouri (1976) [184].

Early warning system (EWS) for currency crises can be designed into two main approaches:

(a) **Signal Processing Approach** (Kaminsky & Reinhart (1999)) [171] : It is a non-parametric approach to determine the risk of financial crisis. Here a variable is considered to be issuing a warning signal if it goes beyond a certain threshold level in the *bad* signal.

(b) **Econometric Approach** (Eichengreen et al. (1996)) [115] : 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.

(2) Agent-Based Currency Crisis Models

These type of models (Farmer and Foley (2009) [125]; Thurner, Farmer and Geanakoplos (2009) [288]; Korobeinikov (2009) [183]) explain 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.

1.3.2.1 Currency Crisis Models on Early Warning System (EWS)

In this section we shall review empirical modes of currency crisis on early warning system (EWS).

(a) Signal Processing Approach of Currency Crisis

In this section we present a review of signal processing approach of currency crisis of early warning system (EWS). This is also termed as *signals approach*.

Kaminsky et al. (1998) [170] reviewed the empirical literature examining methodologies and variables used to estimate the probability of a crisis. They suggested a specific early warning system for currency crises in the context of a signals approach. They identified variables that determine a large variety of indicators useful in predicting crises. These indicators can be grouped into six possible categories:

(1) the external sector (capital account, external debt profile and current account international variables);
(2) the financial sector (financial liberalization and other financial variables);
(3) the real sector (real GDP growth, the output gap, employment/unemployment, wages, and changes in stock prices);
(4) the public finances (fiscal variables);
(5) institutional and structural variables; and
(6) political variables.

This scheme chose fifteen indicators which were taken based on theoretical considerations and availability of information on a monthly basis. Each of the indicators was compared one at a time with a crisis index. The indicators apparently behave differently close to the border of crises. Here the probability of a crisis is defined by higher indicator signals. Vulnerability to crisis is signaled when the indicator variable deviates from its usual behavior. The period of target is 24 months. The model estimated an optimal threshold value for each country and maximized the correct signals while minimizing the false signals. This signals approach is popularly known *KLR Signal Approach* according to the names of Kaminsky – Lizondo – Reinhart (KLR) [170].

Kaminsky and Reinhart (1999) [171] used a non-parametric approach to find variables and compared the behavior of such variables in pre-existing crises. This model was examined to study the behavior of the variables around the time of balance-of-payment crises, banking crises, and twin crises. A single composite indicator is expressed as a weighted sum of the indicators, where the weights are defined by the inverse of its *signal-to-noise ratio* (SNR) . In many emerging economies the indicator performed comfortably well in the case of some currency crises.

Kaminsky (2000) [172] described a method for finding the degree of distress of the economy using the methodology of leading indicators. A warning system is developed based on the empirical regularities from a sample of 20 countries with 76 currency crises and 26 banking crises. The information from each variable is combined, using each variables forecasting track record to produce a composite measure of the probability of a crisis.

Edison (2003) [108] extended the early warning systems by adding more countries and indicator variables compared to those used by Kaminsky et al. (1998) [170] and Kaminsky and Reinhart (1999) [171]. Edison (2003) [108] approached the benchmark model on different indicators and evaluated the in-sample performance and out-of-sample probability indicators of a crisis. And also defined a crisis as an event where the exchange market pressure index rises above an extreme value as shown in Eqn. (1.1):

$$\text{Crisis} = \begin{cases} 1,\ \text{emp}_t > 2.5\sigma_{\text{emp}} + \mu_{\text{emp}}; \\ 0,\ \text{Otherwise} \end{cases} \tag{1.1}$$

where,

t = Time instant,

emp_t = the exchange market pressure index at time t,

σ_{emp} = sample standard deviation of exchange market pressure,

μ_{emp} = sample mean of exchange market pressure,

Again, the probability of future crisis is defined as in Eqn. (1.2).

$$P(\psi_{t,t+h}|I_i^k, I_t^k, I_j^k) = \frac{\text{Months with } I_i^k < I_t^k < I_j^k \text{ and a crisis with } h \text{ months}}{\text{Months with } I_i^k < I_t^k < I_j^k} \tag{1.2}$$

where,

t = Time instant,

P = Probability,

$\psi_{t,t+h}$ = The occurrence of a crisis in the interval $[t, t+h]$,

I_i^k = Four different composite leading indicators with $k = 1,2,3,4$

Edison [108] attempted to take account of signals in overlapping crises windows.

Zhuang (2005) [301] presented two early warning system (EWS) models, (1) one for currency crises, and (2) the other for banking crises. These are designed based on the signaling approach by Kaminsky and Reinhart (1999) [171]. These models are tested using monthly data of six East Asian countries: (1) Indonesia, (2) Republic of Korea (Korea), (3) Malaysia, (4) Philippines, (5) Singapore, and (6) Thailand.

Peng and Bajona (2008) [242] used the approach of the model Kaminsky – Lizondo – Reinhart (KLR) (Kaminsky, et al. 1998) [170] to conduct an ex-post study of the probabilities of China suffering a currency crisis during the period, January 1991 – December 2004. Two high-probability periods are identified: (1) July 1992 – July 1993 and (2) August 1998 – May 1999. The first period correctly predicts China's 1994 devaluation. The second period predicts currency devaluation in the after effect of the Asian crisis, which did not occur. The results of the model indicate that the fundamentals were weak enough for China to experience contagion of the Asian crisis, and raise the question of the possible role of China's institutional arrangements in preventing the crisis.

Modekurti (2015) [223] identified robust lead indicators to serve as early warning signals for a currency crisis in India. The signals approach of Kaminsky – Lizondo – Reinhart (KLR) [170] is used to identify the lead indicators, and *logistic regression* is used to verify their statistical significance. Monthly data for the period April 1990 – December 2014 is considered for the analysis. Export Weighted REER (real effective exchange rate), domestic price of gold, broad money, interest rate differential (between United State of America (USA) and India), Money Market Pressure Index, and Forex Reserves emerge as robust lead indicators (in ascending order of noise-to-signal ratio) with noise to signal ratios of less than 0.5. Index of Industrial Production and Net FII (Foreign Institutional Investment) flows follow in order, with noise to signal ratios of greater than 0.5 but less than 1. Interest Rate Differential, Terms of Trade, Domestic Price of Gold, and Export Weighted REER (real effective exchange rate) are statistically significant at 5% level with correct signs. The logistic regression model calls 74% of the 6 crisis points. The significant lead indicators warn 12-16 months ahead of crisis, with a KLRs conditional probability of 84%. Time varying behavior of lead indicators and central banks intervention in pre-empting crisis may vitiate the signal approach. There is no study on India using KLR, 1998, signals approach for an early warning system on currency crisis. For the first time gold price is included to verify its power to signal a currency crisis and it displays robust signaling power. Crude Oil price lacks the power to signal a currency crisis.

Anh (2017) [16] identified the leading indicators of a currency crisis in Vietnam based on an early warning system for the period 1996 – February 2016. The global financial shocks (e.g., regional and global financial crisis, unexpected changes in monetary policy of largest economies such as the United States and the Peoples Republic of China), and domestic credit growth rate are leading indicators of a currency crisis in Vietnam. Deficits in trade balance, international reserves, and overvaluation of the currencies are also good indicators. In addition, a model in which a currency crisis or turbulence in the foreign exchange market is defined based on the exchange market pressure and parallel market premium, with window length of 2 months, outperformed for predicting a currency crisis in Vietnam. Empirical results suggested that probability of predicting a true currency crisis was 77.5%.

As a result of global integration and financial liberalization, financial crises have been experienced quite frequently in the world since the 1980s. The effects of the financial crises in the international arena are severe and rapidly spreading. For this reason, in the studies on the crisis, various methods for early warning models have been developed on the prediction of crises. The aim of the study by Buyukakin and Aydin (2018) [59] was to estimate the financial crisis for Turkey case by *KLR Signal Approach* [170]. Buyukakin and Aydin (2018) [59] has chosen 7 macroeconomic variables belonging to the period of January 1990 – September 2018 for testing the model. Also they introduce a new crisis variable that successfully indicates the crisis signal.

(b) Agent-Based Currency Crisis Models

In economics, an agent is an individual or a decision maker or a body in a model of some aspect of the economy. Typically, every agent makes decisions by solving a well-posed or ill-posed optimization or choice problem. There are four major economic agents:

(1) households/individuals,
(2) firms,
(3) governments, and
(4) central banks.

Also it is well-known that the financial markets are complex system and it involves human activities and their behavior. Therefore, there is a need to understand the behavior of the whole economic system in a simplistic manner. One way to understand human behavior better is by using *agent analysis*. Agent-based modeling appears to be one of the better ways to explain the behavior of the economic systems, since it does not assume that the economy can achieve a settled equilibrium. Moreover, it uses a bottom-up approach that assigns behavioral rules to each agent.

Farmer and Foley (2009) [125] made a strong case for the use of agent-based models in economics. The authors suggested that agent-based models are capable of generating complex dynamics even with simple behavioral rules. In fact, the use of rules can give rise to emergent properties that could not possibly be deduced by examining the rules themselves.

Thurner, Farmer and Geanakoplos (2009) [288] designed an agent-based model that deals specifically with the financial crisis. They investigated the effects of use of leverage and margin calls on the stability of the market. Also they [288] showed that when individual lenders seek to control risk through adjusting leverage, they may collectively amplify risk. The authors concluded that this mechanism comes into play with other risk control mechanisms, such as stop-loss orders and derivatives; whenever they generate buying or selling in the same direction as price movement.

Korobeinikov (2009) [183] developed an agent-based model and considered an economy as a population of interacting economic agents. This model provides a general idea of what can be done to avoid a crisis and explains how one can reduce the length of infection time such that the crisis can slow down and reduce its consequence. This model clearly indicates how *dangerous* fraudulent companies could exist in reality, and indeed how important it is to detect and remove them in time.

In the Nature, Bchanan (2009) [35] wrote:

No government was able to carry out any such **'war room'** *analyses as the current financial crisis emerged, nor does the capability exist today. Yet a growing number of scientists insist that something like it is needed if society is to avoid similar crises in future.*It is likely to remain fiction

Bookstaber (2017) [48] designed an agent-based approach to modeling financial crises. This model focuses on:

(1) the interactions of agents, and
(2) its feedback to change the financial environment.

Also this model explains:

(1) the technique of formation of the contagion and cascades
(2) market concentration of the agents,
(3) the liquidity of the markets.

Bookstaber (2017) [48] compared the agent-based models to the standard economic approach to crises. Also he discussed the process of improvement of agent-based models to overcome the limitations of economic models when dealing with financial crises. Bookstaber also demonstrated the technique as follows:

(1) the agent-based model replaces homogeneous, representative agents with heterogeneous agents and optimization with heuristics, and
(2) these models move away from a focus on equilibrium, allowing non-ergodic dynamics that are manifested during financial crises to emerge.

Pinheiro and Coelho (2017) [248] developed an agent-based model for the study of how the leverage through the use of repurchase agreements can function as a mechanism for the propagation and amplification of financial shocks in a financial system. Based on the analysis of financial intermediaries in the repo and interbank lending markets during the 2007-08 financial crisis they developed a model that can be used to simulate the dynamics of financial contagion.

Napoletano, Guerci and Hanaki (2018) [227] studied the literature inspired by the complexity-based approach to economic analysis and the contributions are divided into two groups.

(1) **Group I** develops network models of financial systems and showed how these models can shed light on relevant issues that emerged in the aftermath of the last financial crisis.
(2) **Group II** deals with the issue of validation of agent-based model.

Agent-based models have proven extremely useful to account for key features economic dynamics that are usually neglected by more standard models. At the same time, agent-based models have been criticized for the lack of an adequate validation against empirical data. They developed an useful techniques to validate agent-based models, thus contributing to the wider diffusion of these models in the economic discipline.

1.3.3 Review on Early Next Generation Models of Economic Crisis

In this section we reviewed the financial crisis models using advance computing tools and techniques inspired from biology or from the nature. Here the published works in economic crisis using softcomputing paradigm are classified as (1) neural network (NN) approach, (2) fuzzy logic (FL) approach, (3) genetic algorithm approach and (4) their hybridization such as (a) neuro-fuzzy, (b) neuro-genetic, (c) fuzzy-genetic or (d) neuro-fuzzy-genetic approaches.

A very little work on financial crisis using softcomputing or computational intelligence paradigm are available in the literature. These works are stated below using softcomputing tools.

Neural Networks: The scientists who contributed on crisis using neural networks of softcomputing are: Nag and Mitra (1999) [226], Franck and Schmied (2004) [133], Arciniegas Rueda and Arciniegas (2009) [264], Liu, Eklund, Collan and Sarlin (2010a) [207], Liu, Eklund, Collan, and Sarlin (2010) [207], Sarlin and Marghescu (2010) [269], Sarlin and Marghescu (2011) [271], Sarlin (2012) [273], Sarlin (2013) [275], Claveria, Monte, and Torra (2015) [74], Claveria, Monte and Torra (2016) [75], Teresa Sorrosal-Forradellas, Martinez and Terceno (2017) [287], Dungey, Islam, and Volkov (2019) [99], Kinsella (2019) [180].

Fuzzy logic: The scientists who contributed on crisis using fuzzy logic (FL) of softcomputing are : Lindholm and Liu (2003) [203], Liu and Lindholm (2006) [206], Rajanen, Liu and Sarlin (2010) [252], Marghescu and Sarlin (2010) [211], Marghescu, Liu and Sarlin (2010) [210], Mezei and Sarlin (2017) [221], Dincer, Hacioglu and Yuksel (2017) [92].

Hybrid Models: The scientists who contributed on crisis using hybrid models of softcomputing are in

(a) *Neuro-Fuzzy Models*: Sarlin and Eklund (2011) [272].

(b) *Neuro-Genetic Models*: Sarlin (2012) [274], Salam et al.(2015) [265].

1.4 Cross-Country Evidence on Economic Crises

In the new global economy, the economic crisis has become a central issue for the whole world. A major crisis of the 1980s that shook the world's financial markets was the 1987 U.S. market crash. In the 1990s there have been a large amount of financial crises in the world that have been characterized as *financial contagion*, namely the Tequila Effect of the Mexican peso of December 1994, the *Asian Flu* or *yellow fever* at the end of 1997, the

Russian Cold of August 1998, the Brazilian Sneeze of January 1999, and the Nasdaq Rash that began in April 2000. In these crises the shock was spread to other markets with no obvious linkage to the initial shock. Since all the crises in the late nineties, the economic and financial crisis of 2007 until 2009 marks the first major economic downturn for most of western economies. What started as a financial turbulence in the summer of 2007 threatened financial stability primarily in the advanced economies, especially the United States and the United Kingdom. The crisis started as a local problem to the US mortgage market, but became a worldwide problem for financial stability. A global macroeconomic shock led the US into recession, along with Europe and Japan. This crisis, which started in 2007, is the largest we have known in history and way bigger than other currency crises before. Also the debt crisis in 1980 is in a shadow next to the economic crisis in 2007. The last major financial crisis was the Greek Depression of 2009-16.

Financial contagion is a phenomenon which causes countries that may not be directly affected by a financial shock to experience an economic crisis. Detailed examination of contagion by Claessens, Dornbusch and Park (2000) [72] showed that in general contagion is used to refer to the spread of market disturbance mostly on the downside from one (emerging market) country to the other, a process observed through co-movements in exchange rates, stock prices, sovereign spreads and capital flows. Forbes and Rigobon (2001) [131], Cleassens et al. (2001) [73] state that defining contagion is a problem on its own; there is much disagreement about this concept. The narrow definition of contagion that is used the most is that contagion occurs when cross-market linkages in a stable period increase after a shock to a market (Forbes and Rigobon, 2002) [132]. Contagion is also said to occur when shocks spread through herding or irrational behaviour. Other economists argue that contagion occurs when a shock is transmitted from one country to another country even if the cross-market linkages do not increase.

Calvo and Reinhart (1996) [63] provide evidence of contagion during the Mexican crisis, as they find increased correlations across stock and bond returns for emerging markets in Latin America. It is easier for banks to have loans around the world and trade with a lot of countries. As a result of contagion linkages between banks increased, and also the size of the claims increased.

Baig and Goldfajn (1999) [27] suggest discernible patterns of contagion during the East Asian crises, and present evidence in favor of substantial contagion in the foreign debt markets, as well as more tentative evidence on stock market contagion.

Corsetti et al. (2005) [83] find evidence of contagion for a small number of countries during the East Asian crisis.

Cerra and Saxena (2002) [68] investigate the reasons behind the currency crisis in Indonesia in 1997 and provide evidence that the crisis was a result of contagion from speculative pressures in Thailand and Korea.

Glick and Rose (1999) [138] identified currency market contagion across five Asian countries and show that the primary channel of contagion was the strong trade linkages among countries. A similar result is provided by Van Rijckeghem and Weder (2001) [293].

Dungey et al. (2002) [95] examine the transmission of the Russian crisis and the Long Term Capital Management (LTCM) near-collapse to 12 countries among several world regions, employing the daily behavior of the risk premia in those countries. The results show that there exists significant contagion from both crisis events to other economies in the sample. The LTCM near-collapse appears to have had a larger effect than the Russian crisis on most of the countries. The level of volatility results on whether contagion is more substantial for developed or emerging markets are mixed. Emerging markets such as Brazil and Thailand were more affected by contagion than the U.K., however, Indonesia, Mexico and Korea were less affected by contagion than the U.S. and the Netherlands. On the other hand, it was shown that the level of volatility results in higher magnitude of contagion relative to emerging countries.

Economists since time immemorial have been working on this subject. Morgenstern (1959) [224] showed a series of stock market panics and bank runs in some European countries from 1880-1939 with a high degree of cross-country coherence. Bordo (1986) studied 4 major European nations (viz., UK, France, Germany and Sweden) and US and Canada from 1870 to 1939 and concluded that financial crisis, bank runs and stock market crashes have international coincidence under both classical gold standard and gold exchange standard.

As we look into the literature of this particular topic we come across Kindleberger's *Manias, Panics, and Crashes*. Kindleberger believed that *markets work well on the whole*, but occasionally *will be overwhelmed and need help* from a lender of last resort. He understood both the danger of inaction by such a lender and the *moral hazard* that its mere existence can create, by encouraging investors to be reckless in the belief that they will be bailed out if all goes wrong. Thus, he argued, a *lender of last resort should exist, but its presence should be doubted*. It should always come to the rescue, but *always leave it uncertain whether the rescue will arrive in time or at all, so as to instil caution.* Pulling this off is, he noted, a *neat trick*. Kindleberger (1986) [178] chronologically presented some common incidence of crisis in Europe and US markets since seventeenth century which is a great historical tool for this study.

So we can argue that global investment and cross-border trade makes financial contagions more likely, especially among developing countries or emerging markets. In these markets, contagions are often exacerbated by asymmetric information, which results in both unsustainable investments and reactionary market downturns in response to the weakening of nearby or closely correlated markets. Generally, larger and more established markets are better able to weather financial contagions than developing economies. Contrary to these ideas, Bordo and Murshid (2000) [49] showed that the effect of contagion is weak in the recent times compared to World War I era; even PCA (Principal Component Analysis) estimates among different market groups and regions as well as different groups of countries showed similar results. They even argued that the crises of 1990s are due to bad fundamentals or cross-country linkages and not contagion. Generally, results on the existence of contagion are mixed.

Various empirical studies show that correlations increase in stock markets during hectic periods and contagious effects occur (Walti, 2003; Corsetti et al., 2005; Billio and Caporin, 2010; Hossein and Nossman, 2011) [297, 83, 42, 159]. Cross-asset correlations generally decrease in times of crises, especially in the case between bonds and stocks (Hunter and Simon, 2004; Connolly et al., 2005). This result can be explained by the flight-to-quality episodes that take place leading to *decoupling*, where high positive correlations among stock markets are observed, but negative correlations between stock and bond markets (Gulko, 2002) [147].

The investigation of mean and volatility spillovers across developed and emerging stock markets has provided useful insights. Studies such as those by Koutmos and Booth (1995) [185], Ng (2000) [231], and Worthington and Higgs (2004) [298], suggest that spillovers mainly move from developed to emerging markets, and that emerging markets are more integrated than the developed ones. Masson (1998)[215] refers to an effect known as *monsoonal* where countries are affected simultaneously by crises caused by common shocks, which in turn causes a withdrawal of offshore funds. This simultaneous movement among countries and markets can be explained by common external factors, such as a rise in U.S. interest rates or a devaluation of the dollar, as well as trade linkages and market sentiments.

Another type of contagion is *shift contagion*. This contagion has been defined by Forbes and Rigobon (1999) [130] as a significant change in cross-market linkages after a shock in an individual country (or group of countries). Earlier tests for a *shift*, in the way shocks are transmitted across countries have suggested the existence of contagion. For example, King and Wadhwani (1990) [179] find the significant increase in the cross-country correlation coefficients of returns and equities after the October 1987 crash, and Lee and Kim (1993) [196] arrive at a similar conclusion. The studies by Hamao et al. (1990) Hamao:1990 and Lin et al. (1994) [201] also find their roots in the stock market crash of October 1987. Both studies investigate the extent of price volatility and the correlation degree between volatility and returns in New York, Tokyo, and London, and find evidence of contagion across equity markets. But Forbes and Rigobon (1999)[130] and others argue that the conclusions from such studies could be misleading, because the simultaneous nature of financial interactions and data heteroscedasticity are not taken into account. For example, in the case of heteroscedasticity, they point out that when the variances of two assets increase (as they typically do during periods of crises), their correlation coefficient will increase regardless of whether the transmission of shocks between these variables increases. Taking such econometric concerns into account, these authors conclude that there is, in fact, little or no contagion. For example, Lomakin and Paiz (1999) [208] find low probabilities of contagion between various country bond markets when they compute the likelihood that a crisis will occur in one country given that it has occurred in another. Forbes and Rigobon (1999) [130] and Rigobon (2001) [257] find little incidence of shift contagion during the Mexican, Asian, and Russian/LTCM crises in various emerging-country equity and bond markets. Similarly, Rigobon (2000) [256] concludes that no shift contagion occurred between 1994 and 1999 in the Brady bond markets of Argentina and Mexico.

But these methods were flawed due to a number of reasons, as was pointed out by Gravelle (2003) [144], viz.; one is that crisis periods are designated as such ex post. That is, the beginning and ending dates of crises are determined exogenously. Yet, while there is relative agreement in the literature on the starting date of crises, there is far less consensus with respect to ending dates. The associated low-variance periods are generally also determined by a rule of thumb. Because test conclusions depend on the choice of the normal and crisis periods, such practices may lead to spurious results. A second disadvantage with some of these techniques is the ambiguity of how to interpret a rejection of the null hypothesis. These methods make the assumption that increases in the variance of returns during crises are caused entirely by increases in the idiosyncratic shock of the country in which the crisis originated. Therefore, a rejection of the null implies that either the propagation mechanism was unstable (i.e., shift contagion occurred) or variances of several countries increased simultaneously at the onset of the crisis. A related drawback is that the country generating the crisis is assumed to be known, which may not always be the case.

Gravelle et al. (2003) [145] focus on shift contagion and develop a methodology to detect it statistically. In particular, they examine whether existing linkages between assets of different countries remain stable during crises, or whether they grow stronger. They conduct their analysis on the bond markets of four emerging countries and on the currency markets of seven developed countries and provide evidence of shift contagion among these assets. Their empirical results suggest that, for Latin-American countries, shocks are transmitted via long-term linkages between countries, so that longer-term strategies to deal with contagion might be more effective. Also, for developed currency markets, they suggest that shocks are transmitted only during turbulent periods implying that short-term strategies to stabilize markets may be warranted.

Beirne et al. (2013) [37] apply the concept of shift contagion to the analysis of spillovers from mature to emerging stock markets and test for shifts in the transmission mechanism during episodes of extreme movements in mature markets. Their analysis covers a large sample of 41 emerging market economies in Asia, Europe, Latin America, and the Middle East. They show that spillovers from mature markets influence the dynamics of conditional variances of returns in emerging stock markets, and that the spillover parameters change during turbulent episodes in mature markets.

Fundamentals-based contagion (interdependence) is the transmission of global or local shocks across countries through fundamentals (spillover effects). According to this definition, contagion could arise also during stable periods (Calvo and Reinhart (1996), Pristker (2000)) [63], [251]. Connolly and Wang (2003) [80] investigate the return co-movement in international equity markets with a focus on the distinction between economic fundamentals and contagion. In particular, they examine the potential macro news effect based on a data set of macroeconomic news announcements made in the U.S., U.K., and Japan. Their findings suggest that future inquiry on market co-movement may focus on the distinction between contagion and trading on private information, rather than public information.

Chan-Lau et al. (2004) [71] introduce global extreme contagion measures constructed from bivariate extreme dependence measures. Their main results suggest that contagion patterns differ within regions and across regions, with Latin America showing a secular increase in contagion, and that only the 1998 Russian and Brazilian crises led to a global increase in contagion.

Dungey and Martin (2004) [96] measure the contribution of contagion to the volatilities of exchange rates during the East Asian currency crisis, using a multifactor model of exchange rates which allows for both time-dependent common and idiosyncratic factors, as well as unanticipated shocks across currency markets. The empirical results show evidence of significant contagion, especially for Indonesia. Dungey and Martin (2007) [98] formulate an empirical model of multiple asset classes across countries, in which spillover and contagion effects are formally specified. The framework is applied to modeling linkages between currency and equity markets during the East Asian financial crisis of 1997-1998. The results show that spillovers have a relatively larger effect on volatility than contagion, but both are statistically significant. Moreover, in a similar study Dungey et al. (2004) [97] show that there is evidence that the transmission of volatility in the East-Asian currency markets to the developed markets in the region is not due to contagion but due to common world factors. Ito and Hashimoto (2005)[165] find contagion between equity and currency markets.

Bohl and Serwa (2005) [45] test whether European stock markets were affected by a range of crises, namely the Asian, Russian, Brazilian, Argentinean, Turkish, and U.S. ones and find no contagion effects among countries and markets, but only interdependence. Caporale et al. (2005) [65] test for contagion within the East Asian region using a parameter stability test and controlling for three types of bias, resulting from heteroscedasticity, endogeneity and omitted variable. Their findings suggest the existence of contagion within the East Asian region, consistent with crisis-contingent theories of asset market linkages.

Baur and Schulze (2005) [33] introduce a new model to analyze financial contagion based on a modified coexceedance measure. They define contagion as the crisis-specific coexceedance not explained by the covariates for different quantiles. Results for daily stock index returns show that some contagion exists and is predictable within and across regions. Also they show that, contagion depends on a regional market return and its volatility and is stronger for extreme negative returns than for extreme positive returns. On the other hand, the scale by the level of volatility results show that the magnitude of contagion is relatively larger for emerging countries.

Bekaert et al. (2011) [38] analyzed the transmission of crises to country-industry equity portfolios in 55 countries using the 2007-2009 financial crises as a laboratory. They find evidence of systematic contagion from U.S. markets and from the global financial sector although the effects are very small, however, they show that there is substantial contagion from domestic equity markets to individual domestic equity portfolios. Briere et al. (2012) [52] reject contagion for fixed-income assets, detect contagion effects at the 5% level in stocks, and finally conclude that contagion is an artifact caused by globalization. A similar result (but no similar interpretation) has been provided by Forbes and Rigobon (2002) [132], and Rigobon (2002b, 2003) [258, 259] who find little evidence of shift contagion during the Mexican, Asian, and Russian crises in several emerging markets, as well as between 1994 and 1999 in the Argentinean and Mexican bond markets. Instead, they find a continued high level of correlation during calm periods which they interpret as interdependence.

Beirne and Gieck (2012) [36] provide an empirical assessment of interdependence and contagion across bonds, stocks, and currencies for over 60 economies over the period 1998 to 2011. Their findings indicate that interdependence is most notable across advanced and emerging economies, in the case of the equity market, while contagion effects are most apparent in Latin America and Emerging Asia. However, they also find evidence of contagion from global bonds to regional stocks in Central and Eastern Europe, Middle East and Africa regions. Interdependence within the bond market applies mainly to the advanced economies, whereas evidence for bond market contagion is found for Mexico, Venezuela and Philippines. Cross-market interdependence and contagion from global equities and global currencies to local bonds is not prevalent. Finally, exchange rate interdependence is important for advanced economies, whereas contagion is present in domestic currencies in Hong Kong, Korea, Thailand, Slovakia and Australia that are susceptible to global currency shocks.

Kristin Forbes 1999 argues that policy makers and regulators should pay careful attention to the externalities their corrective actions may have on other economies and try to avoid measures that increase fiscal liabilities and trigger additional contagion. A recent study by Ather Elahi (2011) [23] mentioned in their paper that it is important to monitor financial stability, because of the still ongoing bank problems in the world. He also found that illustration is important locally as well globally. So it is worth studying the channels between countries and banks, so one can identify the weaknesses in the international banking system.

1.5 Trade and Crises: The Essential Models

The Gravity Model of Trade is well-known as the workhorse version of north-south trade involving multiple source-destination relations. We will review the essential features of the gravity model and bring to attention, the Radiation Model of Trade as a an alternative to the gravity model. A review on gravity model and radiation theory in international trade are presented in the following section.

1.5.1 Review on Gravity Model of International Trade

In 1954, Walter Isard (1954) [163] was inspired by the Newton's law of gravitation and developed an analytical framework for the study of international trade in international economics. Later Tinbergen (1962) [289], Poyhonen (1963) [250], and Linneman (1966) [204] independently proposed an analytical framework for the study of international trade inspired by the Newton's law of gravitation in classical mechanics of physics. Now this frame work is popularly known as the *Gravity model*. This model computes the flow of trade force between two countries as Newton computes the force of attraction between two bodies. This model is successfully applied by different economists like Anderson (1979) [12], Bergstrand (1985) [40], Bergstrand (1989) [41], Davis (1995) [85], Deardorff (1998)

[87], Dhar and Panagariya (1994) [90], Eaton and Kortum (1997) [104], Evenett and Keller (1998) [124], Feenstra, Markusen, and Rose (1999) [126], Helpman (1987) [150], Linneman (1966) [204], Markusen (1986) [213], Poyhonen (1963) [250] and Tinbergen (1962) [289] in their works.

In order to define the scope of this research with suitable perspectives, let us reiterate Newton's law of universal gravitation in the following terms: that every particle attracts every other particle in the universe with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centers. However, before we lay out the details of how Newton's Law influences the gravity model in clearer terms, it might be useful to discuss the broad connections at the outset.

It follows from the seminal work of Tinbergen (1962) [289] that the size of bilateral trade flows between any two countries can be approximated by a law called the '*gravity equation*', which as mentioned above is a derivative of the Newtonian theory of gravitation. Just as planets are mutually attracted in proportion to their sizes and proximity, countries trade in proportion to their respective GDPs and proximity [300]. It is well-known that the gravity model in trade was initially considered merely as an empirical observation with little theoretical basis. Empirically speaking, the stable relationship between the size of trading economies, their distance and the amount of trade explained the creation and sustenance of networks successfully, but these did not seem to subscribe to the fundamental theorems of international trade relying heavily on the Ricardian structure highlighting differences in technology across countries to explain trade patterns, and the Heckscher-Ohlin model holding differences in factor endowments among countries as the basis for trade. It was believed that gravity equations introduced factors that were either (indirectly) subsumed under the explanations available in the classical models; or that the factors were too esoteric to have wider applicability. For example, country size has little to do with the structure of trade flows in classical models. Regardless, the extraordinary stability of the gravity equation and its power to explain bilateral trade flows prompted the search for a theoretical explanation for it. With regard to gravity models while empirical analysis predated theory, it presently appears that most trade models require gravity in order to work. In this connection, later modification to the trade theory *a'la* Krugman (1980) [186] is more amenable to the empirical observations from the gravity model. In fact, Bergstrand (1985, 1989) [40, 41] also shows that a gravity model reflects trade due to monopolistic competition in the product market and that a preference for variety between identical countries influences the network formation. It argues that the presence of monopolistic competition and taste for variety within similar countries overcome the undesirable features of Armington models where goods are differentiated only by location of production. Consequently, firm location is endogenous rather than based on restrictive assumptions in other models and all trading countries could specialize in the production of different sets of goods. Notwithstanding, Deardorff (1998) [87] showed that a gravity model can arise from differences in factor-proportions as part of traditional explanations. Further, Eaton and Kortum (2002) [105] derived a gravity-type equation from a Ricardian model, while Helpman *et al.* (2008) [151] and Chaney (2008) [70] related the structure of gravity equations to models with differentiated goods and heterogeneous firms.

In 2010, Kepaptsoglou, Karlaftis and Tsamboulas [177] studied the works on gravity models and its application for last 10 years form 1999 to 2009.

A survey of empirical studies [177] on international trade modeling is summarized in Table 1.1.

Table 1.1 Empirical Studies on International Trade Modeling.

Year	Authors	Objective	Dataset	Dependent Variables	Explanatory Variables	Estimation Technique
1999	Breuss and Egger [51]	Examination of East - West Europe trade potentials	Cross sectional data, old (24) OECD countries, averages of the period 1990 - 1994	Exports	GDPs per capita, population, distance, common language, EU12 and NAFTA memberships	OLS
1999	Endoh [120]	Investigation of trade creation and diversion in the EEC, LAFTA and CMEA	Panel Data, EEC, LAFTA and CMEA members, 1960-1994	Exports	GDPs, population, distance, common language, intra- member, inter-member trade and trade with non-members	OLS

Table 1.1 Empirical Studies on International Trade Modeling (cont.).

Year	**Authors**	**Objective**	**Dataset**	**Dependent Variables**	**Explanatory Variables**	**Estimation Technique**
1999	Kalirajan [168]	Incorporation of stochastic aspects in the gravity model coefficients	Panel Data, Australia and Indian Ocean rim trading partners, 1990-1994	Exports	GDP, GDP per capita, distance	Stochastic Varying Coefficients model
2000	Arghyrou [19]	Investigation of effects in trade by Greece's participation in the EU	Panel data, Greece and major trade partners, Averages 1970-1980, 1981-1992	Imports and Exports	GDP, Pre-Post integration period in the EU, exchange rate, monetary policy	OLS
2000	Nitsch [230]	Investigation of natural border effect in trade in the EU	Panel data, EU-12 countries, 1979-1990	Exports	GDP, distance, common border, common language, country remoteness	OLS and Fixed effects model
2000	Rose [262]	Analysis of common market effects on trade	Panel data, 186 countries, 1970, 1975, 1980, 1985, 1990	Exports	GDP, distance, common border, common language, FTA, common nation, colony, common currency, bilateral exchange rate	OLS
2001	Buch and Piazolo [54]	Investigation of the impact of EU enlargement	Cross sectional data, 9 OECD and their partner countries, 1998	Imports and Exports	GDPs per capita, distance, EU membership	OLS
2001	Feenstra et al. [127]	Evaluation of alternative theories of trade	Cross sectional, 110 countries, 1970, 1975, 1980, 1985, 1990	Exports	GDPs, distance, common border, common language, existence of FTA, remoteness	OLS

Table 1.1 Empirical Studies on International Trade Modeling (cont.).

Year	Authors	Objective	Dataset	Dependent Variables	Explanatory Variables	Estimation Technique
2001	Porojan [249]	Investigation of the spatial effects in the gravity model	Cross sectional, EU-15 and 7 OECD countries, 1995	Imports and Exports	GDPs per capita, distance, EU and NAFTA membership, contiguity	OLS, spatial error, spatial lag, spatial error and lag
2001	Sapir [267]	Investigation of domino effects in Western European regional trade	Cross sectional, 16 western european countries, annual 1960-1992	Exports	GDPs, distance, common language, EU and EFTA membership	OLS
2001	Soloaga and Winters [281]	Analysis of regionalism and trade agreement effects in trade in the 1990s	Cross sectional, 58 countries, 1980-1996, analysis per year and averages	Imports and Exports	GDP, population, remoteness, distance, land area, common border, island, common language, trade agreement membership	Tobit, fixed effects.
2002	Egger [110]	Econometric view on the estimation of the gravity model	Panel data, OECD and 10 Central-Eastern Europe countries, 1986-1997	Exports	GDP, similarity in country size, exporter and importer viability of contracts, exporter and importer rule of law, real exchange rate, distance, common border, common language	Fixed / random effects models
2002	Glick and Rose [139]	Investigation of currency union effects to trade	Panel data, 217 countries, 1948-1997	Exports	Currency union, distance, GDP, GDP per capita, common language, common border, FTA existence, country landlocked, number of islands, land areas, common colonizer, current colony, ever colony, same nation	'OLS, GLS fixed effects, GLS random effects, between estimator'

Table 1.1 Empirical Studies on International Trade Modeling (cont.).

Year	Authors	Objective	Dataset	Dependent Variables	Explanatory Variables	Estimation Technique
2003	Baltagi et al. [29]	Development of a generalized trade flow model	Panel data, EU-15, USA, Japan, 1986-1997	Exports	GDP, GDP per capita, similarity in country size, distance	OLS with two way fixed effects
2003	Egger and Pfaffermayr [111]	Investigation of a proper specification of the gravity equation using two way fixed effects	Panel Data, 11 APEP countries, 1982-1998	Exports	GDP, population, foreign currency reserves, exchange rate, distance, common border, common language	OLS, two way fixed effects model.
2003	Filippini and Molini [128]	Analysis of east Asian trade flows	Panel data, 11 EY countries, USA, Japan, China, 6 Asian and 6 Latin America countries, 1970-2000	Exports	Past exports, GDP, population, distance, technological differences, region	OLS with fixed effects
2003	Fukao et al. [134]	Analysis of trade effects under NAFTA	Panel data, NAFTA members, 1992-1998	Imports	GDP per capita, tariffs, total commodity exports, country specific factors	OLS with fixed effects
2003	Kangas and Niskanen [175]	Trade in forest products in EU and Central and Eastern Europe	Cross sectional data, EU-15 and 10 accession countries, 1998	Exports	GDP, GDP per capita, distance, common border, flow between an EU and accession country	OLS
2003	Kurihara [193]	Impacts of trade flows by APEC	Panel data, 17 APEC countries (out of 21), 1980, 1985, 1990, 1995, 1998	Exports	Past exports, exchange rate, GDP, GDP per capita, distance, common language, common border, FTA, political union membership, colony - colonizer	OLS,

Table 1.1 Empirical Studies on International Trade Modeling (cont.).

Year	Authors	Objective	Dataset	Dependent Variables	Explanatory Variables	Estimation Technique
2003	Wilson et al. [296]	Investigation of trade facilitation and trade flows	Panel data, APEC countries, 1989-2000	Exports	GDP, GDP per capita, distance, NAFTA, ASEAN, LAIA membership, language (English, Spanish, Chinese), common border, tariff, port efficiency, customs environment, regulatory environment, e-business	OLS with two way fixed effects
2004	Egger [112]	Estimation of regional trade bloc effects	Panel data, OECD countries, 1986-1997	Exports	GDP, similarity, capital - labor ratio, high and low skilled labor ratio to transportation costs, exporter and importer viability of contracts, exporter and importer rule of law, EU, EFTA and NAFTA membership	Two way fixed effects - two way random effects
2004	Gopinath and Echeverria [142]	Effects: Foreign direct investment - trade relationship	Panel data, six countries, 1989-1998	Trade to FDI ratio	GDP, GDP per capita, population, distance, accountability, EU membership	OLS with fixed effects
2004	Longo and Senkat [209]	Investigation of the expansion of Intra African trade	Panel data, 41 African and 15 industrial countries, 1988 - 1997	Exports	GDP, GDP per capita, country surface area, common border, distance, landlocked country, road length per capita, telephones per capita, internal political tension indicators, oil exporting, FTA participation	OLS, TOBIT

Table 1.1 Empirical Studies on International Trade Modeling (cont.).

Year	Authors	Objective	Dataset	Dependent Variables	Explanatory Variables	Estimation Technique
2004	Pelletiere and Reinert [241]	Investigation of used automobile protection and trade	Panel data, US and 113 countries, 1998-2000.	Exports	GDP, population, distance, left side driving pattern, protection measure, average tariffs for new and used cars, region	OLS
2004	Roberts [260]	Analysis of the proposed China- Asean FTA	Cross sectional, China and Asean Countries, 1996	Exports	GDP, GDP per capita, distance, FTA	OLS
2005	Augier et al. [24]	Investigation of the impacts of rules-of-origin	Cross sectional, 38 countries (EU and partners), total of 1992-1995	Exports	GDP, population, distance, FTA membership, EU membership, other country, common border, common language, cumulation impact,	Fixed effects
2005	Kandogan [173]	Examination of the Natural Trade Partners Theory for the Euro-Mediterranean Region	Cross sectional, EU countries, 1999, 2000	Imports	GDP, distance, per capita GDP, real exchange rates, foreign currency reserves, similarity in economic sizes, relative factor endowments	OLS with fixed effects
2005	Martinez - Zarzoso and Suarez - Burguet [214]	Investigation of the relationship between trade flows and transport cost	EU and five Latin America countries	Imports/ Exports	GDP, GDP per capita, transportation cost as a function of weight to value ratio, distance, volume of imports or exports, landlocked country, language, transportation and port infrastructure characteristics.	OLS with fixed effects

Table 1.1 Empirical Studies on International Trade Modeling (cont.).

Year	Authors	Objective	Dataset	Dependent Variables	Explanatory Variables	Estimation Technique
2005	Musila [225]	Examination of the intensity of trade creation and diversion in COMESA, ECCAS and ECOWAS	Cross sectional data, 20 African countries, 1991-1998	Exports	GDP, population, distance, border, language, CFA Francophone zone, Intra COMESA, ECCAS, ECOWAS trade, Extra COMESA, ECCAS, ECOWAS exports and imports	OLS
2005	Paas and Tafenau [236]	Investigation of trade flows for countries involved in the EU eastwards enlargement process.	Panel Data, EU-25, 1993-2002	Exports	Population, GDP, distance, EU- 15 membership, post-socialist accession countries, land border existence, Baltic sea country, Central European country, Mediterranean country	OLS
2005	Peridy [243]	Analysis of the AGADIR FTA effects	Panel data, 5 MENA and 42 import partners, 1975- 2001	Exports	GDPs, distance, FTA, common border, common language, trade complementarity	OLS with two way random effects
2005	Peridy [244]	Investigation of EMFTA effects to trade.	Panel Data, Mediterranean countries with 42 partners, 1975-2001	Exports	GDP, country similarity in size, distance, border type, regional arrangement between EU and Mediterranean countries, language	OLS, Fixed effects, Random Effects
2005	Sohn [280]	Analysis of South Korea's trade floes	Cross sectional. Korea and 30 trading partners, 1995	Bilateral trade flows	GDP, GDP per capita, distance, trade complementarity, APEC membership	OLS

Table 1.1 Empirical Studies on International Trade Modeling (cont.).

Year	Authors	Objective	Dataset	Dependent Variables	Explanatory Variables	Estimation Technique
2005	Tang [285]	Analysis of RTA for the NAFTA, ANZCER and ASEAN countries	Panel data, 21 NAFTA, ANZCER, ASEAN and non- member countries, 1989-2000	Exports	GDP, GDP per capita, distance, volality of exchange rate, income similarity, developed/developing country, NAFTA membership for both or one partner, ANZCER membership for both or one partner, ASEAN membership for both or one partner,	OLS, 2SLS
2005	Thorpe and Zhang [290]	Investigation of the development of intra-industry trade (IIT)	Panel Data, East Asian Economies, 1970-1996.	Index of intra-industry trade (function of imports and exports)	GDP, differences in per capita income, distance, bilateral exchange rate, trade orientation, trade imbalance, economies of scale.	OLS
2006	Antonucci and Manzocchi [17]	Analysis of the special trade relation between EU and Turkey	Panel data, Turkey and trading partners, 1967-2001.	Exports	GDP, measure of similarity between countries, relative factor endowments, EU membership, evolving EU relationship, existence of trade agreements, distance, border type (sea, land), specific features of trade partnerships	GLS with fixed effects.

Table 1.1 Empirical Studies on International Trade Modeling (cont.).

Year	Authors	Objective	Dataset	Dependent Variables	Explanatory Variables	Estimation Technique
2006	Baier and Bergstrad [25]	Examination of FTA effects	Panel data for years 1960, 1965, ..., 2000, 96 trading partners	Bilateral Flows	GDP, distance, common border, common language, FTA membership	OLS, FE, two-way FE, RE, differentiated estimates
2006	Carrere [66]	Investigation of the effects of regional trade agreements	Panel data, 130 countries, 1962-1996	Exports	GDP, GDP per capita, population, distance, shared borders, landlocked country, level of infrastructure, exchange rates, dummies for FTAs	OLS with two way random effects
2006	Kang and Fratianni [174]	Investigation of the effects of OECD membership and Religion in trade flows	Panel Data, OECD and non- OECD countries, 1980-2003	Exports	GDP, GDP per capita, region, common currency, distance, common border, common language, common colonizer, colonian relationship, OECD membership	OLS
2006	Kucera and Sarna [192]	Evaluation of trade union rights and democracy effects in exports	Cross sectional, 162 countries, averages for period 1993-1999	Exports	GDP per capita, population, distance, country surface area, common border, country landlocked, island, FTA, exchange rate	OLS, TOBIT, WLS
2007	Abedini and Peridy [3]	Analysis of the GAFTA agreement effects	Panel data, 15 GAFTA countries, 8 GAFTA countries, other 35 countries, 1985 - 2000	Exports	GDP, distance, language, multilateral trade resistance, information costs, border, FTA participation (EU, NAFTA, GAFTA, etc.)	Fixed effects, random effects, HTM, ABB

Table 1.1 Empirical Studies on International Trade Modeling (cont.).

Year	Authors	Objective	Dataset	Dependent Variables	Explanatory Variables	Estimation Technique
2007	Bun and Klaasen [56]	Investigation of Euro Effects in trade	Panel data, EU-15, Norway, Switzerland, Canada, Japan, USA, 1967-2002.	Bilateral trade flows	GDP, GDP per capita, FTA membership, Euro integration	OLS with fixed effects, DOLS
2007	Elliot [118]	Analysis of trade flows in the Caribbean sea.	Panel data, Barbados, Jamaica, Trinidad and Tobago, 1968-2001 and 1969- 2003.	Imports, exports	Population, distance, membership in CARI-COM market union.	OLS
2007	Iwanow and Kirkpatrick [166]	investigation of trade facilitation, regulatory quality and export performance	Panel data, 78 countries, 2000-2004	Exports	GDP, population, distance, remoteness, tariff, common language, colony (past/present), common border, FTA membership, trade facilitation, quality of regulation, infrastructure	GLS with fixed effects
2007	Kalirajan [169]	Investigation of regional cooperation effects in trade	Panel data, Australia and IOR- ARC members, 1992 - 1996 and 1999 - 2002	Exports	GDP, GDP per capita, population, distance, APEC membership	GLS
2007	Lee and Park [197]	Investigation of optimized regional trade agreements for east Asia	Panel data, 50 countries, 1994-1999	Bilateral trade flows	GDP, distance, country surface area, common border, common language, common colonizer, colony (past or present), participation in currency union, tariff, trade facilitation, FTA membership	OLS with fixed/ random effects

Table 1.1 Empirical Studies on International Trade Modeling (cont.).

Year	Authors	Objective	Dataset	Dependent Variables	Explanatory Variables	Estimation Technique
2007	Melitz [219]	Examination of North - South Distance	157 Countries, 1970-1995, five year intervals	Bilateral trade flows	GDP, Distance, common border, difference North - South, common language, currency union, FTA, common country, ex-colony, common colonizer	OLS fixed effects
2007	Nowak-Lehmann et al. [232]	Analysis of customs union between EU and Turkey	Panel data, Turkey and 10 EU countries, 1998-2002	Exports	GDP, GDP per capita, exchange rate, transport costs	OLS with fixed effects
2007	Papazoglou [238]	Analysis of Potential Trade Flows in Greece.	Panel of cross-country data,1993 - 2003, 26 countries: 14 EU members and 12 major trading partner countries.	Exports	GPD, population, distance, EU membership, common border, exports of intra-industry type	OLS
2007	Sarker and Jayasinghe [268]	Analysis of RTA and trade in agri-food products	EU-15 from 1985 to 2000, 57 countries.	Bilateral trade flows	Distance, GPD, GPD per capita, EU member, EUO (degree of openness of the EU members)	OLS
2007	Tzouvelekas [292]	Development of a stochastic coefficient gravity model	1997, 15 EU-countries.	Bilateral trade flows	GPD, distance, population	OLS.
2008	Boriss Siliverstovs, Dieter Schumacher [276]	Comparison of the OLS approach applied to the log-linear form of the gravity model with the estimation procedure PQML	1988 - 1990, 22 OECD countries	Bilateral trade flows	Distance, adjacency, membership in a preference area: EU, EFTA, FTA between the USA and Canada, Asia-Pacific Economic Co-operation, ties by language, historical ties.	OLS, Poisson Quasi Maximum Likelihood (PQML)

Table 1.1 Empirical Studies on International Trade Modeling (cont.).

Year	Authors	Objective	Dataset	Dependent Variables	Explanatory Variables	Estimation Technique
2008	Bussiere, Fidrmuc, and Schnatz [58]	Analysis of the rapid trade integration that took place in the past decade between the CSEECs and the euro area.	Annual data from 1980 to 2003, 61 countries	Bilateral trade flows	Distance, territory, border, language, free trade arrangements: EU, NAFTA, MERCOSUR, CEFTA, ASEAN	OLS, FE, RE, dynamic OLS, fixed effects with regional-specific time effects
2008	Grant and Lambert [143]	Investigation of the trade flow effects of Regional Trade Agreements (RTAs).	1982 - 2002, AGR and NAGR commodities, COMTRADE Database.	Bilateral trade flows	GDP, Distance, Adjacency, Language, Land locked, RTA	OLS fixed effects
2008	Henderson and Millimet [152]	Estimation of gravity models- in levels and logs- via non parametric methods	132 non-industrial countries, 1948 - 1997	Bilateral trade flows.	Distance, Currency Union, Common Language, Regional trade agreement, Adjacent, Number landlocked, Number of islands	
2008	Lampe [194]	Investigation of bilateral trade flows in Europe	1857-1875	Imports	National incomes of importer and exporter, distance, common border, American Civil War, tariff levels.	OLS, GLS, PPML both core and extended
2008	Soonchan Park and Innwon Park [240]	Estimation of the investment creation and diversion effects of RTAs	OECDs International Direct Investment Statistics covering from 24 OECD countries to 50 host countries for the period of 1982 - 1999.	FDI	GDP in pairs, Skill, openness, reform, RTA/ Insiders, RTA/ Outsiders, RTA, (RTA/ Insiders)Reform, (RTA/ Outsiders)Reform, log of distance, common land border, common language, ex- colony-colonizer	OLS Fixed effects, Random Effects

Table 1.1 Empirical Studies on International Trade Modeling (cont.).

Year	Authors	Objective	Dataset	Dependent Variables	Explanatory Variables	Estimation Technique
2009	Kepaptsoglou et al. [176]	Analysis of the EMFTA trade agreement	Panel data, EU and Mediterranean countries, 1993-2007	Bilateral trade flows	Exports and imports, transportation costs, free trade agreements, tariffs	SURE with two way fixed and random effects.
2009	Baier and Bergstrand [26]	Analysis of a simple method for approximating international trade-cost effects using the gravity equation				
2010	Anderson [14]	Interaction across space in bothtrade and factor movements				Clustering of coefficient estimation
2010	Taningco & Hernandez [286]	Trade flow between countries			Input and prices, economic and non-economic variables, barriers of trade, quotas and tariffs, technical barriers, airports, ports, nonclassical variables	
2013	Reinert [253]	Numerous variants of gravity model	Historical data	Import, export	Labour, population, etc.	Regression
2014	Nasira & Kalirajan [228]	Economic growth and development				
2017	Abueg [4]	Historical claims analysis	Opening of suez canal in 1869			Statistical evidence

Table 1.1 Empirical Studies on International Trade Modeling (cont.).

Year	Authors	Objective	Dataset	Dependent Variables	Explanatory Variables	Estimation Technique
2018	Abueg [5]	A review of literature on gravity models on international trade, with a proposed model for the Philippines linking trade and employment	CEPII Geography Dataset	Import, export	Behind-the-border barriers, free trade agreements, labour markets, employment, etc.	Regression
2018	Chandran [69]	Trade impact of the India-ASEAN FTAs	ASEAN Statistics	Import, export	Total trade, GDP, per capita income, free trade agreements, distance between countries, ASEAN FTA membership, border, language, colony, etc.	Regression OLS, MLE, FEVD, BE, RE,

1.5.2 Review on Radiation Theory in International Trade

In 1971 famed economist William Alonso described a mathematical model of human mobility [11] with a remark: "It is almost as if an urban area were a radioactive body, emitting particles at a steady rate." Later different researchers like Hong et al. [157], Kong et al. [182], Masueci et al. [216], Ren et al. [254], Simini et al. [278], Stefanouli and Polyzos [284], etc. Ren and his group [254] exploited the concept by Alonso [11] and used the same kinds of mathematical terms to their work in the field of social science for human mobility, commuter flows, etc. Stefanouli and Polyzos [284] stated that radiation model is a good alternative to the use of gravity models in spatial interaction analysis.

We applied the radiation theory in the international trade and analyzed it with three statistical distributions such as uniform, exponential and power-law of economic masses.

1.6 Brief Review on Welfare

Welfare theory by Adam Smith (1776) [279] stated two major concepts:

(1) *Invisible hand conjecture* and
(2) *Water and Diamond Paradox*.

After a long time Jules Dupuit (1844) [100] and Heinrich Gossen (1854) both proposed the concept of modern utilitarian framework in economics, but the actual development of welfare theory started from Leon Walras (1874) [295]. He introduced the concept of general equilibrium system based on the fundamental principles of optimization such as

(1) utility maximization,
(2) profit maximization, etc.

with various constraints on budget, price, manpower, etc. The concept on welfare theory by Pareto (1909) [239] opened new dimensions such as

(1) concepts of utility function,
(2) demand vector,
(3) partial ordering,
(4) inter-personal welfare, etc.

He observed :

(1) welfare increases if some people gain and nobody loses,
(2) welfare declines if some people lose and nobody gains,
(3) if some gain and some lose, the welfare change is ambiguous, thus no verdict.

His work introduced few popular terms such as

(1) *Pareto criterion*,
(2) *Pareto optimality*,

The concept of contract curve and a box was used by Pareto (1909) [239] for Pareto optimality but the concept of contract curve and a box was proposed by Francis Ysidro Edgeworth (1881). This box is popularly known as *Edgeworth box*.

The modern welfare theory was proposed by Arthur Cecil Pigou (1912, 1920) [245, 246] in his works

(1) *Wealth and Welfare* (1912),

(2) *The Economics of Welfare* (1920), and

(3) *A Study in Public Finance* (1947) [247].

In *Wealth and Welfare* (1912) he discussed how a judicious government can increase welfare; but the concrete concept of modern welfare theory was fleshed out in *The Economics of Welfare* (1920). *A Study in Public Finance* (1947) contains fundamental insights with respect to public good provision, i.e., the concept of *marginal cost of public funds*.

Abba P. Lerner (1934, 1944) [198, 199, 200] contributed the welfare concepts in economics and the First Fundamental Theorem of Welfare Economics. A formal proof of Adam Smith's invisible hand conjecture is given by Kenneth Arrow (1951) [20, 21] using topological methods and separating hyperplane theorems.

Arbraham Bergson (1938) suggested solving the unsolved problem *'Pareto criterion leaves the distributional problem'* by a welfare function, which is an increasing function of the consumers utility function.

Salant and Henderson (1978) [266] observed that the fixed exchange rate regime for a small open economy in a welfare system will not continue forever, though the foreign exchange reserves in the Central Bank may not fully exhaust due to domestic money supply. These observations are mathematically modeled by Krugman (1979)[187]. Later a number of researchers (Calvo (1987) [61], Dornbusch (1987) [94], Obstfeld (1994) [233], Obstfeld and Rogoff (1995) [234], Eichengreen, Rose and Wyplosz (1994) [114], Calvo (1998) [64], Cole and Kehoe (1996) [76]) worked on exposition of the Krugman model [187]).

1.7 Scope of this Research Work

Based on the fairly detailed characterization of international trade and factor flows as a potential source of cross-country economic crises, one could objectively raise a number of questions that the subsequent chapters have tried to answer. Note that, the above reviews clearly delineate that a lot has been done in terms of assessing potential gaps in the field. Yet, a few areas, of which tracing the theoretical links between economic crises and gravity models from the perspective of natural sciences and their empirical validation remain largely uncharted. The following questions are designed to address these gaps.

The main aim of this study is to look into the effect of such a crisis across international borders and the nature of its proliferation. Moreover the manifestation is different for different strata of the society. It will try to decipher these pathways of spread of contagion in the global economy. The proposed thesis shall look into the effects of the components of the shock on economic outcomes across countries and consequent welfare implications. Another part looks into the welfare implication in general and in particular for different income groups and ethnic groups (if possible). In this study we are trying to answer the following questions both theoretically and empirically, an attempt that is fairly uncommon in the related field.

1. What are the most prominent factors that connect natural sciences, such as Physics, and the general adaptation of important tenets in Economics, such as the Gravity Model?
2. Does Gravity Model of international trade and dynamic changes in the parameters closely resemble the flow of particles and the development of resistance functions applicable to the law of gravity and electrical circuits?
3. What are the empirical relevance of the gravity model in estimating co-movements of important macroeconomic variables representing economic crises? Do physical distance, cultural proximity, religion, free trade areas, etc. influence these movements as extensions of the main principles developed under natural sciences?
4. Is it appropriate to consider Radiation Theory of Physics as another source of explanation for trade and flow of economic crises across countries? What dynamic changes are integral to this formalization?

The first chapter of this thesis will look into introduction and literature. In the next chapter a theoretical model will be developed in steps which answer the research questions one by one. The third chapter will provide empirical evidence of the model suggested in chapter 2 and analysis on its basis. The last chapter will provide policy implications that might help contain the spread of contagion through better trade routes that minimize the effect of the shock.

Chapter 2

Gravity Models in International Trade : An Exploration in Econo-Physics [1]

2.1 Brief Review

In 1954, Walter Isard (1954) [163] was inspired by Newton's law of gravitation and developed an analytical framework for the study of international trade in international economics. Later Tinbergen (1962) [289], Poyhonen (1963) [250], and Linneman (1966) [204] independently proposed an analytical framework for the study of international trade inspired by Newton's law of gravitation in classical mechanics of physics. Now this frame work is popularly known as the *Gravity model*. This model computes the flow of trading force between two countries as Newton computes the force of attraction between two bodies. This model is successfully applied by different economists like Anderson (1979) [12], Bergstrand (1985) [40], Bergstrand (1989) [41], Davis (1995) [85], Deardorff (1998) [87], Dhar and Panagariya (1994) [90], Eaton and Kortum (1997) [104], Evenett and Keller (1998) [124], Feenstra, Markusen, and Rose (1999) [126], Helpman (1987) [150], Linneman (1966) [204], Markusen (1986) [213], Poyhonen (1963) [250] and Tinbergen (1962) [289] in their works.

In order to define the scope of this research with suitable perspectives, let us reiterate Newton's law of universal gravitation in the following terms: that every particle attracts every other particle in the universe with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between their

[1] An adaption of this chapter has been published [237] by South Asian Journal of Macroeconomics and Public Finance (ISSN: 2277-9787, Online ISSN: 2321-0273), an international peer reviewed journal published by Sage Publications Pvt. Ltd. in 2021, DOI:10.1177/2277978721989922

centers. However, before we lay out the details of how Newton's Law influences the gravity model in clearer terms, it might be useful to discuss the broad connections at the outset.

It follows from the seminal work of Tinbergen (1962) [289] that the size of bilateral trade flows between any two countries can be approximated by a law called the '*gravity equation*', which as mentioned above is a derivative of the Newtonian theory of gravitation. Just as planets are mutually attracted in proportion to their sizes and proximity, countries trade in proportion to their respective GDPs and proximity [300]. It is well-known that the gravity model in trade was initially considered merely as an empirical observation with little theoretical basis. Empirically speaking, the stable relationship between the size of trading economies, their distance and the amount of trade explained the creation and sustenance of networks successfully, but these did not seem to subscribe to the fundamental theorems of international trade relying heavily on the Ricardian structure highlighting differences in technology across countries to explain trade patterns, and the Heckscher-Ohlin model holding differences in factor endowments among countries as the basis for trade. It was believed that gravity equations introduced factors that were either (indirectly) subsumed under the explanations available in the classical models; or that the factors were too esoteric to have wider applicability. For example, country size has little to do with the structure of trade flows in classical models. Regardless, the extraordinary stability of the gravity equation and its power to explain bilateral trade flows prompted the search for a theoretical explanation for it. With regard to gravity models while empirical analysis predated theory, it presently appears that most trade models require gravity in order to work. In this connection, later modification to the trade theory *a'la* Krugman (1980) [186] is more amenable to the empirical observations from the gravity model. In fact, Bergstrand (1985, 1989) [40, 41] also shows that a gravity model reflects trade due to monopolistic competition in the product market and that a preference for variety between identical countries influences the network formation. It argues that the presence of monopolistic competition and taste for variety within similar countries overcome the undesirable features of Armington models where goods are differentiated only by location of production. Consequently, firm location is endogenous rather than based on restrictive assumptions in other models and all trading countries could specialize in the production of different sets of goods. Notwithstanding, Deardorff (1998) [87] showed that a gravity model can arise from differences in factor-proportions as part of traditional explanations. Further, Eaton and Kortum

(2002)[105] derived a gravity-type equation from a Ricardian model, while Helpman *et al.* (2008) [151] and Chaney (2008) [70] related the structure of gravity equations to models with differentiated goods and heterogeneous firms.

2.2 Newton's Law of Gravitation

In 1686, Sir Isaac Newton postulated a law which is well-known as Newton's law of universal gravitation in classical mechanics of physics. This law measures the force of attraction between two different bodies placed at a particular distance. The law as shown in Fig. 2.1.

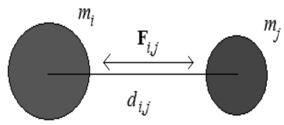

Fig. 2.1 Newton's law of gravitation: Two bodies with mass m_i and m_j separated by a distance $d_{i,j}$ then force of attraction is $\mathbf{F}_{i,j}$.

Gravitational Law: Newton's law of universal gravitation is stated as that every particle attracts every other particle in the universe with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centers.

Mathematical Formulation

This law is mathematically described as follows.

Let

m_i = mass of a particle or body$_i$,

m_j = mass of another particle or body$_j$,

$d_{i,j}$ = distance between the particle or body$_i$ with mass m_i and the particle or body$_j$ with mass m_j (Note: the distance is measured between the centres of them)

$F_{i,j}$ = force of attraction between the particle or body with mass m_i and the particle or body with mass m_j, and

G = a constant, known as *Gravitational constant*.

Then the model can be described mathematically, as

$$F_{i,j} \propto m_i m_j$$

when $d_{i,j}$ remains unchanged, and

$$F_{i,j} \propto \frac{1}{d_{i,j}^2}$$

when m_i and m_j are remain unchanged.

Now by joint variation

$$F_{i,j} \propto \frac{m_i \times m_j}{d_{i,j}^2} \tag{2.1}$$

when m_i, m_j and $d_{i,j}$ are variables.

Therefore Newton's law of gravitation is mathematically described by Eqn. (2.2):

$$F_{i,j} = G\frac{m_i \times m_j}{d_{i,j}^2} \tag{2.2}$$

where, G = a constant, known as *Gravitational constant*.

Illustration 2.1. Suppose mass of two bodies are 5.5×10^8 kg and 2.3×10^{15} kg respectively. They are separated by a distance of 2000 m. Compute the force of attraction between the bodies. Assume gravitational constant $G = 6.67 \times 10^{-11} Nm^2/kg^2$

Here

$m_i = 5.5 \times 10^8$ kg,

$m_j = 2.3 \times 10^{15}$ kg,

$d_{i,j} = 2000$ m and

$G = 6.67 \times 10^{-11} Nm^2/kg^2$

then

Force of attraction between m_i and m_j placed at distance $d_{i,j}$ is

$$
\begin{aligned}
F_{i,j} &= G\frac{m_i \times m_j}{d_{i,j}^2} \\
&= 6.67 \times 10^{-11} \times \frac{(5.5 \times 10^8) \times (2.3 \times 10^{15})}{2000^2} \\
&= \frac{6.67 \times 5.5 \times 2.3}{4} \times 10^{-11+8+15-6} \\
&= 2.1 \times 10^7 N
\end{aligned}
$$

$\therefore$ Force of attraction is 2.1×10^7 N ■

2.3 Newton's Law of Gravitation in Economics

In this section we apply the concepts of Newton's gravity law in international economics.

2.3.1 Analogy of Gravitation in Economics

Newton's law of gravitation can be viewed in economics as follows.

Let

M_i = Economic mass for country$_i$,

M_j = Economic mass for country$_j$,

$D_{i,j}$ = Geographical distance between country$_i$ and country$_j$,

$F_{i,j}$ = Force of trade flow between country$_i$ and country$_j$

Assume M_i and M_j are described in the same scale or unit.

The following hypothesis are the basis of international trade

(1) Larger countries trade more than smaller ones, that means trade depends on the economic mass of the country, and

(2) Geographical distance between two trade partners (i.e., countries) reduce trade force between them.

2.3.2 Intuitive Idea of Gravity Model in Economics

Newton's law of gravitation is the inspiration for the design of an intuitive gravity model for trade.

(1) The trade force depends on the economic mass of the countries. This says that the trade force is directly proportional to the economic mass of the countries.

Mathematically,

$$F_{i,j} \propto M_i M_j,$$

when $D_{i,j}$ remains unchanged.

(2) Geographical distance between two trade partners (i.e., countries) reduce trade force between them. This says that the trade force is inversely proportional to the geographical distance between partner countries.

Mathematically,

$$F_{i,j} \propto \frac{1}{D_{i,j}^2},$$

when M_i and M_j remain unchanged.

(3) These may be combined and described as in Eqn. (2.3).

$$F_{i,j} = C\frac{M_i M_j}{D_{i,j}^2} \tag{2.3}$$

where, $C =$ Constant of variations.

Here we can assume that economic mass means, say GDP (or export or import) of the country and distance means physical distance between two partner countries for trade. Intuitively export (or trade) between two countries depend positively on their economic masses and negatively related to distance between them.

Illustration 2.2. In 1996 the GDP of India is \$3.83 $\times 10^{11}$ and the GDP of Australia is \$4.01 $\times 10^{11}$. The geographical distance between India and Australia is 10363.85 Km. Compute the trade force of attraction between India and Australia. Assume constant $C = 1$

This is shown in Fig. 2.2.

Fig. 2.2 Illustration of gravity model: trade between India and Australia.

Here

M_{India} = Economic mass, i.e, GDP of India = $\$3.83 \times 10^{11}$,

$M_{Australia}$ = Economic mass, i.e, GDP of Australia = $\$4.01 \times 10^{11}$,

$D_{India,Australia}$ = Geographical distance between India, and Australia = 10363.85 Km, and

$C = 1$

then

trade force of attraction between India and Australia is

$$\begin{aligned} F_{India,Australia} &= C \times \frac{M_{India} \times M_{Australia}}{D^2_{India,Australia}} \\ &= 1 \times \frac{(3.83 \times 10^{11}) \times (4.01 \times 10^{11})}{(10363.85)^2} \\ &= 1.43 \times 10^{15} \end{aligned}$$

$\therefore$ Trade force of attraction is 1.43×10^{15} unit ■

2.3.3 Gravity Model in International Trade

In Newton's law of gravitation, Newton postulated and described mathematically that it strictly follows the rule defined in Eqn. (2.1) in case of earth science. But in case of international economics, the trade flow apparently follow the rule defined in Eqn. (2.3). It varies from case to case, in this context we define a generalized model for Eqn. (2.3) in Eqn. (2.6).

$$F_{i,j} = CM_i^{\alpha} M_j^{\beta} D_{i,j}^{\gamma} \tag{2.4}$$

where,

M_i = Economic mass for country$_i$,

M_j = Economic mass for country$_j$,

$D_{i,j}$ = Geographical distance between country$_i$ and country$_j$,

$F_{i,j}$ = Force of trade flow between country$_i$ and country$_j$

α, β, γ = parameters of the model.

If we assume α, β are positive and γ is negative then Eqn. (2.6) is a generalized version of Law of Gravity defined in Eqn. (2.2).

Illustration 2.3. If we choose $\alpha = 1, \beta = 1$ and $\gamma = -2$ then Eqn. (2.6) can be written as

$$F_{i,j} = CM_i^1 M_j^1 D_{i,j}^{-2} = C\frac{M_i M_j}{D_{i,j}^2}. \tag{2.5}$$

this is equivalent to Newton's law of gravitation. ■

2.3.4 Empirical Gravity Model in Econometrics

An empirical gravity model is designed based on the relation (2.6).
Now we introduce a random fluctuation $U_{i,j}$ with Eqn. (2.6), then we can write it as

$$F_{i,j} = CM_i^{\alpha} M_j^{\beta} D_{i,j}^{\gamma} U_{i,j} \tag{2.6}$$

when the expected value of $U_{i,j}$, i.e., $E(U_{i,j}) = 1$

By taking $'\ln'$ i.e., 'log' operator on both sides of Eqn. (2.6), we get

$$\ln F_{i,j} = \ln C + \alpha \ln M_i + \beta \ln M_j + \gamma \ln D_{i,j} + \ln U_{i,j} \tag{2.7}$$

Therefore an empirical equation for basic gravity model is described by relation (2.8) which is almost similar to Eqn. (2.7)

$$\ln X_{i,j} = b_0 + b_1 \ln Y_i + b_2 \ln Y_j + b_3 \ln D_{i,j} + e_{i,j} \tag{2.8}$$

where,

Y_i = Economic mass for country_i,

Y_j = Economic mass for country_j,

$D_{i,j}$ = Distance between country_i and country_j,

$X_{i,j}$ = Force of trade flow between country_i and country_j

$e_{i,j}$ = Random error term when trade flow between country_i and country_j
i.e., $e_{i,j} \sim N(0, \sigma)$ i.e., normal distribution with standard deviation σ and mean 0,

$E(e_{i,j})$ = expected value of $e_{i,j}$
= 0

b_0, b_1, b_2, b_3 = Parameters of the model.

Note that conditions $b_1, b_2 > 0$; $b_3 < 0$ says that it is similar to Gravity model.

2.4 Constituents of the Gravity Model

The gravity models have a number of features that make it quite distinct:

(1) The gravity model yields good results in explaining bilateral flows; and more fundamentally,

(2) The gravity model helps identifying countries that would realistically engage in trade – a prediction that Heckscher-Ohlin model leaves unspecified. (Marimoutou, Peguin, and Peguin-Feissolle, 2010) [212]

In addition:

(1) The mass variables, such as, GDP, exports or imports, can be easily accommodated in the gravity model (Feenstra, Markusen, and Rose, 1999) [126].

(2) Since, geographical distance, as an indicator could approximate the cost of entry in a market (e.g., the greater the distance, the higher the entry cost) in a gravity model (see Egger, 2008) [113].

The geographical distance $D_{i,j}$ between country$_i$ and country$_j$ is a fixed quantity in the gravity model, but the economic mass of a country changes with time t. So it is necessary to introduce the time variable t with the gravity model. In this context Eqn. (2.6) can be rewritten as Eqn. (2.9)

$$F_{i,j,t} = CM_{i,t}^{\alpha} M_{j,t}^{\beta} D_{i,j}^{\gamma} \tag{2.9}$$

where,

$M_{i,t}$ = Economic mass for the country$_i$ at time t,

$M_{j,t}$ = Economic mass for the country$_j$ at time t,

$D_{i,j}$ = Geographical distance between country$_i$ and country$_j$, (Note: this variable does not change with time t)

$F_{i,j,t}$ = Force of trade flow between country$_i$ and country$_j$ at time t

α, β, γ = parameters of the model.

Similarly Eqn. (2.8) can be rewritten as Eqn. (2.10)

$$\ln X_{i,j,t} = b_0 + b_1 \ln Y_{i,t} + b_2 \ln Y_{j,t} + b_3 \ln D_{i,j} + e_{i,j} \tag{2.10}$$

where,

$Y_{i,t}$ = Economic mass for the country$_i$ at time t,

$Y_{j,t}$ = Economic mass for the country$_j$ at time t,

$D_{i,j}$ = Distance between country$_i$ and country$_j$,

$X_{i,j,t}$ = Force of trade flow between country$_i$ and country$_j$ at time t,

$e_{i,j}$ = Random error term when trade flow between country$_i$ and country$_j$

$E(e_{i,j})$ = expected value of $e_{i,j}$ = 0

b_0, b_1, b_2, b_3 = Parameters of the model in which $b_3 < 0$ since 'distance is negatively proportional to the trade force.'

2.5 Role of Distances in Gravity Model

In international trade, distance plays an important role in determining the trade force between two countries. First of all we have to make a clear idea about the distance between two partner countries. Second, to understand how to measure this distance. A brief idea about this distance is given below.

(1) **Shortest distance between two countries**: It is the minimum distance, $D_{i,j}^{shortest}$, between two points P_i and P_j where $P_i \in$ country$_i$ and $P_j \in$ country$_j$. That means,

$$D_{i,j}^{shortest} = \min_{i,j}\{distance(P_i, P_j)\}$$

$$\text{such that} \quad P_i \in \text{country}_i$$

$$P_j \in \text{country}_j$$

Note that $D_{i,j}^{shortest} = 0$, when country$_i$ and country$_j$ are adjacent country as well as they have common border.

Illustration 2.4. Shortest distance between two countries X and Y is shown in Fig. 2.3. ■

(2) **Geometric distance between two countries**: It is the distance, $D_{i,j}^{geometric}$, between two points P_i and P_j in a straight line,
where,
P_i = centre of area of country$_i$, and
P_j = centre of the area of country$_j$.

Illustration 2.5. Geometric distance between two countries X and Y is shown in Fig. 2.4. ■

(3) **Air distance between two countries**: It is the distance, $D_{i,j}^{air}$, between two points P_i and P_j in a straight line,
where,
P_i = an airport (e.g., source/destination) of country$_i$, and
P_j = an airport (e.g., destination/source) of country$_j$.

Illustration 2.6. Air distance between two countries X and Y is shown in Fig. 2.5. ■

Fig. 2.3 Shortest distance between two countries.

(4) **Shipping distance between two countries**: It is the distance, $D_{i,j}^{ship}$, between two points (basically port) P_i and P_j measured along a straight line or curved path or their mixed path i.e., along the path of movement of the ship,

where,

P_i = a port (e.g., source/destination) of country$_i$, and

P_j = a port (e.g., destination/source) of country$_j$.

Illustration 2.7. Shipping distance between two countries X and Y is shown in Fig. 2.6. ■

(5) **Road distance between two countries**: It is the distance, $D_{i,j}^{road}$, between two connected points P_i and P_j by road and it is measured along the road ways, i.e., along the way the cargo moves,

where,

P_i = location of a transport (e.g., source/destination) of country$_i$, and

P_j = location of a transport (e.g., destination/source) of country$_j$.

Illustration 2.8. Road distance between two countries X and Y is shown in Fig. 2.7. ■

Fig. 2.4 Geometric distance between two countries.

(6) **Geographical distance between two countries**: In general it is any of those distance measured along the path on the globe between two countries and is denoted by $D_{i,j}$, distance between country$_i$ and country$_j$. In gravity model analysis, we have used distance between the capital cities of both the countries.

2.5.1 Role of Geographical Distance

In Newton's law of gravitation, distance plays a major role for the computation of force of attraction between two bodies, where the distance is measured in straight line between the centre of mass of the bodies.

Similarly in the gravity model of international economics, the distance between country$_i$ and country$_j$ (i.e, $D_{i,j}$) also play a very important role for the computation of trade force $X_{i,j}$ between country$_i$ and country$_j$. In this model, distance between the countries is measured along the length of geographical path in which the shipment of goods takes place. From traditional point of view, the force of trade flow decreases as the distance between partner countries increases. During that period of time, people thought that the shipping of

Fig. 2.5 Air distance between two countries.

goods between countries is only possible through sea and river. Therefore the geographical distance between the partner countries play a very important role in measuring the trade force in international economics.

2.5.2 Role of Shipping Cost in Gravity Model

Primarily the shipping cost of goods between country$_i$ and country$_j$ directly depends on the distance $D_{i,j}$ between them. Therefore the force of trade flow between country$_i$ and country$_j$ decreases as the shipping cost increases when the mode of shipping is same. Again the shipping cost of goods depend on the mode of transport and the size of the ship (e.g., small, medium, large) (Hummels, 1999) [160] as well as the volume of goods to transport.

Illustration 2.9. Consider three countries such as country$_i$, country$_j$ and country$_k$ where the distance $D_{i,j} > Di,k$, and the economic mass $M_j = M_k$ then by gravity model, the force of trade flow $F_{i,j} < F_{i,k}$. If we change the mode of shipping for the same volume of goods from country$_i$ to country$_j$ and from country$_i$ to country$_k$ in such a way that their shipping

Fig. 2.6 Shipping distance between two countries.

cost is same. Then the gravity model also computes that the force of trade flow $F_{i,j} < F_{i,k}$. But in the true sense we feel that the expected force of trade flow $F_{i,j} \cong F_{i,k}$ provided the size of the ship.

Discussion: We know $F_{ij} = \dfrac{M_i M_j}{D_{ij}^2}$ and $F_{ik} = \dfrac{M_i M_k}{D_{ik}^2}$

$$\therefore \quad \frac{F_{ij}}{F_{ik}} = \frac{M_i M_j}{D_{ij}^2} \times \frac{D_{ik}^2}{M_i M_k}$$

$$\text{or,} \quad \frac{F_{ij}}{F_{ik}} = \frac{D_{ik}^2}{D_{ij}^2} \times \frac{M_i M_j}{M_i M_k}$$

when $M_j = M_k$

$$\frac{F_{ij}}{F_{ik}} = \frac{D_{ik}^2}{D_{ij}^2}$$

If $D_{ij} > D_{ik}$ i.e., $\dfrac{D_{ik}^2}{D_{ij}^2} < 1$ then

$\dfrac{F_{ij}}{F_{ik}} < 1$, i.e., $F_{ij} < F_{ik}$

Here $M_j = M_k$, but the loading and unloading cost of goods in a ship is a major part of the cost other than cost of sea transport. If the distance is more and also the size of the ship

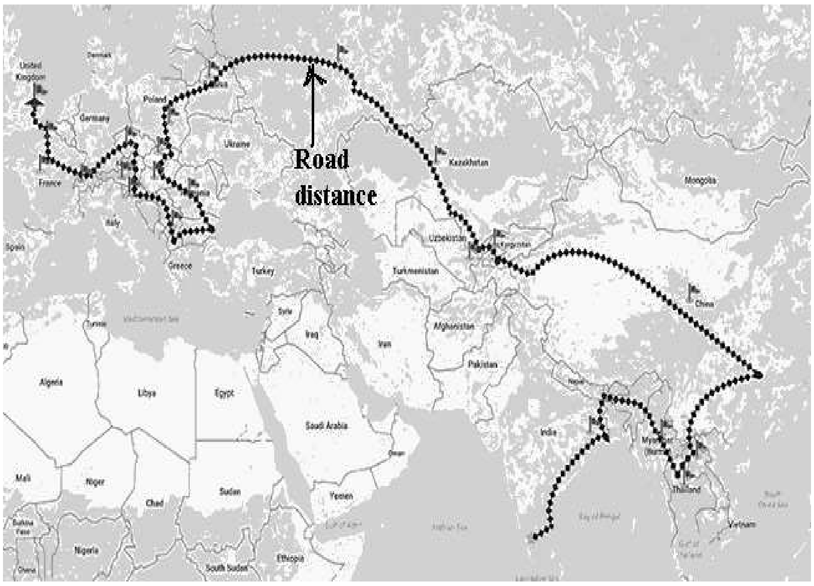

Fig. 2.7 Road distance between two countries.

is large then there is not much effect on trade force of attraction. In this context we can say that $F_{i,j} \approx F_{i,k}$ when $M_j = M_k$. ■

By Illustration 2.9, it is justified that shipping cost is more appropriate than physical distance in the gravity model of international trade. Now we replace $D_{i,j}$ in the gravity model described in Eqn. (2.10) by the shipping cost $T_{i,j}$ then the modified gravity model is described in Eqn (2.11).

$$\ln X_{i,j,t} = b_0 + b_1 \ln Y_{i,t} + b_2 \ln Y_{j,t} + b_3 \ln T_{i,j} + e_{i,j} \qquad (2.11)$$

where,

$Y_{i,t}$ = Economic mass for country$_i$ at time t,

$Y_{j,t}$ = Economic mass for country$_j$ at time t,

$T_{i,j}$ = Shipping cost from country$_i$ to country$_j$,

$X_{i,j,t}$ = Force of trade flow between country$_i$ and country$_j$ at time t,

$e_{i,j}$ = Random error term when trade flow between country$_i$ and country$_j$

$E(e_{i,j})$ = Expected value of $e_{i,j}$
= 0

b_0, b_1, b_2, b_3 = Parameters of the model in which $b_3 < 0$ since 'distance is negatively proportional to the trade force.'

2.5.3 *Effect of Common Border in Gravity Model*

In case of two adjacent countries, with a common border, the shortest distance between them is zero but the geographical distance is not zero in the gravity model because the geographical distance is the length of path on which goods flow between the adjacent countries. Depending on whether the common border is land, or water body, the trade cost would be calculated according to the above specifications. The gravity model described in Eqn (2.11) would suitably use the shipping cost as equivalent to distance.

Generally, in order to consider border as a factor in the gravity model, we introduce two dummy variables:

(1) one for common border
(2) other border types

Then the gravity model in Eqn. (2.11) is modified and described in Eqn (2.12).

$$\begin{aligned} \ln X_{i,j,t} &= b_0 + b_1 \ln Y_{i,t} + b_2 \ln Y_{j,t} + b_3 \ln T_{i,j} \\ &\quad + b_{41} B_{i,j}^{common} + b_{42} B_{i,j}^{type} + e_{i,j} \end{aligned} \tag{2.12}$$

where,

$$B_{i,j}^{common} = \begin{cases} 1, & \text{country}_i \text{ and country}_j \text{ with common border} \\ 0, & \text{country}_i \text{ and country}_j \text{ with no common border} \end{cases}$$

$$B_{i,j}^{type} = \begin{cases} 1, & \text{country}_i \text{ and country}_j \text{ with sea border} \\ 0, & \text{country}_i \text{ and country}_j \text{ with no sea border} \end{cases}$$

b_{41}, b_{42} = parameters related to border in the model

2.5.4 Role of Climate in Gravity Model

As the distance between the partner countries increases, the traveling time to transport of goods also increases. In other words, vessel carrying goods float longer time on the deep sea, often exposing these to adverse climatic conditions and increasing the probability of losses (introduced as a loss parameter) due to damages, delays and additional costs due to hold ups, etc. Despite access to well laid out insurance contracts for the freight, historically speaking, the distance poses a natural barrier to trade between far-off countries, especially via sea routes, automatically lowering the force of business attraction.

So, one can incorporate the climate variable in the gravity model. Subsequently, Eqn. (2.12) can be rewritten as Eqn. (2.13)

$$\begin{aligned} \ln X_{i,j,t} &= b_0 + b_1 \ln Y_{i,t} + b_2 \ln Y_{j,t} + b_3 \ln D_{i,j} \\ &\quad + b_{41} B_{i,j}^{common} + b_{42} B_{i,j}^{type} \\ &\quad + b_5 \ln L_{i,j,t}^{climate} + e_{i,j} \end{aligned} \tag{2.13}$$

where,

$L_{i,j,t}^{climate}$ = Economic loss during shipping of goods from country$_i$ to country$_j$ at time t

b_5 = a parameter of the model

2.6 Role of Demography in Gravity Model

Demographic information of a country means population, language, religion, food habit, etc.

2.6.1 Population

The main theoretical hypothesis of the gravity model, made by Tinbergen (1962)[289] is *distance is negatively proportional to the level of exports*. But we can made another hypothesis on demographic feature such as population of the country as *population of partner countries is positively proportional to the trade force*.

Now we can incorporate the population variable of partner countries to the gravity model. Then Eqn. (2.13) can be rewritten as Eqn. (2.14)

$$\begin{aligned}\ln X_{i,j,t} = & \; b_0 + b_1 \ln Y_{i,t} + b_2 \ln Y_{j,t} + b_3 \ln T_{i,j,t} \\ & + b_{41} B_{i,j}^{common} + b_{42} B_{i,j}^{type} + b_5 \ln L_{i,j,t}^{climate} \\ & + b_6 \ln N_{i,t}^{population} + b_7 \ln N_{j,t}^{population} + e_{i,j}\end{aligned} \tag{2.14}$$

where,

$N_{i,t}^{population}$ = Population of country$_i$ at time t,
$N_{j,t}^{population}$ = Population of country$_j$ at time t,
b_6, b_7 = Parameters of the model related to population in which $b_6, b_7 > 0$.

2.6.2 Common Language

Languages between partner countries in an international trade is also a weak variable. It has been observed that the same language between partner countries is positively proportional to the trade force. Now we define the language variable $L_{i,j}$ between country$_i$ and country$_j$ as

$$L_{i,j}^{language} = \begin{cases} 1, \; L_i = L_j \\ 0, \; L_i \neq L_j \end{cases}$$

where, L_i = Language of country$_i$

Assume that

(1) the language of a country does not change with time, and
(2) one-country one-language (i.e., national language).

Now we incorporate a binary variable $L_{i,j}^{language}$ for language in the gravity model. Then Eqn. (2.14) can be rewritten as Eqn. (2.15)

$$\begin{aligned}\ln X_{i,j,t} = {} & b_0 + b_1 \ln Y_{i,t} + b_2 \ln Y_{j,t} + b_3 \ln T_{i,j,t} \\ & + b_{41} B_{i,j}^{common} + b_{42} B_{i,j}^{type} + b_5 \ln L_{i,j,t}^{climate} \\ & + b_6 \ln N_{i,t}^{population} + b_7 \ln N_{j,t}^{population} \\ & + b_8 L_{i,j}^{language} + e_{i,j} \end{aligned} \tag{2.15}$$

where,

L_i = Language of country$_i$

$$L_{i,j}^{language} = \begin{cases} 1, & L_i = L_j \\ 0, & L_i \neq L_j \end{cases}$$

b_8 = Parameters of the model related to language.

2.6.3 Common Religion and Culture

While, the population size and language for communication are important considerations, for example trade with a sparsely populated country, or very difficult to communicate type of country would be low, common religion and culture have a mixed influence on the countries in international trade networks. It has been observed that the sharing of Buddhist, Confucian, Hindu, Eastern Orthodox Catholic, etc. religion in different countries have a significantly positive influence on bilateral trade. Moreover, religious openness has a strong positive effect on trade. Trade, in general, is influenced differently by every religious belief (Helble, 2006) [149]. For example Islam has stronger influence on trade than Christianity due to their indigenous religious beliefs. Similarly, Hindus trading among each other have a statistically insignificant relationship. Jews prefer trading among themselves, whereas Buddhists avoid trade with people of same religion (Helble, 2006) [149]. On a different note, war and war-like situations (see, Anderton and Carter, 2001; Bayer and Rupert, 2004; Misra and Choudhry, 2020) [15, 34, 222] lead to loss of international trade.

Illustration 2.10. Islam has stronger influence on trade than Christianity due to their indigenous religious beliefs. Similarly, Hindus trading among each other have a statistically insignificant relationship. Jews prefer trading among themselves, whereas Buddhists avoid trade with people of same religion (Helble, 2006) [149]. ■

Illustration 2.11. The sharing of Buddhist, Confucian, Hindu, Eastern Orthodox Catholic, etc. in different countries have a significantly positive influence on bilateral trade. On the other hand, the sharing of Roman Catholic culture has a significantly negative influence on bilateral trade. But the sharing of Islamic and Judaic cultures neither promotes nor discourages international exchange. ■

In the context of religion in international trade network, we introduce a dummy variable that indicates the significance of influence of religion on gravity model. This gravity model computes the trade force by considering the level of influence of religion between the partner countries.

Now the gravity model in Eqn. (2.15) can be modified by incorpating the religion issue as shown in Eqn. (2.16)

$$\begin{aligned}\ln X_{i,j,t} &= b_0 + b_1 \ln Y_{i,t} + b_2 \ln Y_{j,t} + b_3 \ln T_{i,j,t} \\ &+ b_{41} B_{i,j}^{common} + b_{42} B_{i,j}^{type} + b_5 \ln L_{i,j,t}^{climate} \\ &+ b_6 \ln N_{i,t}^{population} + b_7 \ln N_{j,t}^{population} \\ &+ b_8 L_{i,j}^{language} + b_9 R_{i,j}^{religion} + e_{i,j} \end{aligned} \tag{2.16}$$

where,

R_i = Religion of country$_i$

$$R_{i,j}^{religion} = \begin{cases} 1, & R_i = R_j, \\ & R_i, R_j \in \{\text{Buddhist, Confucian, Hundu,} \\ & \quad \text{Eastern Orthodox Catholic}\} \\ 0, & R_i = R_j, \\ & R_i, R_j \in \{\text{Islamic, Judaic cultures}\} \\ -1, & R_i = R_j, \\ & R_i, R_j \in \{\text{Roman Catholic}\} \end{cases}$$

b_9 = Parameter of the model related to religion and culture.

2.7 Country-Specific Variables in Gravity Model

In this section we classify the variables, i.e., features of the country used in the gravity model.

The information related to the country are:

(1) geographical features of the country,
(2) demographical feature of the country,
(3) economic features,
(4) nature of security, etc.

These information are generally represented by some variables. These are called country-specific variables. These variables are introduced in the gravity model of international trade so that it improves the performance of the model.

2.7.1 Country-Specific Geographical Features

Country-specific geographical features of land of a country are:

(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.

Some of these country-specific features can be briefly described below for a country, say country$_i$ and is summarized in Table 2.1.

Note:

The distance is not a country-specific geographical feature because distance of a country is measured with respect to another country.

(1) **Surface area**: It is the prime resource of the country. The possibilities of development of the economy of a country directly depends on its area.
(2) **Border length**: It means perimeter of the country. It gives an indication about the expenditure of country on security purpose and protect unethical international trading.

Table 2.1 Country-specific geographical features of land of the country_i

Feature	Variable	Definition	Remarks
1. Surface area	G_i^{area}	= area in sq. Km.	A numerical value
2. Number of islands	G_i^{Island}	$= \begin{cases} n, \text{ if island present} \\ 0, \text{ if no island} \end{cases}$	0 for no island
3. Country landlocked	$G_i^{landlocked}$	$= \begin{cases} 1, \text{ if landlocked} \\ 0, \text{ otherwise} \end{cases}$	Landlocked means no part of the border of country_i is sea. There is no dock i.e., transportation via ship is not possible.
4. Road length	G_i^{road}	= length of roads in Km.	A numerical value
5. Number of ports	G_i^{ports}	$= \begin{cases} n, \text{ if port present} \\ 0, \text{ if port absent} \end{cases}$	0 for no port
6. Border length	$G_i^{perimeter}$	= length of border of the country in Km.	A numerical value

(3) **Road length**: Certainly total road length of a country is an important variable for local and global trading.

(4) **Number of ports**: Certainly total number of ports of a country is an important variable for trading. Higher efficiency of port service indicates the higher rate of economic development of country. If number of ports is more then the country encourages international trade service.

(5) **Landlocked**: If the country is landlocked then it has some bottleneck. The country do not have port. International trading has to be done either by air or by road so it increases the transport cost of the goods.

(6) **Country type**: It is defined based on its location on the earth surface. Here country types can be Baltic sea country, Central European country, Mediterranean country, etc.

Indirectly it indicates some information regarding country such as culture, demand, location, etc.

2.7.2 Country-Specific Demographical Features

Country-specific demographical features of a country are:

(a) Population,
(b) Language,
(c) Religion,
(d) Culture
(e) Nation,
(f) Colonizer,
(g) Internal political tension,
(h) War,
(i) Car driving pattern, etc.

Now we briefly describe below some of these features or variables for a country, say country$_i$ and summarize it in Table 2.2.

(1) **Population**: Certainly population is a major factor for domestic and international trade. They are the consumers and producers. So demand and supply chain directly depends on the population of the country.

(2) **Language**: Before discussing language, first we assume that one country has one language for communication. If country has more than one language then we assume that the national language is the only language of the country.
In international trading, if both the countries have a common language then sometimes both get a benefit in trading.

(3) **Religion and Culture**: Common religion and culture have a mixed influence on the countries in international trade networks. It has been observed that the sharing of Buddhist, Confucian, Hindu, Eastern Orthodox Catholic, etc. in different countries have a significantly positive influence on bilateral trade. On the other hand, the sharing of Roman Catholic culture has a significantly negative influence on bilateral trade. But the

Table 2.2 Country-specific demographical features for the country$_i$

Feature	Variable	Definition	Remarks
1. Population	$D_i^{population}$	= Number of people in the Country$_i$	A numerical value changes with time t
2. Language	$D_i^{language}$	$= L_i$, Language of a Country$_i$	One element of a set of languages
3. Religion	$D_i^{religion}$	$= R_i$, Religion of a Country$_i$	One element of a set of religions
4. Colony	D_i^{colony}	$= \begin{cases} 1, \text{ if country}_i \text{ was colonized} \\ 0, \text{ otherwise} \end{cases}$	Whenever country$_i$ is/was related to any kind of colony such as common colonizer, current colony, ever colony, ex-colony.
5. Car driving	$D_i^{driving}$	$= \begin{cases} 1, \text{ if country}_i \text{ left sided driving} \\ 0, \text{ otherwise} \end{cases}$	People of country$_i$ drive by sitting on left hand side of the car.

sharing of Islamic and Judaic cultures neither promotes nor discourages international exchange.

(4) **Nation**: If partner countries belong to the same continent then they have some special advantage in international trade than if they belong to different continents.

(5) **Colonizer**: If a country is/was related to any kind of colony (e.g., common colonizer, current colony, ever colony, ex-colony) then the people of the country has an additional culture. Sometimes this influence international trading.

(6) **Internal political tension**: The international traders (either exporters or importers) study the internal politics of both the countries (importer and exporter). They judge the situation and estimate tension and instability in the market. Sometimes the internal politics by the people/political parties of the country creates tension as well as an ad-

verse situation for the country. Even international traders are afraid of trading with that country. Internal political tension is a variable with uncertainty in international trading.

(7) **War**: The behavior of some people and the government of a country is to promote or encourage or maintain a war-like situation with other countries. In that case country suffers from international trading. If war happens in a country, obviously country suffers in all respects of development of the country.

(8) **Car driving pattern**: It is also a variable for a country because left and right handed car driving facilities are available. If car driving facilities are not same in both countries, under trade, then in some cases it creates a negative impact on trade, especially for automobile industry.

2.7.3 Country-Specific Economic Features

Some country-specific economic features or variables of the country are:

(a) gross domestic product (GDP),
(b) national income,
(c) currency,
(d) exchange rates
(e) tariffs,
(f) trade barrier,
(g) trade agreements,
(h) imports and exports,
(i) economically developed/developing country,
(j) shadow related features,
(k) currency crisis, etc.

Now we briefly describe below some of these features or variables for a country, say country$_i$ and summarize in Table 2.3.

(1) **Gross domestic product (GDP)**: This is an indicator of the overall economy of a country. The purchasing power of the people of the country directly depends on GDP or GDP per capita.

Table 2.3 Country-specific economic features for country$_i$ at time t

Feature	Variable	Definition	Remarks
1. GDP	$E^{GDP}_{i,t}$	$= GDP_{i,t}$	GDP of Country$_i$ at time t.
2. Exchange rate	$E^{rate}_{i,t}$	$= ExchangeRate_{i,t}$	Exchange rate of currency with respect USD for country$_i$ at time t.
3. Tariffs	$E^{tariffs}_{i,t}$	$= TariffsRate_{i,t}$	Tax rate for import/export at time t and country$_i$.
4. Trade barrier	$E^{barrier}_{i,t}$	$= \begin{cases} 1, \text{ if country}_i \text{ under trade barrier} \\ 0, \text{ otherwise} \end{cases}$	If country$_i$ impose any trade barrier at time t then it is 1.
5. Trade agreement	$E^{agreement}_{i,t}$	$= \begin{cases} 1, \text{ if country}_i \in \text{ Economic body} \\ 0, \text{ otherwise} \end{cases}$	Existence of trade agreements for the country$_i$ at time t when country$_i$ $\in$ any economic body e.g., EU, ASEAN, EFTA, etc. where each economic body is a set of countries.
6. Total exports	$E^{export}_{i,t}$	$= Export_{i,t}$	Total commodity exports from country$_i$ at time t.
7. Total imports	$E^{import}_{i,t}$	$= Import_{i,t}$	Total commodity imports to country$_i$ at time t.
8. Rule	$E^{rule}_{i,t}$	$= \begin{cases} 1, \text{ if rule exists} \\ 0, \text{ otherwise} \end{cases}$	Export-import laws that exist for country$_i$ at time t.

(2) **National Income**: It is an indicator of the economy of a country.

(3) **Currency**: Currency is a unit of measurement of financial status.
Common currency is an added advantage for the partner countries as there is no charge on exchange of money. It is easy to start trading between the countries when they use the same currency (for eg, Euro of European Union)

(4) **Exchange rate**: The economic value of the currency of the country depends on the exchange rate with respect to other countries when we measure it in an unified scale such as USD. Then this is known as *exchange rate of currency with respect to U.S. dollar (USD)*. Note that sometimes in international trade a country may define different types of exchange rate to their partner countries in their agreements, some of these are fixed, floating, spot, dual etc.

(5) **Tariffs**: It means a tax or duty to be paid on a particular class of imports or exports.

(6) **Trade barriers**: These are government-induced restrictions on international trade. There are three major barriers to international trade. They are

  (1) natural barriers, such as distance (geographical feature) and language (demographical feature);
  (2) tariff barriers, or taxes on imported goods; and
  (3) non-tariff barriers., this includes,
    (a) import quotas,
    (b) embargoes,
    (c) buy-national regulations, and
    (d) exchange controls.

(7) **Trade agreements**: Trade agreement between countries affect the volume and speed of trade, such as ANZCER, ASEAN, CEFTA, CFA, COMESA, ECCAS, ECOWAS, EFTA, EU, FTA, MERCOSUR, NAFTA, RTA, etc.
Some economic body allows *free trade* arrangements between their member countries.

Illustration 2.12. Membership of EU, NAFTA, MERCOSUR, CEFTA, ASEAN, etc. ■

Some economic body allows trade at *discounted rate* between their member countries.
(a) EU membership,
(b) evolving EU relationship,
(c) trade agreement membership,

(d) membership for both or one partner,

(e) Francophone zone,

etc.

(8) **Total commodity imports**: It is the total import value of a country measured in terms of USD.

(9) **Total commodity exports**: It is the total export value of a country measured in terms of USD.

(10) **Past exports**: This is a series of amount of export of the country with respect to time period. The trend of this series can predict the amount of present export.

(11) **Trade law**: A country sets a set of laws to regulate export and import. These laws are applicable to the exporter and importer of the country. This law is termed as exporter and importer rule of law or trade law.

(12) **Economic status of a country** : It indicates that the country is economically developed or economically developing. This status play a great role in international trade.

2.7.4 Country-Specific Ratio Features

Some ratios are computed from the data available for the country. These ratios are considered as features in gravity model for better judgement. These computed ratios are:

(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.

Some of the definition of these ratios are as below.

(1) **GDP per capita**: It means GDP per person in the country.
Mathematically,

$$\text{GDP per capita at time } t = \frac{\text{GDP of the country at time } t}{\text{Population of the country at time } t}$$

(2) **Road length per capita**: It means total road length per person in the country.
Mathematically,

$$\text{Road length per capita at time } t = \frac{\text{Total road length of the country at time } t}{\text{Population of the country at time } t}$$

(3) **Capital-labor ratio**: It means a ratio between total capital of the country and the total number of labors available in the country.
Mathematically,

$$\text{Capital-labor ratio at time } t = \frac{\text{Total capital of the country at time } t}{\text{Total number of labors available in the country at time } t}$$

(4) **High and low skilled labor ratio**: It is a ratio between the available number of high skilled labor with the available number of low skilled labor in the country at a particular time.
Mathematically,
High and low skilled labor ratio at time t

$$= \frac{\text{Available number of high skilled labor of the country at time } t}{\text{Available number of low skilled labor in the country at time } t}$$

(5) **Telephones per capita**: It means total numbers of telephones (not device, only telephone number) per person in the country.
Mathematically,
Telephones per capita at time t

$$= \frac{\text{Total numbers of telephone number that exists in the country at time } t}{\text{Population of the country at time } t}$$

Note: Counting the total number of workable telephone devices in the country is difficult and also not logical.

(6) **Trade complementarity**: It basically looks after the import-export pattern between countries. This ratio is computed as follows.
Trade complementarity of country$_i$ for a product P at time t

$$= \frac{\text{Number of countries to which country}_i \text{ export the product } P \text{ at time } t}{\text{Number of countries that report importing the product } P \text{ at time } t}$$

Note: A high degree of trade complementarity is assumed to indicate more favorable prospects for a successful trade arrangement.

2.8 Measures of Remoteness (or Nearness) in Gravity Models

Some features are computed based on the present trading (international) position of a country. A country$_i$ is trading with her partner countries at time t. That means country$_i$ is trading with a set of countries at time t but at time $t+1$ the set of country may not be the same. Country-specific dynamic dependent features are the features of a country which depends on other countries and it also changes from time to time. Some features of this kind are listed below.

(a) Remoteness (or Nearness),
(b) Similarity,
  (i) Similarity in country size,
  (ii) Measure of similarity between countries,
  (iii) Similarity in income,
  (iv) Similarity in economic sizes,
(c) 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

2.8.1 Remoteness

Remoteness as a factor is introduced by Anderson and Wincoop (2003) [13] and is related to the study of gravity model of international trade. Remoteness is defined as follows. It is a competitive feature/factor between two partner countries with respect to other partner countries in international trade. This is an indicator of willingness of trade flow between two countries in their trading network.

The remoteness of country$_i$ with respect to country$_j$ is defined as follows:

$$\text{REM}_i = \sum_{m \neq j} \frac{d_{im}}{y_m}$$

where,

y_m = GDP of country$_m$, for $m = 1, 2, \cdots, n$

d_{im} = Distance of country$_m$ from country$_i$ for $m = 1, 2, \cdots, n$ & $m \neq i$

So the remoteness variable is intended to reflect the average distance of country$_i$ from all trading partners other than country$_j$.

2.8.1.1 Computation of Remoteness

Suppose there are n countries in a trade network. We want to compute remoteness for country$_i$ with respect to country$_j$ for $j = 1, 2, \cdots, n$ and $j \neq i$. In this situation country$_i$ has $n-1$ partner countries for trading. So country$_i$ has $n-1$ remoteness values for its partner countries. Therefore remoteness of country$_i$ is a vector of size $n-1$. Computational formula for the computation of remoteness of country$_i$ is given in Eqn (2.17).

$$\text{REM}_i = \sum_{\substack{m=1 \\ m \neq j \neq i}}^{n} \frac{d_{im}}{y_m} \tag{2.17}$$

for $j = 1, 2, \cdots, n, \& j \neq i$

where,

y_m = GDP of country$_m$, for $m = 1, 2, \cdots, n$

d_{im} = Distance of country$_m$ from country$_i$ for $m = 1, 2, \cdots, n$ & $m \neq i$

A numerical example for the computation of remoteness for a country is given in Illustration 2.13.

Illustration 2.13. In 2011, the partner countries of India are Australia, Austria, Canada, Germany, and Spain. The GDP of each country in international trade for the year 2011 and their distance from India are given in Table 2.4. Now the computation of remoteness variable of India for a country like Australia, Austria, Canada, Germany, or Spain is given in Table 2.4.

Table 2.4 Remoteness computation for India using GDP and Distance from India for 2011

Country	GDP in \$ y_m	Distance in Km d_{im}	Ratio $\frac{d_{im}}{y_m}$	Remoteness $\sum_{\substack{m=1 \\ m\neq j\neq i}}^{n} \frac{d_{im}}{y_m}$
1 Australia	1.39665×10^{12}	10363.850	7.42051×10^{-09}	2.57356×10^{-08}
2 Austria	4.31120×10^{11}	5571.096	1.29224×10^{-08}	2.02338×10^{-08}
3 Canada	1.78914×10^{12}	11349.870	6.34375×10^{-09}	2.68124×10^{-08}
4 Germany	3.74441×10^{12}	5785.567	1.54512×10^{-09}	3.16110×10^{-08}
5 Spain	1.47877×10^{12}	7282.046	4.92438×10^{-09}	2.82318×10^{-08}
6 India	1.82000×10^{12}	0		

Now the remoteness of India for Australia is
$1.29224 \times 10^{-08} + 6.34375 \times 10^{-09} + 1.54512 \times 10^{-09} + 4.92438 \times 10^{-09}$
$= 2.57356 \times 10^{-08}$
Similarly the remoteness of India for Austria is
$7.42051 \times 10^{-09} + 6.34375 \times 10^{-09} + 1.54512 \times 10^{-09} + 4.92438 \times 10^{-09}$
$= 2.02338 \times 10^{-08}$
Remoteness of India for Canada is
$1.29224 \times 10^{-08} + 7.42051 \times 10^{-09} + 1.54512 \times 10^{-09} + 4.92438 \times 10^{-09}$
$= 2.68124 \times 10^{-08}$
$\therefore$ The remoteness of India is a vector as
$(2.57356 \times 10^{-08}, 2.02338 \times 10^{-08}, 2.68124 \times 10^{-08}, 3.16110 \times 10^{-08}, 2.82318 \times 10^{-08})$ ■

Illustration 2.14. In 2011, the partner countries of Spain are Australia, Austria, Canada, Germany, and India. The GDP of each country in the international trade for the year 2011 and their distance from Spain are given in Table 2.4. Now the computation of remoteness variable of Spain for a country like Austria, Canada, Germany, or India is given in Table 2.5.

Table 2.5 Remoteness computation for Spain using GDP and Distance from Spain for 2011

Country	GDP in \$ y_m	Distance in Km d_{im}	Ratio $\frac{d_{im}}{y_m}$	Remoteness $\sum_{\substack{m=1 \\ m\neq j\neq i}}^{n} \frac{d_{im}}{y_m}$
1 Australia	1.39665×10^{12}	17591.480	1.25955×10^{-08}	1.18810×10^{-08}
2 Austria	4.31120×10^{11}	1811.999	4.20300×10^{-09}	2.02734×10^{-08}
3 Canada	1.78914×10^{12}	5695.349	3.18329×10^{-09}	2.12932×10^{-08}
4 Germany	3.74441×10^{12}	1873.129	5.00247×10^{-10}	2.39762×10^{-08}
5 India	1.82000×10^{12}	7282.046	3.99443×10^{-09}	2.04820×10^{-08}
6 Spain	1.47877×10^{12}	0		

$\therefore$ The remoteness of Spain is a vector as

$(1.18810 \times 10^{-08}, 2.02734 \times 10^{-08}, 2.12932 \times 10^{-08}, 2.39762 \times 10^{-08}, 2.04820 \times 10^{-08})$ ■

Note: The remoteness of India for Spain is 2.82318×10^{-08} (Illustration 2.13) and remoteness of Spain for India is 2.04820×10^{-08} (Illustration 2.14)

Anderson and Wincoop (2003) [13] stated that commonly used remoteness variables are entirely disconnected from the theory. They showed that adding remoteness indices for both country$_i$ and country$_j$ changes the border coefficient estimates very little and also has very little additional explanatory power.

2.8.2 Nearness

In gravity model we propose a new feature *nearness* between trade network. This feature is described as follows.

Objective: It is used in the opposite sense of remoteness. It is also a competitive feature between two partner countries with respect to other partner countries in network of international trade. This is an indicator of willingness of trade flow between two countries in the trade network which consists of their partner countries.

Definition: It measures the effectiveness of resistance of a country in their trade network for smooth trade flow. The nearness of country$_i$ with respect to country$_j$ is defined as follows:

$$\text{NEAR}_i = \sum_{m \neq j} \frac{y_m}{d_{im}}$$

So the nearness variable is intended to reflect the effective flow of country$_i$ from all trading partners other than country$_j$.

Illustration 2.15. In 2011, the partner countries of India are Australia, Austria, Canada, Germany, and Spain. The GDP of each country in the international trade for the year 2011 and their distance from India are given in Table 2.4. Now the computation of nearness variable of India for a country like Austria, Canada, Germany, or Spain is given in Table 2.6.

Table 2.6 Nearness computation for India using GDP and Distance from India for 2011

Country	GDP in \$ y_m	Distance in Km d_{im}	Ratio $\frac{y_m}{d_{im}}$	Nearness $\sum_{\substack{m=1 \\ m \neq j \neq i}}^{n} \frac{y_m}{d_{im}}$
1 Australia	1.39665×10^{12}	10363.85	134761686.7	1085289805
2 Austria	4.3112×10^{11}	5571.096	77385187.78	1142666304
3 Canada	1.78914×10^{12}	11349.87	157635344.3	1062416147
4 Germany	3.74441×10^{12}	5785.567	647198209.4	572853282
5 Spain	1.47877×10^{12}	7282.046	203071063.3	1016980428
6 India	1.82×10^{12}	0		

Now nearness of India for Australia is

$77385187.78 + 157635344.3 + 647198209.4 + 203071063.3$

$= 1085289805$

$\therefore$ The nearness of India is a vector as

(1085289805, 1142666304, 1062416147, 572853282, 1016980428) ■

2.8.2.1 Results and Proof

Suppose each partner country performs trade in such a way that the trade network is in steady state. That means algebraic sum of trade flow that either comes in or goes out is same. Then this situation can be summarized as a theorem (Theorem 2.1).

Theorem 2.1. *Country$_i$ has $n-1$ partner countries in a trade network with n countries. The nearness of country$_i$ with respect to country$_j$ is*

$$NEAR_i = \sum_{\substack{m=1\\ m\neq j\neq i}}^{n} \frac{y_m}{d_{im}} = \frac{(n-1)y_i}{HM_i} - \frac{y_j}{d_{ij}} \tag{2.18}$$

for $j = 1, 2, \cdots, n, \& j \neq i$
where,

y_m = *GDP of country$_m$, for* $m = 1, 2, \cdots, n$
d_{im} = *Distance of country$_m$ from country$_i$ for* $m = 1, 2, \cdots, n,\ \&\ m \neq i$
HM_i = *Harmonic mean of distances for country$_i$*

Proof. Given that country$_i$ is a member of a trading network with n countries. So country$_i$ has $n-1$ partner countries. The relation of country$_i$ with other $n-1$ partner countries is shown in Fig. 2.8.

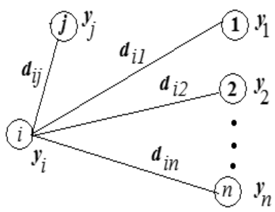

Fig. 2.8 Connection of country$_i$ with other $n-1$ partner countries with GDPs and distances from country$_i$.

Suppose,

y_m = GDP of country$_m$, for $m = 1, 2, \cdots, n$

d_{im} = Distance of country$_m$ from country$_i$ for $m = 1, 2, \cdots, n,$ & $m \neq i$

HM$_i$ = Harmonic mean of distances for country$_i$

By the definition of harmonic mean (H.M.) for the quantities $(x_1, x_2, \cdots, x_n)$ we can write

$$\text{H.M.} = \frac{n}{\frac{1}{x_1} + \frac{1}{x_2} + \cdots + \frac{1}{x_n}}$$

Now we apply the definition of harmonic mean (H.M.) for the distances d_{im} for $m = 1, 2, \cdots, n$, $m \neq i$ then

$$\text{HM}_i = \frac{n-1}{\sum\limits_{\substack{m=1 \\ m\neq i}}^{n} \frac{1}{d_{im}}}$$

$$\therefore \quad \sum_{\substack{m=1 \\ m\neq i}}^{n} \frac{1}{d_{im}} = \frac{n-1}{\text{HM}_i} \tag{2.19}$$

Now by applying the definition of nearness for Country$_i$ with respect Country$_1$ is

$$\text{NEAR}_i(1) = \sum_{m=2}^{n} \frac{y_m}{d_{im}}$$

Similarly, value of nearness for Country$_i$ with respect Country$_j$ is

$$\text{NEAR}_i = \sum_{\substack{m=1 \\ m\neq j\neq i}}^{n} \frac{y_m}{d_{im}} \qquad \text{for } j = 1, 2, \cdots, n \quad \& \quad j \neq i \tag{2.20}$$

Analogy with electrical network

Here we assume that the trade network is equivalent of an electrical network. Each country of a trade network is a node of an electrical network. The GDP of a country is equivalent to a voltage of that node, i.e., voltage potential of the node. The distance between two countries is equivalent to resistance between the corresponding nodes. The equivalent electrical circuit corresponding to the part of trade network (Fig. 2.8) is shown in Fig. 2.9.

Now we analyze the ith node whose potential is y_i. Here we consider the following.

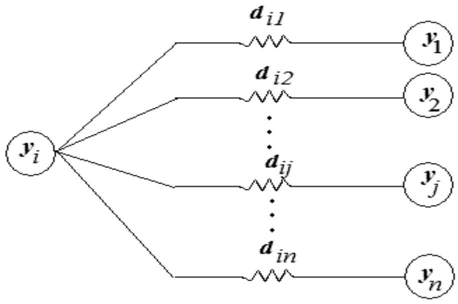

Fig. 2.9 An equivalent electrical network of Fig. 2.8 where GDPs and distances are equivalent to node potentials and resistances.

(a) Current is always flowing from higher potential to lower potential.

(b) If current is negative then it flows in the reverse direction.

(c) **Ohm's law**:

$$\text{current} = \frac{\text{potential difference}}{\text{resistance}}$$

(d) Consider the node i and node 1 where resistance between the nodes is d_{i1} and assume that y_1 is higher voltage than y_i. Therefore the potential difference $= y_1 - y_i$
Now by Ohms law we get

$$\text{current} = \frac{\text{potential difference}}{\text{resistance}} = \frac{y_1 - y_i}{d_{i1}}$$

is flowing from node 1 to node i

The Kirchhoff's current law says that
In an electrical network, the algebraic sum of currents meeting at a point (i.e., node) is zero.
Therefore we can write as

$$\frac{y_1 - y_i}{d_{i1}} + \frac{y_2 - y_i}{d_{i2}} + \cdots + \frac{y_j - y_i}{d_{ij}} + \cdots + \frac{y_n - y_i}{d_{in}} = 0$$

or, $\sum_{\substack{m=1 \\ m \neq i}}^{n} \frac{y_m - y_i}{d_{im}} = 0$

or, $\sum_{\substack{m=1 \\ m \neq i}}^{n} \left[\frac{y_m}{d_{im}} - \frac{y_i}{d_{im}} \right] = 0$

$$\text{or, } \sum_{\substack{m=1\\m\neq i}}^{n} \frac{y_m}{d_{im}} - \sum_{\substack{m=1\\m\neq i}}^{n} \frac{y_i}{d_{im}} = 0$$

$$\text{or, } \left(\sum_{\substack{m=1\\m\neq j\neq i}}^{n} \frac{y_m}{d_{im}} + \frac{y_j}{d_{ij}} \right) - \sum_{\substack{m=1\\m\neq i}}^{n} \frac{y_i}{d_{im}} = 0$$

$$\text{or, } \sum_{\substack{m=1\\m\neq j\neq i}}^{n} \frac{y_m}{d_{im}} = \sum_{\substack{m=1\\m\neq i}}^{n} \frac{y_i}{d_{im}} - \frac{y_j}{d_{ij}}$$

Now by using Eqn. (2.20), we get

$$\text{NEAR}_i = y_i \sum_{\substack{m=1\\m\neq i}}^{n} \frac{1}{d_{im}} - \frac{y_j}{d_{ij}}$$

$$\text{or, } \text{NEAR}_i = y_i \frac{n-1}{\text{HM}_i} - \frac{y_j}{d_{ij}} \qquad \text{[using Eqn. (2.19)]}$$

$$\therefore \text{NEAR}_i = \frac{(n-1)y_i}{\text{HM}_i} - \frac{y_j}{d_{ij}}$$

$$\therefore \text{NEAR}_i = \frac{(n-1)y_i}{\text{HM}_i} - \frac{y_j}{d_{ij}} \tag{2.21}$$

Now using Eqn. (2.20) and Eqn. (2.21) we get

$$\text{NEAR}_i = \sum_{\substack{m=1\\m\neq j\neq i}}^{n} \frac{y_m}{d_{im}} = \frac{(n-1)y_i}{HM_i} - \frac{y_j}{d_{ij}} \text{ for } j = 1,2,\cdots,n, \& j \neq i \qquad \blacksquare$$

In an ideal situation Theorem 2.1 works well.

2.8.3 Similarity and Its Measurement

In international economics, similarity parameters are used by different researchers like Egger [110, 112], Pridy [243, 244] Antonucci and Manzocchi [17], Tang [285], Kandogan [173] and many others. Now it is necessary to study the

(a) similarity in country size, or

(b) measure of similarity between countries,

(c) income similarity,

(d) similarity in economic sizes of the country for the judgement of trading.

First we have to understand the meaning of similarity, and how to measure it for an application like international economics.

Suppose two countries C_i and C_j $(i \neq j)$ are identical. Therefore the feature vector X_i for country C_i and X_j for country C_j are almost same. That means, the similarity measure cs_{ij} between countries C_i and C_j should be large, (say 1, if we choose the scale of the similarity measure cs_{ij} in between 0 and 1). On the other hand, the dissimilarity measure between countries C_i and C_j is very poor (say 0, the lowest value of the dissimilarity measure scale). If we choose the *Euclidean distance* between the feature vectors X_i and X_j, i.e.,

$$dist(X_i, X_j)$$

as a measure, this measure is equal to 0 when both the feature vectors are same, that is,

$$dist(X_i, X_j) = 0 \text{ if } X_i \equiv X_j.$$

Therefore we can define the similarity and dissimilarity measures using the Euclidean distance as:
Dissimilarity measure:

$$ds_{ij} = dist(X_i, X_j)$$

Similarity measure:

$$cs_{ij} = \frac{1}{1 + dist(X_i, X_j)}$$

For m number of countries, we can define similarity and dissimilarity matrices as:
Similarity matrix:

$$CS = [cs_{ij}]_{m \times m},$$

and dissimilarity matrix:

$$DS = [ds_{ij}]_{m \times m}.$$

Proximity Matrix: For convenience, both matrices (similarity matrix and dissimilarity matrix) are commonly referred to as a proximity matrix, P. A proximity matrix,

$$P = [p_{ij}]_{m \times m},$$

contains all the pairwise dissimilarities or similarities between the countries being considered. If vectors X_i and X_j are the representative of ith and jth countries, respectively, then p_{ij} is the similarity, cs_{ij}, or the dissimilarity, ds_{ij}, between the vectors X_i and X_j for the countries C_i and C_j respectively.

Illustration 2.16. Suppose X_i is a vector with 2 components x and y, i.e., $X_i = (x_i, y_i)$ for country C_i where $i = 1,2,3,4$. Assume $X_1 = (0,2)$, $X_2 = (2,0)$, $X_3 = (3,1)$, $X_4 = (5,1)$ These are shown in Fig. 2.10.

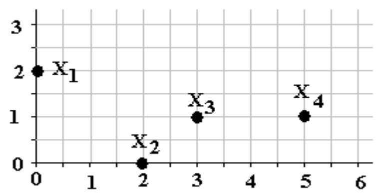

Fig. 2.10 Vectors corresponding to 4 countries.

The point matrix is shown in Table 2.7.

Table 2.7 Point matrix

	Country	Vector	x	y
1	C_1	X_1	0	2
2	C_2	X_2	2	0
3	C_3	X_3	3	1
4	C_4	X_4	5	1

The proximity (distance) matrix is shown in Table 2.8. Here the proximity between C_1 and C_2 is

$p_{11} = ||X_1 - X_1|| = 0$

$p_{12} = ||X_2 - X_1|| = \sqrt{(2-0)^2 + (0-2)^2} = \sqrt{4+4} = 2\sqrt{2} = 2 \times 1.414 = 2.828$

Similarly $p_{13} = ||X_3 - X_1|| = 3.162$, ...

Table 2.8 Proximity Matrix computation

	C_1	C_2	C_3	C_4
C_1	0.000	2.828	3.162	5.099
C_2	2.828	0.000	1.414	3.162
C_3	3.162	1.414	0.000	2.000
C_4	5.099	3.162	2.000	0.000

$$\therefore \; P = \begin{bmatrix} 0.000 & 2.828 & 3.162 & 5.099 \\ 2.828 & 0.000 & 1.414 & 3.162 \\ 3.162 & 1.414 & 0.000 & 2.000 \\ 5.099 & 3.162 & 2.000 & 0.000 \end{bmatrix}$$

Again this matrix form a graph as shown in Fig. 2.11

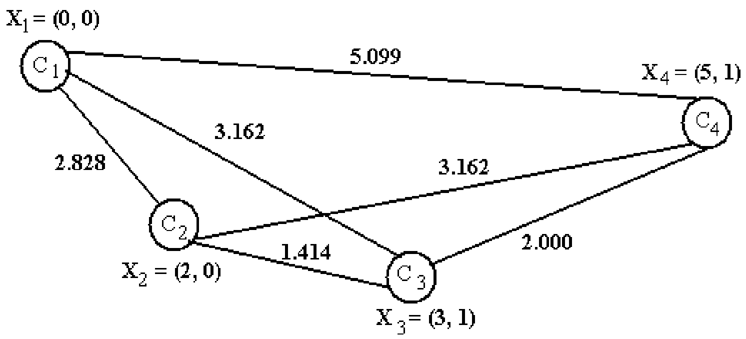

Fig. 2.11 Graph corresponding to 4 countries.

■

Completeness: Countries are generally represented by feature/attribute vectors. Components of a country vector are mostly numerical values but sometimes there are some possibilities of character strings or graphs for the components of vector. Now determining the similarity (or dissimilarity) of two countries in such a situation is more complicated. But there are some techniques that can handle this situation.

2.8.4 Proximity Measures between Two Countries

Proximity (i.e., similarity/dissimilarity) between two countries can be measured when countries are represented by

(A) real-valued vectors,
(B) discrete-valued vectors,
(C) mixed valued vectors.

2.8.4.1 Real-Valued Vectors

Here proximity (i.e., similarity or dissimilarity) is measured between two real valued vectors.

(i) DISSIMILARITY MEASURES

The dissimilarity measures for real valued vectors can be measured by different approaches such as

(a) Minkowski metric,
(b) Mahalanobis distance,
(c) Log measure,
(d) Quotient measure,
etc.

(1) **Minkowski Metric**

The most commonly used proximity measures between two vectors, at least for ratio scales (scales with an absolute 0) is the *Minkowski metric*, which is a generalization of the distance between points in Euclidean space.

Mathematical formulation

The *weighted* L_r metric ds (*Minkowski metric*),

$$ds_{ij}^{(r)} = dist(X_i, X_j) = \left(\sum_{k=1}^{l} w_k \left| x_{ik} - x_{jk} \right|^r \right)^{1/r} \tag{2.22}$$

where,

r = a parameter,

l = the dimensionality of the data object (vector),

w_k = weight,

x_{ik} = the kth components of the ith country (vector),

x_{jk} = the kth components of the jth country (vector).

Case 1: For $r = 1$.

The weighted L_1 or *Manhattan norm*:

$$ds_{ij}^{(1)} = dist(X_i, X_j) = \sum_{k=1}^{l} w_k \left| x_{ik} - x_{jk} \right| \tag{2.23}$$

The L_1 *norm* or *city block distance*:

$$ds_{ij}^{(1)} = dist(X_i, X_j) = \sum_{k=1}^{l} \left| x_{ik} - x_{jk} \right| \tag{2.24}$$

Case 2: For $r = 2$, $w_k = 1$.

The L_2 *norm* or *Euclidean distance*:

$$ds_{ij}^{(2)} = dist(X_i, X_j) = \sqrt{\sum_{k=1}^{l} \left| x_{ik} - x_{jk} \right|^2} \tag{2.25}$$

Case 3: For $r \to \infty$ or *max*, that is, *Tchebyshev (supremum or maximum)* norm.

The *weighted* L_{max} or L_∞ *norm*:

$$ds_{ij}^{(\infty)} = dist(X_i, X_j) = \max_{1 \le k \le l} \left| x_{ik} - x_{jk} \right| \tag{2.26}$$

Occasionally one might encounter the L_{max} norm (L_∞ norm), which represents the case $r \to \infty$.

Illustration 2.17. Consider the data described in Illustration 2.16, that is, $X_1 = (0,2)$, $X_2 = (2,0)$, $X_3 = (3,1)$, $X_4 = (5,1)$. These are shown in Fig. 2.10. The data matrix is displayed in Table 2.9, as in Table 2.7.

Table 2.9 Data matrix

	Country	Vector	x_{i1}	x_{i2}
1	C_1	X_1	0	2
2	C_2	X_2	2	0
3	C_3	X_3	3	1
4	C_4	X_4	5	1

Case 1: Now we compute the proximity (dissimilarity) matrix for L_1 norm and results are shown in Table 2.10.

By definition

$$\begin{aligned} ds_{32}^{(1)} &= dist(X_3, X_2) = \sum_{k=1}^{2} |x_{3k} - x_{2k}| \\ &= |x_{31} - x_{21}| + |x_{32} - x_{22}| \\ &= |3-2| + |1-0| = 1+1 = 2 \end{aligned}$$

Table 2.10 proximity (dissimilarity) matrix for L_1 norm (Case 1)

L_1	C_1	C_2	C_3	C_4
C_1	0.000	4.000	4.000	6.000
C_2	4.000	0.000	2.000	4.000
C_3	4.000	2.000	0.000	2.000
C_4	6.000	4.000	2.000	0.000

Case 2: Now we compute the proximity (dissimilarity) matrix for the L_2 norm and results are shown in Table 2.11.

By definition

$$\begin{aligned} ds_{32}^{(2)} &= dist(X_3, X_2) = \sqrt{\sum_{k=1}^{l} |x_{ik} - x_{jk}|^2} \\ &= \sqrt{|x_{31} - x_{21}|^2 + |x_{32} - x_{22}|^2} \\ &= \sqrt{|3-2|^2 + |1-0|^2} = \sqrt{1+1} = \sqrt{2} = 1.414 \end{aligned}$$

Table 2.11 proximity (dissimilarity) matrix for L_2 norm (Case 2)

L_2	C_1	C_2	C_3	C_4
C_1	0.000	2.828	3.162	5.099
C_2	2.828	0.000	1.414	3.162
C_3	3.162	1.414	0.000	2.000
C_4	5.099	3.162	2.000	0.000

Case 3: Now we compute the proximity (dissimilarity) matrix for the L_∞ norm and results are shown in Table 2.12.
By definition

$$\begin{aligned} ds_{32}^{(\infty)} &= dist(X_3, X_2) = \max_{1 \le k \le l} \left| x_{ik} - x_{jk} \right| \\ &= \max\{|x_{31} - x_{21}|, |x_{32} - x_{22}|\} \\ &= \max\{|3-2|, |1-0|\} = \max\{1,1\} = 1 \end{aligned}$$

Table 2.12 proximity (dissimilarity) matrix for L_∞ norm (Case 3)

L_∞	C_1	C_2	C_3	C_4
C_1	0.000	2.000	3.000	5.000
C_2	2.000	0.000	1.000	3.000
C_3	3.000	1.000	0.000	2.000
C_4	5.000	3.000	2.000	0.000

■

Note:

(i) The L_1 and L_∞ norms may be viewed as overestimation and underestimation of the L_2 norm, respectively,
(ii) $ds_{ij}^{(\infty)}(X_i, X_j) \le ds_{ij}^{(2)}(X_i, X_j) \le ds_{ij}^{(1)}(X_i, X_j)$,
(iii) when $l = 1$ all L_r norms coincide, and
(iv) Based on this ds, we can define corresponding cs as

$$cs_{ij}^{(r)}(X_i, X_j) = ds_{max} - ds_{ij}^{(r)}(X_i, X_j),$$

where, $ds_{max} = \max_{1 \leq i,j \leq n} ds_{ij}^{(r)}(X_i, X_j)$

(2) **Mahalanobis Distance**

Dissimilarity measure $ds_{ij}^{(Mahalanobis)}(X_i, X_j)$ is a generalized weighted L_2 *norm*, or *Mahalanobis distance* between two vectors X_i and X_j which is defined as:
Mahalanobis distance

$$ds_{ij}^{(Mahalanobis)} = dist(X_i, X_j) = \sqrt{(X_i - X_j)^T C^{-1} (X_i - X_j)} \tag{2.27}$$

where,

C^{-1} = a symmetric, positive definite matrix,
= *inverse covariance matrix.*
X_i = a real-valued feature vector, for a country$_i$,
X_j = a real-valued feature vector, for a country$_j$

Note: If C^{-1} = an identity matrix of variances
then $ds_{ij}^{(Mahalanobis)} = ds_{ij}^{(2)}$, the Euclidean distance.

(3) **Some other metric for dissimilarity measures**

Some popular metric for dissimilarity measures are (a) Log measure, (b) quotient measure, etc.
(a) Log Measure: The definition of log measure is

$$ds_{ij}^{(Log)}(X_i, X_j) = -\log_{10}\left(1 - \frac{1}{l}\sum_{k=1}^{l}\frac{|x_{ik} - x_{jk}|}{x_k^{(max)} - x_k^{(min)}}\right) \tag{2.28}$$

where,

l = the dimensionality of the data object (vector),
$x_k^{(max)} = \max_{1 \leq i \leq n}\{x_{ik}\}$,
$x_k^{(min)} = \min_{1 \leq i \leq n}\{x_{ik}\}$,
x_{ik} = the kth feature of ith vector X_i

(b) Quotient Measure: The definition of quotient measure is given below

$$ds_{ij}^{(Quotient)}(X_i, X_j) = \sqrt{\frac{1}{l}\sum_{k=1}^{l}\left(\frac{x_{ik}-x_{jk}}{x_{ik}+x_{jk}}\right)^2} \tag{2.29}$$

where,

l = the dimensionality of the data object (vector),

x_{ik} = the kth components of the ith country (vector) X_i,

x_{jk} = the kth components of the jth country (vector) X_j.

(ii) SIMILARITY MEASURES

The similarity measures for real valued vectors can be measured by different approaches such as

(1) Inner product,

(2) Tanimoto measure,

etc.

(1) **Inner product**

The inner product of two vectors X_i and X_j is denoted by $cs_{ij}^{(inner)}(X_i, X_j)$ and defined by *Inner Product*

$$cs_{ij}^{(inner)}(X_i, X_j) = X_i^T X_j = \sum_{k=1}^{l} x_{ik}x_{jk} \tag{2.30}$$

where,

X_i = a real-valued feature vector, for a country$_i$,

X_j = a real-valued feature vector, for a country$_j$,

X_i^T = Transpose of the vector X_i

Note:

(i) This inner product $cs_{ij}^{(inner)}(X_i, X_j)$ exclusively depends on the angle between X_i, X_j.

(ii) vectors X_i and X_j must be normalized in use.

(iii) Its corresponding dissimilarity measure

$$ds_{ij}^{(inner)}(X_i, X_j) = ds_{max} - cs_{ij}^{(inner)}(X_i, X_j), \tag{2.31}$$

where, $ds_{max} = \max_{1 \le i,j \le n} ds_{ij}^{(r)}(X_i, X_j)$.

(2) **Tanimoto Measure**

The Tanimoto measure of two vectors X_i and X_j is denoted by $cs_{ij}^{(Tanimoto)}(X_i, X_j)$ and defined by

Tanimoto measure between X_i and X_j is

$$\begin{aligned} cs_{ij}^{(Tanimoto)}(X_i, X_j) &= \frac{X_i^T X_j}{||X_i||^2 + ||X_j||^2 - X_i^T X_j} \\ &= \frac{1}{1 + \frac{(X_i - X_j)^T (X_i - X_j)}{X_i^T X_j}} \\ &= \frac{1}{-1 + \frac{a^2}{X_i^T X_j}} \end{aligned} \tag{2.32}$$

where,

X_i = a real-valued feature vector, for a country_i,

X_j = a real-valued feature vector, for a country_j,

X_i^T = Transpose of the vector X_i,

a = length of each vector in X after normalization

Note:

(i) $cs_{ij}^{(Tanimoto)}(X_i, X_j)$ is inversely proportional to $a^2/X_i^T X_j$,

(ii) The more correlated X_i and X_j are, the larger the value of $cs_{ij}^{(Tanimoto)}(X_i, X_j)$.

(3) **Other Measure**

Other types of similarity measure can be defined as:

$$cs_{ij}^{(other)}(X_i,X_j) = 1 - \frac{d_{ij}^{(2)}(X_i,X_j)}{||X_i||+||X_j||} \tag{2.33}$$

Note:

(i) $cs_{ij}^{(other)}(X_i,X_j)$=1 (maximum value) when $X_i = X_j$ and

(ii) $cs_{ij}^{(other)}(X_i,X_j)$=0 (minimum value) when $X_i = -X_j$.

2.8.4.2 Discrete-Valued Vectors

Suppose a discrete-valued vector is

$$X_i = (x_i^{(1)}, x_i^{(2)}, \cdots, x_i^{(l)}) \quad \text{for } i = 1,2,\cdots,n$$

where,

$$\begin{aligned} X_i &\in F^l, \\ x_i^{(m)} &\in F, \text{ for } m = 1,2,\cdots,l \\ F &= \{0,1,\cdots,k-1\}, \\ k &= \text{a positive integer}, \\ n &= \text{Number of vectors}, \\ l &= \text{Dimension of vector} \end{aligned}$$

(1) Contingency Table

Suppose $X_i, X_j \in F^l$ then we can define contingency table as

$$A(X_i,X_j) = [a_{uv}]_{k\times k}, \ \forall\, u,v = 0,1,\cdots,k-1 \tag{2.34}$$

where,

$$\begin{aligned} u &\in F, \\ v &\in F, \\ F &= \{0,1,\cdots,k-1\}, \\ a_{uv} &= \sum_{m=1}^{l} \delta\left(x_i^{(m)},x_j^{(m)}\right), \text{ when } \delta\left(x_i^{(m)},x_j^{(m)}\right) = \begin{cases} 1, \ x_i^{(m)} = u, x_j^{(m)} = v \\ 0, \ \text{Otherwise} \end{cases} \end{aligned}$$

k = a positive integer,

n = Number of vectors,

l = Dimension of vector,

for $i = 1,2,\cdots,n$ and $m = 1,2,\cdots,l$.

Illustration 2.18. Consider two vectors given as

$X_i = (0,1,2,0,1,1,2,1)^T$, and

$X_j = (1,0,2,0,1,2,0,1)^T$

then

$F = \{0,1,2\}$,

Dimension of vector, $l = 8$.

Here $k = 3$.

then contingency table is

$$A(X_i,X_j) = \begin{bmatrix} a_{00} & a_{01} & a_{02} \\ a_{10} & a_{11} & a_{12} \\ a_{20} & a_{21} & a_{22} \end{bmatrix}$$

where,

$$\begin{aligned} a_{00} &= \sum_{m=1}^{8} \delta\left(x_i^{(m)},x_j^{(m)}\right) \\ &= \delta\left(x_i^{(1)},x_j^{(1)}\right) + \delta\left(x_i^{(2)},x_j^{(2)}\right) + \delta\left(x_i^{(3)},x_j^{(3)}\right) + \delta\left(x_i^{(4)},x_j^{(4)}\right) \\ &\quad + \delta\left(x_i^{(5)},x_j^{(5)}\right) + \delta\left(x_i^{(6)},x_j^{(6)}\right) + \delta\left(x_i^{(7)},x_j^{(7)}\right) + \delta\left(x_i^{(8)},x_j^{(8)}\right) \\ &= \delta(0,1) + \delta(1,0) + \delta(2,2) + \delta(0,0) + \delta(1,1) + \delta(1,2) + \delta(2,0) + \delta(1,1) \\ &= 0+0+0+1+0+0+0+0 = 1 \end{aligned}$$

Similarly

$$\begin{aligned} a_{11} &= \sum_{m=1}^{8} \delta\left(x_i^{(m)},x_j^{(m)}\right) \\ &= \delta\left(x_i^{(1)},x_j^{(1)}\right) + \delta\left(x_i^{(2)},x_j^{(2)}\right) + \delta\left(x_i^{(3)},x_j^{(3)}\right) + \delta\left(x_i^{(4)},x_j^{(4)}\right) \\ &\quad + \delta\left(x_i^{(5)},x_j^{(5)}\right) + \delta\left(x_i^{(6)},x_j^{(6)}\right) + \delta\left(x_i^{(7)},x_j^{(7)}\right) + \delta\left(x_i^{(8)},x_j^{(8)}\right) \\ &= \delta(0,1) + \delta(1,0) + \delta(2,2) + \delta(0,0) + \delta(1,1) + \delta(1,2) + \delta(2,0) + \delta(1,1) \\ &= 0+0+0+0+1+0+0+1 = 2 \end{aligned}$$

$$\therefore \quad A(X_i, X_j) = \begin{bmatrix} 1 & 1 & 0 \\ 1 & 2 & 1 \\ 1 & 0 & 1 \end{bmatrix}.$$

■

Note:

(i) $\sum_{u=0}^{k-1}\sum_{v=0}^{k-1} a_{uv} = l$, where l is the dimension of the vector.

(ii) Most of the proximity measures between the vectors X_i and X_j is the combination of the elements of $A(X_i, X_j)$.

(i) DISSIMILARITY MEASURES

The dissimilarity measures for discrete valued vectors can be measured by different approaches. Some of them are discussed below.

(1) **Hamming Distance**

The Hamming distance is the number of places where two vectors differ.

Hamming distance is the sum of all off-diagonal elements of the contingency table $A(X_i, X_j)$, that is,

$$ds_{ij}^{(Hamming)}(X_i, X_j) = \sum_{\substack{u,v=0 \\ u \neq v}}^{k-1} a_{uv}. \tag{2.35}$$

where,

$$\begin{aligned} u &\in F, \\ v &\in F, \\ F &= \{0, 1, \cdots, k-1\}, \\ a_{uv} &= \sum_{m=1}^{l} \delta\left(x_i^{(m)}, x_j^{(m)}\right), \text{ when } \delta\left(x_i^{(m)}, x_j^{(m)}\right) = \begin{cases} 1, \; x_i^{(m)} = u, x_j^{(m)} = v \\ 0, \; \text{Otherwise} \end{cases} \\ k &= \text{a positive integer,} \\ n &= \text{Number of vectors,} \\ l &= \text{Dimension of vector,} \end{aligned}$$

for $i = 1, 2, \cdots, n$ and $m = 1, 2, \cdots, l$.

Illustration 2.19. Suppose
$X_i = (0,1,2,0,1,1,2,1)^T$, and
$X_j = (1,0,2,0,1,2,0,1)^T$
then
$F = \{0,1,2\}$,
Dimension of vector, $l = 8$.
Here $k = 3$.
By Illustration 2.18 we get the contingency table

$$A(X_i,X_j) = \begin{bmatrix} 1 & 1 & 0 \\ 1 & 2 & 1 \\ 1 & 0 & 1 \end{bmatrix}.$$

then

$$\begin{aligned} ds_{ij}^{(Hamming)}(X_i,X_j) &= \sum_{\substack{u,v=0 \\ u\neq v}}^{k-1} a_{uv} \quad \text{i.e., sum of off-diagonal elements} \\ &= a_{01}+a_{02}+a_{10}+a_{12}+a_{20}+a_{21} \\ &= 1+0+1+1+1+0 = 4 \end{aligned}$$

■

Case 1: For $k = 2$ and $X_i, X_j \in F^l$.

$$ds_{ij}^{(Hamming)}(X_i,X_j) = \sum_{m=1}^{l} (x_i^{(m)} + x_j^{(m)} - 2x_i^{(m)}x_j^{(m)}) = \sum_{m=1}^{l} (x_i^{(m)} - x_j^{(m)})^2.$$

Case 2: For $k = 2$; $X_i, X_j \in F_a^l$ and $F_a = \{-1,1\}$.
Here X_i and X_j are bipolar vector.

$$ds_{ij}^{(Hamming)}(X_i,X_j) = \frac{1}{2}\left(l - \sum_{m=1}^{l} x_i^{(m)}x_j^{(m)}\right).$$

Note:

(i) Corresponding similarity measure of $ds_{ij}^{(H)}(X_i,X_j)$ is

$$cs_{ij}^{(Hamming)}(X_i,X_j) = ds_{max} - ds_{ij}^{(H)}(X_i,X_j) \tag{2.36}$$

where, $ds_{max} = Max\{ds_{ij}^{(Hamming)}(X_i, X_j), i, j = 1, 2, \cdots, n\}$.

(ii) The dissimilarity measure $ds_{ij}^{(1)}$, the L_1 *norm* i.e. *city block distance* for continuous-valued vectors and $ds_{ij}^{(Hamming)}$, the Hamming distance measure for binary-valued vectors coincide.

(ii) SIMILARITY MEASURES

The similarity measures for discrete valued vectors can be measured by different approaches. Some of them are discussed below.

(1) **Tanimoto Measure**

It is a widely used similarity measure for discrete-valued vectors. The Tanimoto measure between two sets U_i and U_j is defined as the ratio of the number of common elements, $|U_i \cap U_j|$ to the number of all different elements, $|U_i \cup U_j|$, where $|U_i|$ is the cardinality of the set U_i, that is, the number of elements of the set U_i.

Mathematically,

$$\text{Tanimoto measure} = \frac{|U_i \cap U_j|}{|U_i| + |U_j| - |U_i \cap U_j|} = \frac{|U_i \cap U_j|}{|U_i \cup U_j|}. \tag{2.37}$$

Case 1: Tanimoto measure between two discrete-valued vectors X_i and X_j.

Using $A(X_i, X_j)$ matrix (contingency table) we get

$$cs_{ij}^{(T)}(X_i, X_j) = \frac{\sum_{u=1}^{k-1} a_{uu}}{\sum_{u=1}^{k-1}\sum_{v=0}^{k-1} a_{uv} + \sum_{u=0}^{k-1}\sum_{v=1}^{k-1} a_{uv} - \sum_{u=1}^{k-1}\sum_{v=1}^{k-1} a_{uv}} \tag{2.38}$$

Special case for $k = 2$,

$$cs_{ij}^{(T)}(X_i, X_j) = \frac{a_{11}}{a_{11} + a_{01} + a_{10}}$$

where, contingency table $A(X_i, X_j) = \begin{bmatrix} a_{00} & a_{01} & a_{02} \\ a_{10} & a_{11} & a_{12} \\ a_{20} & a_{21} & a_{22} \end{bmatrix}$

Case 2: Other measures between $X_i, X_j \in F^l$ can be defined using $A(X_i, X_j)$.

Category 1: Similarity measures when the number of places where the two vectors agree and the corresponding value is not 0:

$$\frac{1}{l}\sum_{u=1}^{k-1} a_{uu} \quad \text{and} \quad \frac{1}{l-a_{00}}\sum_{u=1}^{k-1} a_{uu}.$$

Category 2: Similarity measures when all the places where the two vectors agree:

$$\frac{1}{l}\sum_{u=0}^{k-1} a_{uu}.$$

(2) **Between Binary Vectors**

Similarity measures are referred to as similarity coefficients, and typically have values between 0 (not at all similar) and 1 (completely similar). The comparison of two binary vectors, a and b (say), leads to four quantities:

N_{01} = the number of positions where a was 0 and b was 1

N_{10} = the number of positions where a was 1 and b was 0

N_{00} = the number of positions where a was 0 and b was 0

N_{11} = the number of positions where a was 1 and b was 1

Two common similarity coefficients between binary vectors are the simple matching coefficient (SMC) and the Jaccard coefficient.

$$SMC = \frac{N_{11}+N_{00}}{N_{01}+N_{10}+N_{11}+N_{00}} \tag{2.39}$$

$$\text{Jaccard} = \frac{N_{11}}{N_{01}+N_{10}+N_{11}} \tag{2.40}$$

Illustration 2.20. Consider two binary vectors, a and b

where,

a = 1 0 0 0 0 0 0 0 0 0 and

b = 0 0 0 0 0 0 1 0 0 1

Now we determine

N_{01} = the number of positions where a was 0 and b was 1
= 2

N_{10} = the number of positions where a was 1 and b was 0
= 1

N_{00} = the number of positions where a was 0 and b was 0
= 7

N_{11} = the number of positions where a was 1 and b was 1
= 0

$$\therefore \quad SMC = \frac{N_{11}+N_{00}}{N_{01}+N_{10}+N_{11}+N_{00}} = \frac{0+7}{2+1+0+7} = \frac{7}{10} = 0.7$$

and

$$\text{Jaccard} = \frac{N_{11}}{N_{01}+N_{10}+N_{11}} = \frac{0}{2+1+0} = \frac{0}{3} = 0.0$$

Conceptually, SMC equates similarity with the total number of matches, while *Jaccard* considers only matches on 1's to be important. There are situations (Illustrations 2.21 and 2.22) in which both measures are more appropriate.

Illustration 2.21. (**Simple matching coefficient (SMC)**) Suppose vectors represent students' answers to a True-False test. Then both 0-0 and 1-1 matches are very important and these two students are very similar, at least in terms of the grades obtained by the students. ■

Illustration 2.22. (**Jaccard measure**) Suppose a vector represents a list of particular items purchased by a customer. There are two such customers in the shop. Now the purchasing behavior of two customers can be determined by Jaccard measure. Because the vectors indicate particular items purchased by two customers, then the Jaccard measure is more appropriate. Since it would be odd to say that the purchasing behavior of two customers is similar, even though they did not buy any of the same items. ■

2.8.4.3 Mixed Valued Vectors

Suppose

$$X_i = (x_i^{(1)}, x_i^{(2)}, \cdots, x_i^{(l)}) \text{ and } X_j = (x_j^{(1)}, x_j^{(2)}, \cdots, x_j^{(l)})$$

are two l-dimensional vectors in which $x_i^{(m)}$ is real (discrete) valued then $x_j^{(m)}$ is also real (discrete) valued for $m = 1, 2, \cdots, l$. In this mixed valued vectors, the proximity can be measured as follows:

Case 1: **Assuming real valued vectors.**

Apply the proximity measures for real valued vectors as described above.
In this situation, L_1 distance (e.g., Minkowski's L_1 distances such as city block distance, etc.) is a good candidate.

Case 2: **Convert into the discrete valued vectors.**

First convert the real-valued features to discrete-valued ones.
Conversion procedure is described in Algorithm 2.1

Algorithm 2.1. (**Discretizing Procedure**): Suppose a feature $x_i^{(m)} \in X_i$ is real valued in the interval $[\alpha, \beta]$.
Input: A feature $x_i^{(m)} \in X_i$ is real valued in the interval $[\alpha, \beta]$. Here the objective is to discretize the real data $x_i^{(m)}$.
Output: Measurement of proximity for discrete valued vectors.
Step 1: [**Input**] Get a feature $x_i^{(m)} \in X_i$ is real valued in the interval $[\alpha, \beta]$

Step 2: [**Division of interval**] Divide the interval $[\alpha, \beta]$ into k subintervals.

Step 3: [**Select subinterval**] If $x_i^{(m)}$ lies in the rth subinterval,

then the value $r - 1$ will be assigned to it.

Step 4: [**Repeat**] Apply Step 3 for all real valued features in the vector.

Step 5: [**Computation**] Compute proximity for discrete valued vectors.

Step 6: [**Terminate the algorithm**] Stop.

(1) Direct use of Mixed Valued Vectors

The similarity measure between two l-dimensional mixed valued vectors X_i and X_j is

$$cs_{ij}^{(mixed)}(X_i,X_j) = \frac{\sum_{u=1}^{l} s_u(X_i,X_j)}{\sum_{u=1}^{l} w_u} \qquad \text{provided} \quad \sum_{u=1}^{l} w_u \neq 0 \tag{2.41}$$

where,

$s_u(X_i,X_j)$ = similarity between the uth component (feature) of X_i and X_j, and

w_u = weight factor corresponding to the uth component.

(2) Computational Procedure

Case 1: If atleast one of the uth component of X_i and X_j is undefined then

$w_u = 0$.

Case 2: If $x_i^{(u)}$ and $x_j^{(u)}$ are binary,

and both $x_i^{(u)}, x_i^{(u)} = 0$ then

$w_u = 0$.

Case 3: If $w_u = 0$ for all u then

$cs_{ij}^{(mixed)}(X_i,X_j)$ is undefined.

Case 4: If $x_i^{(u)}$ and $x_j^{(u)}$ are binary then

$$s_u(X_i,X_j) = \begin{cases} 1, \; x_i^{(u)} = x_j^{(u)} = 1 \\ 0, \; \text{Otherwise.} \end{cases}$$

Case 5: If qth coordinate correspond to nominal or ordinal variables then

$$s_u(X_i,X_j) = \begin{cases} 1, \; x_i^{(u)} = x_j^{(u)} \\ 0, \; \text{Otherwise.} \end{cases}$$

Case 6: If $x_i^{(u)}$ and $x_j^{(u)}$ correspond to interval or ratio scaled variables then

$$s_u(X_i,X_j) = 1 - \frac{|x_i^{(u)} - x_j^{(u)}|}{r_u},$$

where, r_u is the length of the interval of $x_k^{(u)}$, $\forall k = 1,2,\cdots,n$.

Note:

(i) When $x_i^{(u)}$ and $x_j^{(u)}$ coincide, $s_u(X_i,X_j) = 1$ (maximum).

(ii) If $|x_i^{(u)} - x_j^{(u)}| = r_u$, then $s_u(X_i,X_j) = 0$ (minimum).

(iii) $0 \leq s_u(X_i,X_j) \leq 1$.

2.8.5 Similarity in Country Size

In this section our objective is to determine a similarity factor between two countries with respect to size. But in international economics, the factor of similarity in country size or country size related similarity are used by different researchers like Egger (2002, 2004) [110, 112], Pridy (2005) [243, 244] Antonucci (2006) [17], Manzocchi (2006) [17], and others.

Measure of similarity between countries is an *explanatory variable* in the models. First we have to understand the meaning of country in international economics. Is a country only a part of the map on the globe? And its size is a polygon as shown in the map along with its area and perimeter. In the sense of geography it is ok. But from the point of view of international economics, this information is not sufficient. It is much more than that. In economics a country is represented by various information such as

(1) geographical parameters,
(2) demographical parameters,
(3) economic parameters, and so on.

Intuitively these information helps us to analyze the economic condition of the country and its size.

Now our objective is to define a country mathematically and also we define a scale for comparison between countries in terms size or economy. This scale is termed as a similarity factor of the country with respect to others.

Mathematically, a country is represented by a l-dimensional vector, where each component of this vector belongs to any of the following domains (1) geographical parameters, (2) demographical parameters, (3) economic parameters, etc. even some computed parameters in a time frame. That means

$$X = \{x_1, x_2, \cdots, x_l\} \tag{2.42}$$

where, $x_i \in$ {geographical, demographical, economic, computed features, time, ...}
for $i = 1, 2, \cdots, l$.

Computational point of view, some x_is are real or integer type, some are string or character, and also some are logical, i.e., binary values.

Therefore X_i and X_j are two countries.
The similarity computation procedure between two countries is described above for different data types.

Mathematically, similarity between two countries with vectors X_i and X_j is

$$cs_{ij} = \text{similarity}(X_i, X_j) \quad \text{for } j \in \{1, 2, \cdots, n\}, j \neq i \tag{2.43}$$

where,

cs_{ij} = similarity factor between two countries C_i and C_j
X_i = Representative vector for country C_i,
X_j = Representative vector for country C_j,
n = Number of countries in the trade,
for $j \in \{1, 2, \cdots, n\}$, $j \neq i$

International trade takes place among two or more countries and its objective is to maximize benefits and minimize operating costs. Volume of trade depends on the size of the country and its economy. In this context the size and economy terminology is not absolute value, it is basically in comparison to the other countries. When we shall define the country size or economy size in an international trade network then we consider factors of other countries in the network. Suppose we describe the size of a country then the possible vector components for the representation of the country are:

1. **Year**
2. **Name of country**
3. **Geographical information**

    (a) Surface area of land,
    (b) Number of islands,
    (c) If it landlocked or not,
    (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),

4. **Demographical information**

(a) Population,

(b) Common language,

(c) Common religion,

(d) Common culture

(d) Common nation,

(e) Colonizer,

(f) Internal political tension,

(g) War,

(h) Car driving pattern, ...

5. **Economic information**

(a) Gross domestic product (GDP),

(b) National income,

(c) Common currency,

(d) Currency union,

(e) Exchange rate of currency with respect to U.S. dollar (USD),

(f) Tariffs,

(g) Trade barrier,

(h) Existence of trade agreements,

(i) Total commodity exports,

(j) Total commodity imports,

(k) Past exports,

(l) Exporter and importer rule of law,

(m) Economically developed/developing country,

(o) Real exchange rate,

(p) Volatility of exchange rate,

6. **Ratio information**

(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.

Applications

First of all we have to define a country and its size; after that we shall compute similarity between countries. In the globe all countries are different in the sense of geography but two countries may be similar in terms of different features such as area, population, religion, etc.

Application of similarity in country size is a two-step process:

Step 1: Define country in terms of size as per application

Step 2: Measure of similarity between countries

Some of the above listed information are used by different researchers like Antonucci and Manzocchi (2006) [17], Pridy (2005) [243, 244], Egger [110, 112], in their model. Other researchers also used country similarity in terms of size.

2.8.6 Similarity in Economic Sizes

In this section our objective is to determine a similarity factor between two countries with respect to economic size. Different researchers have used similarity in economic sizes of a country in different forms: (1) income similarity by Tang [285], (2) similarity in economic sizes, Kandogan [173], etc.

The measurement of similarity in economic size of a country is almost similar to the measurement of similarity in country size described in previous section.

2.8.7 Summary of Country-specific Dynamic Dependent Features

In this section we have summarized various country-specific dynamic dependent features/factors as shown in Table 2.13.

Table 2.13 Country-specific Dynamic Dependent Features for the country$_i$ at time t

Feature	Variable	Definition	Remarks
1. Remoteness	$G_i^{remoteness}(j)$	$= \sum_{\substack{m=1 \\ m\neq j\neq i}}^{n} \frac{d_{im}}{y_m}$ for $j = 1,2,\cdots,n,\ \ \&\ \ j \neq i$	$n-1$ remoteness components for country$_i$.
2. Nearness	$G_i^{nearness}(j)$	$= \sum_{\substack{m=1 \\ m\neq j\neq i}}^{n} \frac{y_m}{d_{im}}$ for $j = 1,2,\cdots,n,\ \ \&\ j \neq i$	$n-1$ nearness components for country$_i$.
3. Similarity	$G_i^{similarity}(j)$	$= cs_{ij}(t)$	similarity between two vectors related to country$_i$ and country$_j$ at time t.

2.9 Multi-Channel Gravity Model in a Trade Network

In this section we first state the traditional gravity model. Then we extend this model to multi-channel activities in a trade network.

2.9.1 Gravity Model of Trade between Two Countries

The traditional gravity model in international trade between two countries is stated below.

The objective of trade flow between two countries is directly proportional to the product of their economic sizes and inversely proportional to the distance between two countries. Mathematically we obtain

$$F_{i,j} = C \times \frac{M_i M_j}{D_{i,j}^2} \tag{2.44}$$

where,

M_i = Economic size for country$_i$,

M_j = Economic mass for country$_j$,

$D_{i,j}$ = Distance between country$_i$ and country$_j$,

$F_{i,j}$ = Force of trade flow between country$_i$ and country$_j$

C = Constant

Analysis

The distance $D_{i,j}$ between country$_i$ and country$_j$ in Eqn. (2.44) is invariant of time t. Therefore the force of trade flow $F_{i,j}$ between country$_i$ and country$_j$ totally depends on the economic masses M_i and M_j of the countries. Also these economic masses change with time. So $F_{i,j}$ changes with time. Therefore $F_{i,j}$ is a function of time t as both M_i and M_j are function of t.

Again we look at distance $D_{i,j}$ between country$_i$ and country$_j$. In international trade $D_{i,j}$ indicates the transport cost $T_{i,j}$ of commodities between country$_i$ and country$_j$. Again $T_{i,j}$ is not fixed and varies with the mode and technology of transport. Therefore $T_{i,j}$ is a time dependent function as technology gets upgraded with time. So far $T_{i,j}$ is deterministic in nature. But there are some uncertainty in $T_{i,j}$ because the vessel for transportation may not reach the destination due to some adverse weather conditions or other reason. Also there are some probabilistic part with $T_{i,j}$. Any way $T_{i,j}$ is a function of t.

Now we can conclude that $F_{i,j}$ is a function of t.

2.9.2 Concepts of Multi-Channel Gravity Model in International Trade

Traditional gravity model computes the trade flow between two countries using the economic mass for the countries and the distance between them. The economic mass of a country can be viewed in different channels.

Before the discussion of the channels we consider few notations as given in Table 2.14.

Table 2.14 Some notations used in multi-channel gravity model

$\mathscr{V}$	= A set of countries under trade,
n	= $\|\mathscr{V}\|$
	= Cardinality of the set $\mathscr{V}$
	= Number of countries in set $\mathscr{V}$,
i	= a country, where $i \in \mathscr{V}$,
j	= another country, where $j \in \mathscr{V}$, $i \neq j$
$D_{i,j}$	= Distance between country$_i$ and country$_j$,
t	= time,
Import$_{i,j}(t)$	= Import size from country$_i$ to country$_j$ at time t,
Export$_{i,j}(t)$	= Export size of country$_i$ from country$_j$ at time t,
GDP$_i(t)$	= Gross Domestic Product (GDP) of country$_i$ at time t,
GNI$_i(t)$	= Gross National Income (GNI) of country$_i$ at time t,
PriceIndex$_i(t)$	= Price Index of country$_i$ at time t,
Demand$_i(t)$	= Demand of country$_i$ at time t,
Population$_i(t)$	= Population of country$_i$ at time t,
ExchangeRate$_i(t)$	= Exchange rate of country$_i$ at time t in USD,
$F_{i,j}^{ImEx}(t)$	= Force of trade flow of country$_i$ between country$_i$ and country$_j$ with respect to Import and Export
$F_{j,i}^{ImEx}(t)$	= Force of trade flow of country$_j$ between country$_i$ and country$_j$ with respect to Import and Export
$F_{i,j}^{GDP}(t)$	= Force of trade flow between country$_i$ and country$_j$ with respect to GDP
$F_{i,j}^{PriceIndex}(t)$	= Force of trade flow between country$_i$ and country$_j$ with respect to *Price Index*
G	= A graph structure of the network c
	= $(\mathscr{V}, \mathscr{E})$,
	where $\mathscr{V}$ = set of vertices v of the graph G
	$\mathscr{E}$ = set of edges e of the graph G

Table 2.14 Some notations used in multi-channel gravity model (cont.)

e	=	(i,j) Assume vertices means countries
	=	An edge of the graph G
	=	connection between two countries i and j
	$\in$	$\mathscr{E}$
	=	$\begin{cases} 1, \text{ if } v \text{ and } v' \text{ is connected} \\ 0, \text{ otherwise} \end{cases}$
$\lvert\mathscr{E}\rvert$	=	Number of elements in $\mathscr{E}$
	$\leq$	$n \times n = n^2$ where, $n = \lvert\mathscr{V}\rvert$
τ	=	Order of the model

The force of trade flow between country$_i$ and country$_j$ can be computed using their economic mass or the parameters of the country that are directly related to the economic mass. Also these parameters are obtained from different channels. The trend of the force of trade flow between the countries is almost same. Some of the possible channels with major parameters are:

Channel 1. Gross Domestic Product (GDP)

It is the traditional channel of the economic mass of a country.

The force of trade flow between country$_i$ and country$_j$ can be computed as defined in Eqn. (2.45)

$$F_{i,j}^{GDP}(t) = C_1 \times \frac{\text{GDP}_i(t) \times \text{ GDP}_j(t)}{D_{i,j}^2} \tag{2.45}$$

where, $C_1 =$ a constant.

Channel 2. Gross National Income (GNI)

It is directly related to GNI of the country.

The force of trade flow between country$_i$ and country$_j$ can be computed as defined in Eqn. (2.46)

$$F_{i,j}^{GNI}(t) = C_2 \times \frac{\text{GNI}_i(t) \times \text{ GNI}_j(t)}{D_{i,j}^2} \tag{2.46}$$

where, $C_2 =$ a constant.

Channel 3. Import-export

The combination of import and export of a country may be another channel.

The force of trade flow between country$_i$ and country$_j$ can be computed as defined as Eqn. (2.47)

$$F_{i,j}^{ImEx}(t) = C_{31} \frac{\text{Import}_{i,j}(t) \times \text{Export}_{i,j}(t)}{D_{i,j}} \tag{2.47}$$

where, C_{31} = a constant.

or

$$F_{j,i}^{ImEx}(t) = C_{32} \frac{\text{Import}_{j,i}(t) \times \text{Export}_{j,i}(t)}{D_{i,j}} \tag{2.48}$$

where, C_{32} = a constant.

Note: In general it is trivial that

$$F_{i,j}^{ImEx}(t) \neq F_{j,i}^{ImEx}(t) \tag{2.49}$$

Channel 4. Price index

It is another channel that represent the economic mass of the country.

The force of trade flow between country$_i$ and country$_j$ can be computed as defined in Eqn. (2.50)

$$F_{i,j}^{PriceIndex}(t) = C_4 \times \frac{\text{PriceIndex}_i(t) \times \text{PriceIndex}_j(t)}{D_{i,j}^2} \tag{2.50}$$

where, C_4 = a constant.

Channel 5. Total demand

It is directly proportional to the population of the country.

The force of trade flow between country$_i$ and country$_j$ can be computed as defined in Eqn. (2.51)

$$F_{i,j}^{Demand}(t) = C_{51} \times \frac{\text{Demand}_i(t) \times \text{Demand}_j(t)}{D_{i,j}^2} \tag{2.51}$$

where, C_{51} = a constant.

and

$$F_{i,j}^{Population}(t) = C_{52} \times \frac{\text{Population}_i(t) \times \text{Population}_j(t)}{D_{i,j}^2} \tag{2.52}$$

where, C_{52} = a constant.

Again

$$\text{Demand} \propto \text{population} \tag{2.53}$$

Now from Eqn (2.51) using Eqn (2.53) we get

$$\begin{aligned} F_{i,j}^{Demand}(t) &= C_{51} \times \frac{\text{Demand}_i(t) \times \text{Demand}_j(t)}{D_{i,j}^2} \\ &\propto \frac{\text{Population}_i(t) \times \text{Population}_j(t)}{D_{i,j}^2} \\ &\propto F_{i,j}^{Population}(t) \qquad \text{[using Eqn (2.52)]} \end{aligned}$$

Channel 6. **Exchange rate**

It is an indicator of the economic mass of the country. Exchange rate of a country is measured in terms of a standard currency (say, USD).

$$F_{i,j}^{ExchangeRate}(t) = C_{61} \times \frac{\text{ExchangeRate}_i(t) \times \text{ExchangeRate}_j(t)}{D_{i,j}^2} \tag{2.54}$$

where, C_{61} = a constant.

The performance of these channels can be improved by introducing some other variables like common border, common language, common religion, common currency, internal political tension, etc.

2.9.3 Interaction Between Different Channels

Channel 1 to Channel 6 compute the trade force between countries.

Channel 1 and Channel 2:

Here Channel 1 is using GDP whereas Channel 2 is using Gross National Income (GNI). We know GDP is a monetary measure of the market value of all the final goods and services produced in a specific time period and GNI is the total domestic and foreign output claimed by residents of a country, consisting of gross domestic product, plus factor incomes earned by foreign residents, minus income earned in the domestic economy by nonresidents. Both are economic mass of the country, that means both indices are the measure of economic health of the country at different scales.

Again GDP and GNI are closely related to each other.
GNI = GDP + Net Receipts from abroad
Net Receipts from abroad = Total Export - Total Import
Therefore GNI - GDP = Export - Import

Channel 3:
But $F_{i,j}^{GDP}(t) \approx F_{i,j}^{ImEx}(t)$

or, $\dfrac{F_{i,j}^{GDP}(t)}{F_{i,j}^{ImEx}(t)} \approx f_i(t)$

or, $\dfrac{\text{GDP}_i(t)\times\ \text{GDP}_j(t)}{\text{Import}_{i,j}(t)\times\ \text{Export}_{i,j}(t)} \approx f_i(t)$

Guess

Suppose $f_i(t)$ will be a constant or linear with t. At some period of time it fluctuates and then become steady. This phenomenon is observed for other country i but not at the same period of time then we can say that the financial effect propagates from one country to other with a time lag. This financial effect may be a crisis. This phenomenon may be an indicator of contagion in trade.

Observation

It is observed that $f_i(t)$ is not a constant nor linear with t. But the nature of curve on normalized observations is

$$F_{i,j}^{ImEx}(t) = G_1 \frac{\text{Import}_{i,j}(t)\times\ \text{Export}_{i,j}(t)}{D_{i,j}}$$

and

$$F_{i,j}^{GDP}(t) = G_2 \frac{\text{GDP}_i(t)\times\ \text{GDP}_j(t)}{D_{i,j}}$$

for a country is almost same in shape but there is translation

$$F_{i,j}^{ImEx}(t) = F_{i,j}^{GDP}(t) + c$$

Their smoothened curve is a rising curve, either parabolic or exponential. This can be modeled empirically as

$$F_{i,j}^{GDP}(t) = G_2 \frac{\text{GDP}_i(t) \times \text{ GDP}_j(t)}{D_{i,j}} = k(t-t_0)^2$$

In general an empirical model for gravity trade force is a parabolic curve with time

$$F(t) = c + k(t-t_0)^2$$

Remark : If the trade force $F(t)$ does not follow its traditional nature then there is a crisis in the economy. If this crisis continue and also affect other related countries then contagion has already set in.

Channel 4:

This phenomenon is also observed by considering price index instead of GDP.

$$\frac{F_{i,j}^{PriceIndex}(t)}{F_{i,j}^{ImEx}(t)} \approx g_i(t)$$

or, $$\frac{\text{PriceIndex}_i(t) \times \text{ PriceIndex}_j(t)}{\text{Import}_{i,j}(t) \times \text{ Export}_{i,j}(t)} \approx g_i(t)$$

2.10 Unified Gravity Model in International Trade

In this section we shall describe an unified gravity model in international trading. Estimation of model parameters and data preparation for this model are also discussed in this section.

2.10.1 Specification of the Early Gravity Model

Gravity model, independently proposed by Walter Isard (1954) [163], Tinbergen (1962) [289] and Poyhonen (1963) [250], is the workhorse model to explain bilateral trade flow among countries as a function of import and export market sizes (i.e., GDP) and trade-resistance factors, provided by geographical distance.

2.10.2 Specification of the Unified Gravity Model

The most general and unified gravity model can be represented in Eqn.(2.55)

$$\begin{aligned} w_{ij}(t) = {} & \alpha_0 Y_i(t)^{\alpha_1} Y_j(t)^{\alpha_2} d_{ij}^{\alpha_3} \\ & \times \left[\prod_{k=1}^{K} X_{ik}(t)^{\beta_{1k}} X_{jk}(t)^{\beta_{2k}} \right] \\ & \times \exp\left(\sum_{h=1}^{H} \theta_h D_{ijh}(t) + \sum_{l=1}^{L} \left(\delta_{1l} Z_{il} + \delta_{2l} Z_{jl} \right) \eta_{ij}(t) \right) \end{aligned} \tag{2.55}$$

where,

t = time,

i = country$_i$,

j = country$_j$,

w_{ij} = trade force from country$_i$ to country$_j$,

$\approx$ exports from country$_i$ to country$_j$,

$w_{ij}(t)$ = exports from country$_i$ to country$_j$ at time t (i.e., in the year t)

Y_i = trade mass of country$_i$,

= GDP of exporter country$_i$,

$Y_i(t)$ = GDP of exporter country$_i$ in the year t,

Y_j = trade mass of country$_j$,

= GDP of importer country$_j$,

d_{ij} = geographical distance from country$_i$ to country$_j$,

X_i = country-size effects of country$_i$,

$\equiv$ These effects are related to country size such as area, population, etc.

$\mathbf{X}_i$ = vector of country-size specific parameters of country$_i$,

X_{i1} = area of country$_i$,

X_{i2} = population of country$_i$,

X_{i3} = total metal road length (in km) of country$_i$,

$\vdots$

X_{j1} = area of country$_j$,

X_{j2} = population of country$_j$,

X_{j3} = total metal road length (in km) of country$_j$,

$\vdots$

K = Number of country-size specific parameters,

$X_{jk}(t)$ = kth country-size specific parameters of country$_j$ at time t,

$\mathbf{D}_{ij}$ = vector of bilateral-relationship variables between country$_i$ and country$_j$,

H = Number of bilateral-relationship variables between country$_i$ and country$_j$,
= $|\mathbf{D}_{ij}|$

$D_{ijh}(t)$ = hth bilateral-relationship variable between country$_i$ and country$_j$ at time t,

D_{ij2} = common language between country$_i$ and country$_j$,

D_{ij3} = past and current colonial ties between country$_i$ and country$_j$,

D_{ij4} = common religion between country$_i$ and country$_j$,

D_{ij5} = common currency between country$_i$ and country$_j$,

D_{ij6} = regional trade agreement flag between country$_i$ and country$_j$,

$\vdots$

$\mathbf{Z}_i$ = vector of country-specific dummies for country$_i$,

L = Number of country-specific dummies for country$_i$,
= $|\mathbf{Z}_i|$

$Z_{il}(t)$ = lth country-specific dummies for the country$_i$ at time t,

Z_{i1} = land-locking effects for country$_i$,

Z_{i2} = continent membership for country$_i$,

$\vdots$

Z_{j1} = land-locking effects for country$_j$,

Z_{j2} = continent membership for country$_j$,

$\vdots$

$\eta_{ij}(t)$ = errors of the gravity model at time t when export from country$_i$ to country$_j$,

$E[\eta_{ij}(t)|]$ = 1, i.e., mean conditional to explanatory variables,

$\alpha_0, \alpha_1, \alpha_2, \alpha_3$ = parameters of the gravity model related to GDPs Y_i, Y_j, and the geographical distance, d_{ij}

β_{1k}, β_{2k} = model parameters related to the country-size specifications, for $k = 1, 2, \cdots, K$

θ_h = model parameters related to bilateral-relationship for $h = 1, 2, \cdots, H$

δ_{1l}, δ_{2l} = model parameters related to country-specific information for $l = 1, 2, \cdots, L$

2.10.3 Estimation of Model Parameters

There are number of model parameters in the unified gravity model specified in Eqn. (2.55). So the estimation of these parameters is really a difficult task. A straightforward approach is in log-linearizing the gravity model specification and then using one of the following three techniques to estimate parameters:

The existing empirical literature on gravity model has largely employed this approach (Glick and Rose [138, 139]; Rose and Spiegel (2002) [263]). Some of the models are:

1. OLS (*Ordinary Least Square*) : Standard OLS technique estimates parameters and obtain predicted values.
2. PPML (*Poisson Pseudo-Maximum Likelihood models*) : Fit data to the Poisson pseudo-maximum likelihood models (PPML), either in their standard formulation (Silva and Tenreyro (2006) [277]) or in zero-inflated specifications (Linders and Groot (2006) [202]).
3. ZIP (*Zero-Inflated Poisson*), etc.

2.11 Conclusion

The chapter is a selective technical review of the relation between the laws of physics and those adopted by the theory and applications of gravity models in international trade. We tried to exemplify through various possible angles, the overarching relations between Newton's Law and the structure constructed for understanding the scope and dimensions of bilateral trade between countries that differ according to a host of criteria.

To begin with, we drew parallels between the core components of the two theories and subsequently panned out the constituent elements that keep the gravity equations in international trade in close resemblance to the celebrated natural laws. Indeed, the classical and time-tested theories in international trade do not usually engage with factors that offer salient characteristics to the gravity model. Components like the size of countries engaging in trade, the distance between the countries, which we subsequently comprehend into a discussion on remoteness and nearness, the cultural, religious and even colonial relations developed over centuries provide crucial ingredients to re-estimate the observed patterns of trade at bilateral and multilateral levels.

We used the indices of remoteness and nearness to reflect on trade between India and some of the European countries and generally tried to offer a unified treatment of the early gravity models and the more recent versions, where, as we have also pointed out clearly, the empirical realities find explanations in product differentiated models of trade, in love for variety and in differences between factor proportions across countries. Overall, it is perhaps not surprising that Newton's Law or Ohm's Law have a lot of commonality with the theoretical predictions in trade models, but to the extent these principles find empirical validity and generate a much bigger appeal beyond the limited applications, is useful for the conceptual sphere of the subject in an increasingly multidisciplinary research environment.

Chapter 3

Cross Country Analysis of Gravity Model in the Presence of FTAs

3.1 Introduction

In the recent trends of globalization, people and countries exchange different ideas rapidly over time and over their geographic boundaries. Thus , values, money, and resources has rapidly expanded over the last few decades. Liberalization shows that opportunities are unbounded but there is a price to pay, the countries must face various changes such as free trade agreements (FTA), trade liberalization theories, and comparative advantage policies. As trade boundaries continue to melt economies are opening up to free flow of labour, capital, goods, and services between countries. Thus, trade agreements have become an integral part of today's economy. The countries have signed various free trade agreements, or FTAs among each other such as the ASEAN Free Trade Area (AFTA), European Free Trade Association (EFTA), the North American Free Trade Agreement (NAFTA), the South Asian Free Trade Area (SAFTA), the Trans-Pacific Partnership (TPP), the Pacific Alliance Free Trade Area (PAFTA), the Central European Free Trade Agreement (CEFTA) and the East African Community (EAC) among others. Albania embraced the free market economy in 1990 and passed from a centralized economy in which all assets were publicly owned to an open market, which led to liberalization in foreign direct investment (FDI) and trade. India has become part of many trade agreements over the years, either bilateral or multilateral, such as ASEAN-India Comprehensive Economic Cooperation Agreement, India-MERCOSUR Preferential Trade Agreement, South Asian Free Trade Area, India-Republic of Korea Comprehensive Economic Partnership Agreement, etc.

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 the previous chapters 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.

As discussed earlier the 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 centre. The first part of the 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 Gravity Model applied to the case of India considers 23 partner countries such as Nepal, Bangladesh, Saudi Arabia, UAE, USA, UK, Netherlands, Australia, Austria, Belgium, Canada, France, Germany, Spain, Italy, Ireland, Portugal, Greece, China, Hong Kong, Singapore, Vietnam and Malaysia. The last part of the study provides the conclusions derived by combining both the theoretical development of the subject and the empirical results.

3.2 Trade Liberalization

Trade liberalization has become a very popular word for the past three decades. Although it is still often debated, a number of researchers prove that trade liberalization is able to boost a country's economic growth. Therefore it is not surprising when the open economy through trade liberalization has been adopted by almost all countries (Haryadi, 2009, 2012, 2015) [154, 155, 156].

Indications of world openness can be seen from the development of a country's export and import ratios. The World Bank shows that of the 160 countries surveyed, 102 countries had a ratio of exports to GDP above 35%. Furthermore 35 countries have an export to GDP ratio of between 25% and 34%, 21 countries have an export to GDP ratio of between 10 percent, and only 2 countries have an export ratio below 10 (Table 3.1).

Table 3.1 Ratio of Export on GDP of all countries in the World

Number	Ratio of Export on GDP	Number of Country
1	> 35 %	114
2	25 to 34 %	34
3	10 to 24 %	10
4	< 10 %	2

Source: International Trade Statistics, WTO (2018).

Based on the facts, trade liberalization is not only triggered by the ability of exports to encourage economic growth, but also caused by economic growth that has been proven to drive exports. Conclusions like this are often found by researchers. Research on the relationship between exports and economic growth has also been carried out by Barro (1991, 1997) [30, 31]; Abbas (2012, 2014) [1, 2] and Haryadi (2015) [156].

3.2.1 Concepts of FTA

Free trade agreement (FTA) is an economic policy of a country. This policy allows buyers and sellers of different nations and countries to freely trade without interventions of the government of the country. For example the interventions may be in forms of quotas, tariffs, or restrictions on their goods and services (Collins, 2018) [78]. Some economists thought that free trade agreements are an easy way to enter a market and a country can adopt such policies unilaterally or on a bilateral basis by joining a free-trade area. There are other studies which refer to free trade as a way of relaxing from previous government interventions and restrictions on the economic policies of countries involved (Melnikas, 2008) [220]. Such trade liberalization increase the efficiency of a country by exposing the economy of a country to international competition. The concept of such free trade used to be barbaric during the periods of ancient history, such as ancient Egypt and slaves. Later the modern concept of 'laissez faire' was introduced by the father of economics, Adam Smith, in the 18th century, as means to recover from Great Depression. He argued that every man is left perfectly free to pursue his own interest in his own way without trade restriction (Smith, 1776) [279].

3.2.2 India ASEAN Free Trade Agreement (IAFTA)

In August 2009, for the first time India signed an FTA with a regional grouping ASEAN. In a large country like India where livelihood of millions of people depend on the performance of some crucial sectors, trade agreements can have a debilitating impact on their lives if it is not calibrated to address their concerns.

3.2.3 Emergence of Asia and the India-ASEAN FTA

Emergence of regionalism makes countries to form clusters or group in competing trade. Some such clusters are EU, NAFTA, ASEAN, Mercuson, etc. Here ASEAN is a regional grouping in Asia for Asian Economic Community. The present trend is that the centre of gravity for the economic production and services in the world is shifting towords Asia with china and India. Also ASEAN influences the trade flow between members and non-members countries/regions for emerging global economic order. In the recent period (except COVID), India is the fastest growing economy of the world and trying to explore regional trade partners with large trade potential. In August 2009, India also signed a FTA with ASEAN in trade of goods. Now India ASEAN trade cooperation is very important in the context of Asian economic Union and emergence of international economic order driven by dynamic Asia.

3.3 India ASEAN Trade

The volume of trade between ASEAN countries (such as Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, Viet Nam) and India at the time periods 2010 and 2015 are shown in Tables 3.2 and 3.3 and also pictorially presented in Fig 3.1 to 3.6 based on ASEAN Statistics database. These two time periods show trade at the time of signing the FTA and its impact on current trade. Table 3.2 showed that ASEAN import to India remained almost static during this period since

39.89 billion in 2010 to 39.10 billion in 2015. This stagnation in trade was prevailing in the global environment.

Table 3.2 ASEAN Countries Exports to India

Reporter Country	2010	[%]	2015	[%]	% Change in Export
Brunei Darussalam	48,8158529.2	[1.22]	57,7977953.2	[1.48]	18.40
Cambodia	8065592.899	[0.02]	10369525.96	[0.03]	28.56
Indonesia	991,5038943	[24.85]	1173,1001068	[30.00]	18.32
Lao PDR	46842	[0.001]	1,5294021.31	[0.04]	32550.23
Malaysia	651,2144922	[16.32]	812,2762776	[20.77]	24.73
Myanmar	95,8859242.1	[2.40]	101,3990785	[2.59]	5.75
Philippines	40,9844634	[1.03]	37,2886853	[0.95]	-9.02
Singapore	1715,1303835	[42.99]	1064,6671024	[27.23]	-37.93
Thailand	345,7513441	[8.67]	413,4988467	[10.58]	19.59
Viet Nam	99,1629596	[2.49]	247,4806392	[6.33]	149.57
ASEAN	39,89,2605578	[100.00]	39,10,0748866	[100.00]	-1.98

Source: ASEAN Statistics

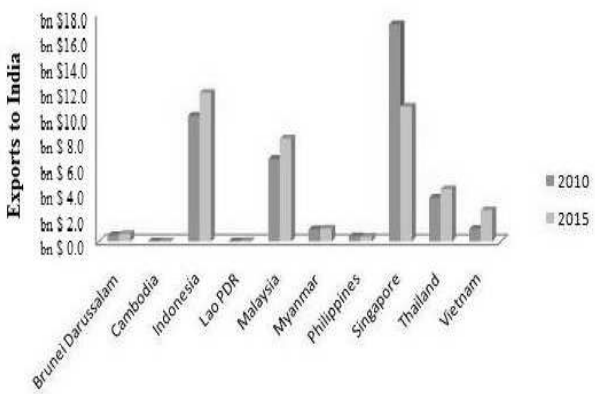

Fig. 3.1 ASEAN country’s export to India.

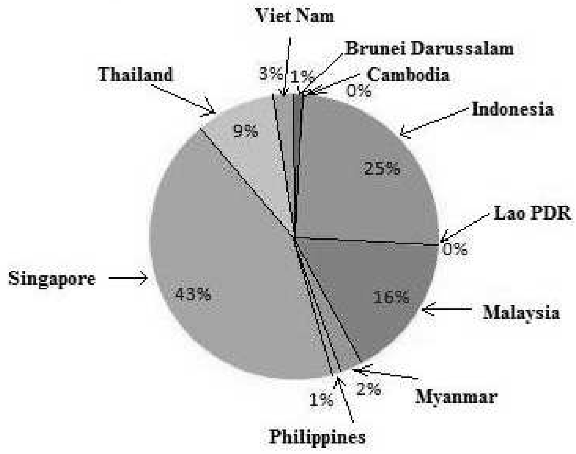

Fig. 3.2 ASEAN country's export to India for 2010.

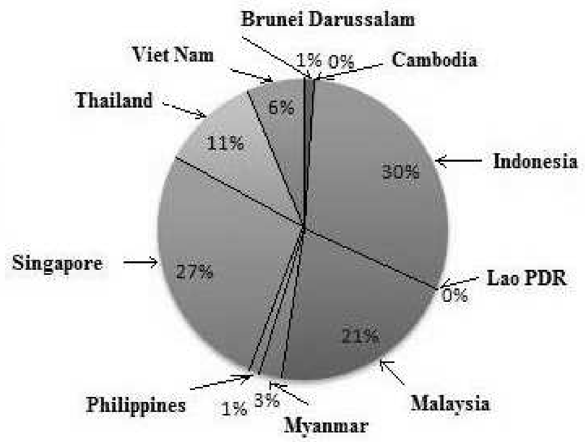

Fig. 3.3 ASEAN country's export to India for 2015.

In Table 3.3, imports from ASEAN countries to India for the period 2010 and 2015 are much lower than ASEAN exports for both the periods. In 2010, imports from India to ASEAN countries is 0.537 times exports to India from ASEAN countries. Again in 2015, imports from India to ASEAN countries is 0.4975 times exports to India from ASEAN countries. Table 3.3 shows that ASEAN exports to India remained static in the post FTA period. On the other hand, it shows that ASEAN imports from India declined from 21.42 billion to 19.45 billion. This fact attributed to global recession which affected the ASEAN countries much more than India. In this situation, India was still in a state to behold the economic growth. But in Table 3.3, it is observed that the highest decline in imports from India ranges from 43.09% in 2010 to 29.73% in 2015 for Singapore. Similarly Thailand declined from 18.8% to13.15%. But other countries like Cambodia, Philippines, Malaysia, Lao PDR, Myanmar, Viet Nam and Brunei Darussalam improved their import share during the period 2010 and 2015.

Table 3.3 ASEAN Countries Imports from India

Reporter Country	2010	[%]	2015	[%]	% Change in Import
Brunei Darussalam	2,2509836.85	[0.11]	3,7470528.23	[0.19]	66.46
Cambodia	5,2571900.36	[0.25]	11,4463288.5	[0.59]	117.73
Indonesia	310,2118308	[14.48]	262,6866633	[13.50]	-15.32
Lao PDR	8161486.13	[0.04]	3,1930469.88	[0.16]	291.23
Malaysia	248,3788923	[11.59]	389,5727198	[20.03]	56.85
Myanmar	16,6697568.5	[0.78]	47,4040990.1	[2.44]	184.37
Philippines	56,5755543	[2.64]	128,7366863	[6.52]	127.55
Singapore	923,2741141	[43.09]	578,3297481	[29.73]	-37.36
Thailand	402,8148492	[18.80]	255,8142098	[13.15]	-36.49
Viet Nam	176,2034464	[8.22]	264,3465011	[13.59]	50.02
ASEAN	21,42,4527663	[100.00]	19,45,2770561	[100.00]	-9.20

Source: ASEAN Statistics

3.4 Models for Cross-Country Analysis

In this section we shall discuss the estimation techniques of panel data regression for cross-country analysis.

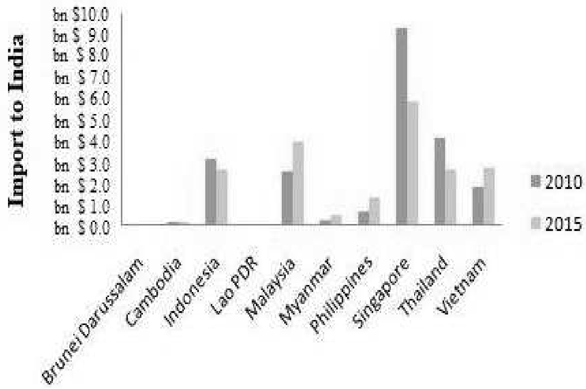

Fig. 3.4 ASEAN country's import from India.

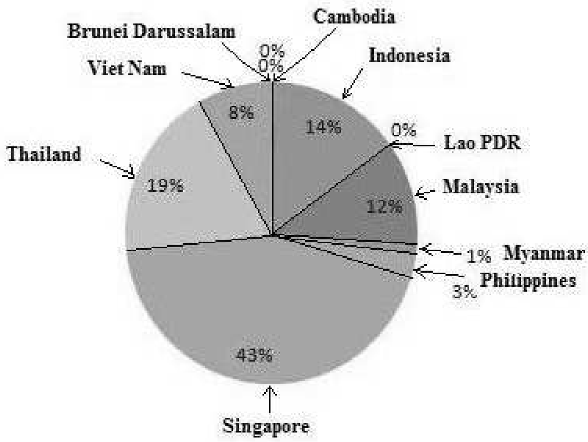

Fig. 3.5 ASEAN country's import from India for 2010.

3.4.1 Empirical Gravity Models

Empirical gravity models are extensively used in assessing the impact of international trade arrangements. The basic idea of these models are to include an additional FTA dummy variable in the standard gravity model of international trade that captures variations in the levels and direction of trade due to the formation of an FTA. The dummy variable takes the value 1 when both countries in a given pair belong to the same regional group and 0 otherwise.

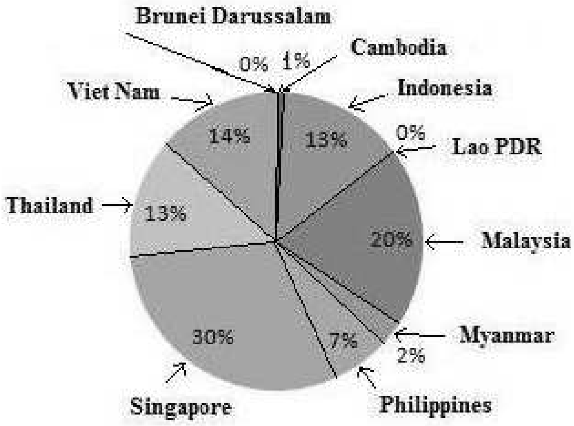

Fig. 3.6 ASEAN country's import from India for 2015.

Mathematically we can write the FTA dummy variable (FTA_{ij}) between country$_i$ and country$_j$ as

$$FTA_{ij} = \begin{cases} 1, & \text{when country}_i, \text{country}_j \in \text{same regional group} \\ 0, & \text{Otherwise} \end{cases}$$

Now we estimate the coefficient of the dummy variable FTA_{ij}. This coefficient will explain the effect of FTA in the trade, i.e., how much additional trade is happening due to the formation of the FTA.

The basic Gravity model can be augmented with large number of other variables to account for large number of factors that are influencing trade. These include (1) cultural factors, (2) geographical factors, (3) historical factors and (4) other factors.

(1) **Cultural factor**: These factors explain whether countries share common language, customs, practices and similar ethnic groups.
(2) **Geographical factor**: These factors explain whether countries share common borders or they are landlocked countries or island nations.
(3) **Historical factor**: Historical nature of the relationship between countries shows that whether one colonized the other, or they have common colonizer.

When all possible factors influencing trade between nations are taken into consideration the remaining unaccounted part is the result of artificial barriers to trade.

3.4.2 Review on Empirical Gravity Models with FTAs

A literature survey on international trade is discussed in section 1.5. In this present section we review on empirical gravity models augmented with free and regional trade agreements.

Different researchers designed their cross-country gravity models with free trade agreements. Some of them are stated below. In their experiments they have used either cross-sectional data or panel data.

Researchers Breuss and Egger (1999) [51], Porojan (2001) [249], Fukao et al. (2003) [134], Wilson et al. (2003) [296], Egger (2004) [112], Abedini and Peridy (2007) [3], Tang (2005) [285], Bussiere, Fidrmuc, and Schnatz (2008) [58] studied international trade using emperical gravity models. They considerd either export, import or both using the augmented dummy variable NAFTA memberships in their study. Breuss and Egger (1999) [51] and Porojan (2001) [249] considered cross-sectional data. As well as other researchers Fukao et al. (2003) [134], Wilson et al. (2003) [296], Egger (2004) [112], Abedini and Peridy (2007) [3], Tang (2005) [285] used Panel data.

Endoh (1999) [120] investigated exports by empirical gravity model with augmented dummy variables of free trades such as LAFTA,EEC, LAFTA and CMEA members using panel data.

In the analysis of empirical gravity model, Rose (2000) [262], Feenstra et al. (2001) [127], Glick and Rose (2002) [139], Kurihara (2003) [193], Longo and Senkat (2004) [209], Augier et al. (2005) [24], Peridy (2005) [243, 244], Baier and Bergstrad (2006) [25], Carrere (2006) [66], Kucera and Sarna (2006) [192], Bun and Klaasen (2007) [56],Iwanow and Kirkpatrick (2007) [166], Lee and Park (2007) [197], Melitz (2007) [219], Roberts (2004) [260], and Chandran (2018) [69] studed the effect of augmented dummy variable FTA by using Panel or cross-sectional data. Most of them studed exports but very few of them studed imports or both import and export (Chandran (2018) [69]).

Sapir (2001) [267] and Egger (2004) [112] studied the effect of augmented dummy variable EFTA for the analysis of exports using empirical gravity model. Sapir (2001) [267] used cross sectional data and Egger (2004) [112] used panel data.

Abedini and Peridy (2007) [3] analysed the GAFTA agreement effects by panel data. They studed exports by emperical gravity model.

Wilson et al. (2003) [296], Roberts (2004) [260], Tang (2005) [285], Bussiere, Fidrmuc, and Schnatz (2008) [58], Chandran (2018) [69] studed the effect of FTA related to ASEAN in the international trade using emperical gravity models.

Economic theory suggests that the overall welfare effects of a FTA depend on the balance between trade creation and trade diversion. Trade creation takes place when a high cost domestic production is replaced by a low cost foreign producer. Trade diversion occurs when the trade with low cost non-member countries are replaced with high cost partner courtiers of the FTA. Trade creation and trade diversion have opposite effects on welfare. Trade creation generates welfare gains for member countries without imposing any losses on non-members. In this case consumer gains in terms of lower prices are higher than the producer surplus and tariff loss to the Government put together. In contrast trade diversion generates a welfare loss. Trade diversion reduces the trade of the non-member country and tariff losses to the home country. Even though consumers pay less price the total loss for the country as a whole is higher.

Now our objective is to study the effect of FTA on exports, imports and net exports related to India and other 23 countries using empirical gravity models where FTA is an augmented dummy variable. We have experimented these augmented gravity model with different sets of variables.

3.5 Analysis of Gravity Model

In this section we discuss gravity models with variables for the analysis, sources of data, data collection, data volume, empirical specification of gravity model, estimation techniques, estimated output from model, and discussions.

3.5.1 Variables for the Analysis

We consider the following gravity variables for the analysis of bilateral trade using gravity model.

Country_i, Country_j, Export_{ij}, Import_{ij}, GDP_i, GDP_j, Population_i, Population_j, Distance_{ij}, Real Effective Exchange Rate_{ij}, Border_{ij}, Developed Country_{ij}, Colony_{ij}, Language_{ij}, Religion_{ij}, FTA_{ij}, Interaction_1, Interaction_2

3.5.2 Sources of Data

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.

3.5.3 Data Collection

The data for the analysis of gravity models are collected from multiple sources. The trade data such as import, export, status of developed country are collected using COMTRADE database of UN. Population, inflation and GDP are collected using World Bank open data. Distance, real exchange rate, colony, language are collected from CEPII of France. Border, currency of a country, religion, FTA are collected from different web address.

3.5.4 Data Specification

The data volume for the analysis of gravity models is collected for 24 partner countries of India representing different geographical regions of the world. Each country has got bilateral trade pair with other 23 countries for 24 years. The study used the data set of $23 \times 24 \times 24$, i.e., 13248 bilateral trade for 552 country pair (panel) for 24 years. The data are collected for the period from 1995 to 2018.

A balanced panel data set consisting 13248 bilateral trade data across different gravity variables is prepared for the analysis of gravity model.

3.6 Empirical Specification of Gravity Model

We have considered gravity model for the study of $\texttt{Net Export}_{ij}$ between $\texttt{Country}_i$ and $\texttt{Country}_j$.

In this model, the dependent variable is $\texttt{Net Export}_{ij}$ between $\texttt{Country}_i$ and $\texttt{Country}_j$. The model used in the study is outlined in Eqn. (3.1).

$$Y_{ij}(t) = w_0 + \sum_{k=1}^{K} w_k X_i^{(k)}(t) + u_{ij} \tag{3.1}$$

where,

t = $\texttt{Time}$,

i = $\texttt{Country}_i$,

j = $\texttt{Country}_j$,

$X_i^{(1)}(t)$ = log of $\texttt{GDP}_i$ of exporter Country_i at time t,
= ln $(\texttt{GDP}_i(t))$

$X_i^{(2)}(t)$ = log of $\texttt{GDP}_j$ of importer Country_j at time t,
= ln $(\texttt{GDP}_j(t))$

$X_i^{(3)}(t)$ = log of $\texttt{Population}_i$ of Country_i at time t,
= ln $(\texttt{Population}_i(t))$= ln $(\texttt{POP}_i(t))$

$X_i^{(4)}(t)$ = log of $\texttt{Population}_j$ of Country_j at time t,
= ln ($\texttt{Population}_j(t)$)

$X_i^{(5)}(t)$ = log of $\texttt{Distance}_{ij}$ between Country_i and Country_j,
= ln ($\texttt{Distance}_{ij}$)

$X_i^{(6)}(t)$ = log of $\texttt{Real Effective Exchange Rate}_{ij}$ between Country_i and Country_j,
= ln ($\texttt{REER}_{ij}$)

$X_i^{(7)}(t)$ = Dummy variable $\texttt{Border}_{ij}$ between Country_i and Country_j,
= $\texttt{Border}_{ij}$

$X_i^{(8)}(t)$ = Dummy variable $\texttt{Developing Country}_i$ for Country_i,
= $\texttt{Develop}_i$

$X_i^{(9)}(t)$ = Dummy variable $\texttt{Colony}_{ij}$ between Country_i and Country_j,
= $\texttt{Colony}_{ij}$

$X_i^{(10)}(t)$ = Dummy variable $\texttt{Common Language}_{ij}$ between Country_i and Country_j,
= $\texttt{Language}_{ij}$

$X_i^{(11)}(t)$ = Dummy variable $\texttt{Common Religion}_{ij}$ between Country_i and Country_j,
= $\texttt{Religion}_{ij}$

$X_i^{(12)}(t)$ = Dummy variable $\texttt{Common FTA}_{ij}$ between Country_i and Country_j,
= $\texttt{FTA}_{ij}$

$X_i^{(13)}$ = $\texttt{Interaction}_1$ between Distance and Real Effective Exchange Rate for Country_i,
= $\texttt{Interaction}_1 = \ln(\texttt{Distance}) \times \ln(\texttt{REER})$

$X_i^{(14)}$ = $\texttt{Interaction}_2$ between Distance and Inflation for Country_i,
= $\texttt{Interaction}_2 = \ln(\texttt{Distance}) \times \ln(\texttt{Inflation})$

K = Number of independent variables,

w_i = weight/coefficient for ith item,

u_{ij} = idiosyncratic error terms,

$Y_{ij}(t)$ = Natural logarithm (ln) of trade force from Country_i to Country_j at time t,
= $\ln(\texttt{Net Export}_{ij}(t))$

3.7 Results of Empirical Gravity Model

In this section we discuss the experimental results from two estimation models: (1) BE (between effect) estimation model and (2) GMM (generalized method of moments) estimation model.

Using a sample of 24 countries between 1995 and 2018 we investigate the following questions with the help of gravity estimates 'How does inflation and real effective exchange rate affect incidences of contagion across countries?' Consequently, we estimate the following structural form equation (3.1). In this gravity model, $\ln(\texttt{Net Export}_{ij}(\texttt{t}))$ represents net export for $\texttt{Country}_i$ to $\texttt{Country}_j$ in year t, while $\ln(\texttt{GDP}_i(\texttt{t}))$ is log of GDP_i of exporter $\texttt{Country}_i$ at time t, $\ln(\texttt{GDP}_j(\texttt{t}))$ is log of GDP_j of importer $\texttt{Country}_j$ at time t, $\ln(\texttt{POP}_i(\texttt{t}))$ is log of $\texttt{Population}_i$ of $\texttt{Country}_i$ at time t, $\ln(\texttt{POP}_j(\texttt{t}))$ is log of $\texttt{Population}_j$ of $\texttt{Country}_j$ at time t, $\ln(\texttt{Distance}_{ij})$ is log of $\texttt{Distance}_{ij}$ between $\texttt{Country}_i$ and $\texttt{Country}_j$, $\ln(\texttt{REER}_{ij})$ is log of $\texttt{Real Effective Exchange Rate}_{ij}$ between $\texttt{Country}_i$ and $\texttt{Country}_j$. The variables $\texttt{Border}_{ij}$, $\texttt{Developing Country}_i$, $\texttt{Colony}_{ij}$, $\texttt{Language}_{ij}$, $\texttt{Religion}_{ij}$, $\texttt{FTA}_{ij}$ are dummy variables for common border, developing reporter country, colonial relation, common language, common religion and free trade agreements between $\texttt{country}_i$ and $\texttt{country}_j$. The first interaction term $\ln(\texttt{distREER}_{ij})$ represents the interaction term between distance between countries and real effective exchange rate, whereas the second interaction term $\ln(\texttt{distinf}_{ij})$ represents the interaction term between distance between countries and inflation between country pairs. w_{13}, w_{14} measures the joint impact of the interaction terms.

Of these, the point estimate of $\ln(\texttt{REER}_{ij})$ for $\ln(\texttt{distance}_{ij})$ is given by

$$\frac{\delta(\ln(\texttt{net export}_{ij}))}{\delta(\ln(\texttt{distance}_{ij}))} = w_5 + w_{13} \times \ln(\texttt{REER}_{ij})$$

Similarly, the point estimate of $\ln(\texttt{Inflation}_{ij})$ for $\ln(\texttt{distance}_{ij})$ is given by

$$\frac{\delta(\ln(\texttt{net export}_{ij}))}{\delta(\ln(\texttt{distance}_{ij}))} = w_5 + w_{14} \times \ln(\texttt{Inflation}_{ij})$$

Based on whether w_5, w_{14}, w_{13} are $>$ = or <0, and depending on the magnitude of $\ln(\texttt{REER}_{ij})$ and $\ln(\texttt{Inflation}_{ij})$, $\frac{\delta(\ln(\texttt{net export}_{ij}))}{\delta(\ln(\texttt{distance}_{ij}))}$ will be $>$ = or <0.

3.7.1 Identification Strategy

One of the foremost challenges that an empirical study with panel data can potentially face is that of presenting a clear identification strategy with regard to the empirical analysis. Identification issues can arise due to reverse causality, or omitted variable bias, or both. `Net export` and `GDP` can be simultaneously determined and, thus, `GDP` can be endogenous. `GDP` can also be endogenous due to omitted variables bias, which we address shortly.

Another challenge faced with this empirical analysis is the sample selection bias. Conclusions drawn from studying a subset that contains non-random elements of the population of interest might not generalize to the whole population if the subset is systematically different from the population. The resulting error from drawing such conclusions is known as sample selection bias [1]. Thus, establishing causality becomes challenging in the face of such bias.

Consequently, the identification strategy uses multiple estimation methods. It is well-known that time invariant factors like geographical location, extent of ethnic diversity, cultural and social capital can affect gravity model of trade. Considering the right hand side variables, especially the potentially endogenous ones in contemporaneous terms will not solve the endogeneity problem. While it would be ideal to use the dynamic panel estimators[2], Difference or System GMM for our benchmark analysis, we use these as part of robustness analysis due to concerns regarding insufficient sample size. The dynamic panel estimators, as described below, use internal instruments generated via moment conditions employing several lags of the endogenous covariates. This reduces the sample size considerably.

Before we go on to describe the dynamic panel estimators, it is important to acknowledge another bias. One serious difficulty with linear dynamic panel data (DPD) models is that the de-meaning process gives rise to a bias called 'Nickell bias'. Specifically, the de-meaning process is applied to remove unobserved heterogeneity that is present in ordi-

---

[1] The most effective way to correct for a sample selection bias is to use the Heckman model. We need to find a variable or variables and control for them so that we can use in our analysis. However, the use of Heckman model is precluded owing to unavailability of data on variables mentioned above.

[2] For recent applications, see, Dutta and Mallick (2018) [101]; Dutta and Williamson (2016) [102]; Dutta and Sobel (2016) [103]; Cooray, Dutta and Mallick (2016) [81]; Asiedu and Lin (2011) [22]; Dollar and Kray (2002) [93]; Bond, Hoeffler and Temple (2001) [46]; to mention a few.

nary least squares models. The de-meaning which entails subtracting the individual's mean value of y (the dependent variable) from each X (independent variable) results in a correlation between the regressor and the error. This is particularly problematic when between effect (BE) estimators are applied for large 'N' and small 'T' samples. We definitely have such a sample where N (number of states) is greater than T (number of years) [3]. As explained later, we resort to Difference GMM estimator that solves the concern of Nickell Bias by first differencing the data as well as satisfying all orthogonality conditions[4].

In our experiment we have considered 8 sets of variables where sets are defined below:

Set_1 = { ln GDP_i, ln GDP_j, ln POP_i, ln POP_j, ln Dist, ln REER, FTA }
Set_2 = { ln GDP_i, ln GDP_j, ln POP_i, ln POP_j, ln Dist, ln REER, $Develop_i$, FTA }
Set_3 = { ln GDP_i, ln GDP_j, ln POP_i, ln POP_j, ln Dist, ln REER, $Develop_i$, Colony, FTA }
Set_4 = { ln GDP_i, ln GDP_j, ln POP_i, ln POP_j, ln Dist, ln REER, Border, $Develop_i$, FTA }
Set_5 = { ln GDP_i, ln GDP_j, ln POP_i, ln POP_j, ln Dist, ln REER, Religion, FTA}
Set_6 = { ln GDP_i, ln GDP_j, ln POP_i, ln POP_j, ln Dist, ln REER, Language, Religion, FTA}
Set_7 = { ln GDP_i, ln GDP_j, ln POP_i, ln POP_j, ln Dist, ln REER, Religion, FTA, Interaction1 }
Set_8 = { ln GDP_i, ln GDP_j, ln POP_i, ln POP_j, ln Dist, ln REER, Religion, FTA, Interaction2 }

3.7.2 Analysis Using BE Estimation Model

In this study we have considered 5385 observations. Then we have applied BE estimation model on each set of variables for net export estimation using gravity model and its output is shown in Table 3.4

Discussion: All the BE models are significant. It is observed that GDP of both the reporter and partner countries (GDP_i, GDP_j) are positively correlated with the value of net export

[3] As Nickell (1981) [229] points out, the correlation results in a bias in the estimate of the coefficient of the lagged dependent variable and this bias is not mitigated by increasing N. Nickell further stresses that in case of small 'T', the bias can be sizeable. The bias will be relatively reduced for large 'T'. It should be further noted that the bias arises even if the error process is i.i.d. First differencing the model takes care of this problem as suggested by the Anderson-Hsiao (AH) estimator. Yet, as suggested by Arellano and Bond (1991) [18], the Anderson-Hsiao estimator, while consistent, fails to take all of the potential orthogonality conditions into account.

[4] We follow Roodman(2009) [261] for use of Difference GMM.

Table 3.4 Results from BE estimation model for net export using empirical gravity model with different sets of variables.

Variation	1	2	3	4	5	6	7	8
ln GDP_i	0.965*** 0.063	0..991*** 0.063	.996*** 0.064	0.985*** 0.064	1.143*** 0.066	1.122*** 0.067	1.148*** 0.066	1.174*** 0.07
ln GDP_j	0.984*** 0.063	.999*** 0.063	1.004*** 0.063	0.998*** 0.063	1.153*** 0.065	1.135*** 0.067	1.136*** 0.066	1.136*** 0.067
ln POP_j	-0.321*** 0.069	-0.32*** 0.068	-0.319*** 0.068	-0.324*** 0.068	-0.412*** 0.067	-0.407*** 0.067	-0.402*** 0.067	-0.39*** 0.069
ln POP_i	-0.184*** 0.057	-0.182*** 0.057	-0.183*** 0.057	-0.187*** 0.057	-0.316*** 0.059	-0.3*** 0.059	-0.31*** 0.06	-0.336*** 0.06
ln Dist	-0.543*** 0.086	-0.689*** 0.103	-0.684*** 0.104	-0.642*** 0.116	-0.869*** 0.097	-0.873*** 0.096	6.348** 3.033	-0.692*** 0.16
ln REER	-0.910 0.657	-0.982 0.653	-0.988 0.653	-0.98 0.653	-1.269** 0.627	-1.296** 0.626	12.314** 5.74	-1.259** 0.626
Border				0.329 0.366				
$Develop_i$		-0.512** 0.206	-0.508** 0.207	-0.496** 0.207				
Colony			-0.218 0.355					
Language						0.34 0.216		
Religion					-1.448*** 0.227	-1.441*** 0.227	-1.483*** 0.226	-1.404*** 0.229
FTA	2.27*** 0.389	2.398*** 0.39	2.381*** 0.391	2.359*** 0.392	2.017*** 0.372	1.921*** 0.376	1.893*** 0.374	2.032*** 0.372
Interation 1							-1.568** 0.658	
Interation 2								-0.021 0.015
Constant	- 15.253*** 3.785	-14.585*** 3.769	-14.865*** 3.799	-14.655*** 3.771	-15.81*** 3.598	-14.998*** 3.628	-78.251*** 26.471	-16.289*** 3.61
Adj R^2	0.624	0.63	0.63	0.631	0.662	0.664	0.667	0.663
Number of observation	5385	5385	5385	5385	5385	5385	5385	5385

Note:

* denotes significant at 10%, ** denotes significant at 5%, *** denotes significant at 1%

with statistically significant coefficients at 1% level of significance. Whereas population of partner country (POP_j) has a significantly negatively correlation throughout the BE models. As for population of reporter country (POP_i), it is negatively correlated. Distance between countries (Dist) has a significantly negative correlation except variation 7 throughout the BE models. Real effective exchange rate (REER) is not significant for the variations 1-4 but not true for remaining variations 5-8. The common border dummy variable (Border) in Variations 4, colony in Variations 3, language in Variations 6, and interaction 2 in Variation 8 are not significant. The development dummy ($Develop_i$) is significant at 5% level and negatively correlated for the variations 2-4. Religion is significant and negatively correlated for the variations 5-8. But FTA dummy is highly significant and positively correlated for all variations.

3.7.3 Analysis Using GMM Estimation Model

In this study we have considered 4560 observations. Then we have applied GMM (generalized method of moments) estimation model on each set of variables for net export estimation using gravity model and its output is shown in Table 3.5.

Discussion: All the GMM models are significant. It is observed that GDP of partner countries (GDP_j) are positively correlated with the value of export with statistically significant coefficients at 1% level of significance. Whereas population of partner country (POP_j) has a significantly and positively correlated throughout the GMM models (from variations 1-8). As for population of reporter country (POP_i), is not significant. Distance between countries (Dist) has a significantly negative correlation for all variations 1-8. Real effective exchange rate (REER) is not significant for the variations 1-4 but not true for remaining variations 5-8. The common border dummy variable (Border), development dummy ($Develop_i$), colony, language and interaction 1 are not significant. But interaction 2 in variation 8 is significant. Religion is significant and negatively correlated for the variations 5-8. But FTA dummy is highly significant and positively correlated for all variations. It is also observed that first lag of net export (ln NX-L1) is s highly significant and positively correlated for all variations.

Table 3.5 Results of the GMM for net export using Gravity Model with different sets of variables.

Variation	1	2	3	4	5	6	7	8
ln GDP_i	-0.015	-0.013	-0.02	-0.013	-0.054	-0.053	-0.063	-0.054
	0.055	0.055	0.055	0.055	0.056	0.057	0.057	0.057
ln GDP_j	0.351^{***}	0.347^{***}	0.352^{***}	0.347^{***}	0.446^{***}	0.443^{***}	0.444^{***}	0.442^{***}
	0.06	0.06	0.06	0.06	0.069	0.069	0.069	0.069
ln POP_j	0.015	-0.003	0.027	-0.003	-0.037	-0.055	-0.036	-0.043
	0.08	0.084	0.09	0.084	0.082	0.087	0.082	0.082
ln POP_i	0.217^{***}	$.216^{***}$	0.22^{***}	0.216^{***}	0.102	0.094	0.1	0.111
	0.054	0.054	0.054	0.054	0.069	0.07	0.069	0.068
ln Dist	-0.538^{***}	-0.445^{**}	-0.467^{**}	-0.454^{**}	-0.853^{***}	-0.857^{***}	-2.152^{**}	-0.891^{***}
	0.132	0.183	0.184	0.194	0.176	0.176	0.877	0.176
ln REER	-0.205	-0.189	-0.189	-0.186	-0.274^{*}	-0.278^{*}	-2.666^{*}	-0.276^{*}
	0.161	0.163	0.163	0.164	0.163	0.163	1.589	0.162
Border				-0.113				
				0.717				
$Develop_i$		0.234	0.202	0.231				
		0.318	0.319	0.318				
Colony			-0.419					
			0.438					
Language						0.223		
						0.362		
Religion					-0.86^{***}	-0.863^{***}	-0.872^{***}	-0.842^{***}
					0.319	0.319	0.32	0.318
FTA	0.655^{***}	0.641^{***}	0.633^{***}	0.641^{***}	0.604^{***}	0.599^{***}	0.594^{***}	0.599^{***}
	0.15	0.152	0.152	0.152	0.151	0.151	0.151	0.151
Interation 1							0.276	
							0.183	
Interation 2								0.003^{**}
								0.001
ln nx L1	0.399^{***}	0.404^{***}	0.4^{***}	0.404^{***}	0.392^{***}	0.396^{***}	0.397^{***}	0.389^{***}
	0.289	0.03	0.03	0.03	0.029	0.03	0.029	0.029
Constant	4.762^{**}	4.065^{*}	3.862^{*}	4.131^{*}	9.571^{***}	9.986^{***}	21.009^{***}	9.81^{***}
	2.125	2.333	2.337	2.37	2.766	2.853	8.059	2.764
Number of observation	4560	4560	4560	4560	4560	4560	4560	4560

Note:

* denotes significant at 10%, ** denotes significant at 5%, *** denotes significant at 1%

3.8 Conclusion

Gravity model estimates the bilateral trade flows between India and other countries, each model suggest there is a positive and significant FTA dummy coefficient which means trade between the both can be improved by forming a free trade agreement.

This chapter showed that the gravity model in trade can be an important source for understanding the trajectory of economic crises in a cross-country structure. The chapter engaged with two principal sources of estimations, namely (i) between effects (BE) to accommodate time invariant factors like distance, religion etc., and (ii) Difference GMM estimates, an empirical strategy that we have delineated in substantial detail above. The period of analysis has been 1995 to 2018 and included approximately 5385 observations across countries paired into bilateral trade relations and exchange rates. The number of observations have often dropped to less than 4000 when variables that are not frequently reported in many countries are included in the various specifications reported in the main tables. Importantly, we established that the main directions and strengths of the BE model have largely been retained in the GMM specifications, which address our concerns over endogeneity among the independent variables and therefore amend for possible sources of biases.

For the difference GMM specifications, it is observed that GDP of partner countries (GDP_j) are positively correlated with the value of export with statistically significant coefficients at 1% level of significance. In addition, the population of the partner country (POP_j) has a significantly and positively correlated throughout the GMM models (from variations 1-8). As for population of reporter country (POP_i), is not significant. Distance between countries (Dist) has a significantly negative correlation for all variations 1-8. Real effective exchange rate (REER) is not significant for the variations 1-4 but not true for remaining variations 5-8. The common border dummy variable (Border), development dummy ($Develop_i$), colony, language and interaction 1 are not significant. But interaction 2 as reported in specification 8 in Table 3.5 is significant. The importance of this result needs to be highlighted. The interaction term explains that between partner countries, even if distance rises, for a given level of inflation (or deflation) across pair of countries, net exports rises. Alternatively, one could argue that while distance by itself reduces net exports, for a given distance, co-movements of inflation rate between the paired countries helps to raise net exports. Obviously, the transmission of inflationary pressure (or deflation) could well be brought about by rise in trade between such partners. Since the FTA dummy is positive and highly significant, we find further support in favor of the claim that proximity would enhance the effect of this interaction unambiguously. These results could be refined further in future by bringing in more direct measures of contagion of financial and economic crises across country pairs. It should ideally strengthen the results obtained in this thesis.

Chapter 4

The Theory of Radiation and Bilateral Trade Between Regions

4.1 Introduction

It is well-known that the gravity model in international trade has offered extensive methodological and numerical analysis over several decades, quantifying on the aggregate bilateral transactions across countries and more recently in a modified form, between regions [60]. As directly derived from the gravitational laws of physics, it is among one of the most popular adaptations in economics catering to a wide range of applications. In comparison, a number of other fundamental laws in physics also offer parallel inferences for the subject of spatial economics, but remain less traversed in adaptive models. It is partly due to information gaps across disciplines, but more often owing to lack of non-experimental micro-data from the real world that establishes scientific principals pervasively. In this connection, the present paper brings to attention the applications of Radiation Theory in understanding inter-regional and international trade in goods at bilateral levels. In previous attempts, the radiation theory has been invoked in cases of inter-regional and international factor mobility only. Note that, the gravity model has also been popularly used for computation, prediction and understanding of various issues like human mobility [141, 282, 283], capital flows [148] between an origin and a destination often based on such geographical distances between locations [302, 122, 32]. It also determines the dynamics of mobility networks [77, 28, 53] across regions. Indeed, earlier work by Isard [163], Tinbergen (1962) [289], Poyhonen (1963) [250], and Linneman (1966) [204], etc. set the stage for a barrage of empirical work on the relevance and applicability of gravity models in international economics. These include significant contributions and advances by Anderson (2010)[14], Feenstra, Markusen, and Rose (1999) [126], Deardorff (1998) [87], Davis (1995) [85], Bergstrand (1989) [41], Bergstrand (1985) [40], Anderson(1979) [12], among others. We will briefly compare the accumulated wisdom on gravity models with more recent predictions of the radiation theory in the end.

Referring to parallel theoretical adaptations in economics, Alonso (1971) [11] described a strand of mathematical models utilizing core elements of physics, whereby human mobility was described as follows, "It is almost as if an urban area were a radioactive body, emitting particles at a steady rate." Subsequently, supporting evidence was available from Hong *et al*. [157], Masueci *et al*. [216], Ren *et al*. [254], Simini *et al*. [278], Stefanouli and Polyzos [284], Kong *et al*. [182], etc. Among these, Ren *et al.* [254] developed the concept by Alonso [11] to focus exclusively on international migration, and sub-regional commuter flows. Indeed, Stefanouli and Polyzos [284] stated that the radiation model is a good alternative to the use of gravity models for analyzing spatial interactions. They further argue that since, the radiation model is 'rooted in diffusion dynamics and inspired by the intervening opportunities theory' it overcomes the mis-specifications of gravity models. Indeed, radiation theory is based exclusively on the spatial distribution of population and is parameter free. In other words, it relies on the involved regions populations and the distance from each other to predict factor (or trade) flows.

In physics, radiation is commonly understood as the emission, absorption or transmission of particles through space. Radiation constitutes flow of atomic and subatomic particles and of waves, such as those that characterize heat rays, light rays, and X rays. All matter is constantly bombarded with radiation and its models study the process of energetic particles traveling through space/vacuum. However, that does not explain how radiation connects with the principles of economics, directly or indirectly. One way to find a relation is to discuss the inter-regional movement of goods and factors. The observed transactions between the source and the destination could indicate how and why such trade takes place. The rate of transmission and absorption are not uniform and depends on industry types, regional prosperity, population density, etc. Furthermore, just as radiation is not an end in itself - trade between locations also gives rise to several adjustments that needs analysis.

Inter-regional trade in commodities display different elasticity based on varying tastes and preferences among consumers. This may cause high dispersion in the degree of transmission and absorption in view of two or more regions involved. Some commodities are transported in bulk, some in smaller units across locations and the demand corresponding to these also come either from large buyers, including government purchases or from unit households. Similarly, at the cross-country level capital (foreign direct investments or institutional investments) and labor (migrants, including refugee movements) may also move in masses or as small units specific to economic activities and individual choices. Therefore, we offer analytical formulations about bilateral trade based on regional specifications to predict the direction and magnitude of transactions commensurate with observations on particle radiation.

The rest of the chapter is planned as follows. In section 4.2 we discuss the radiation theory in substantial detail, followed by multiple uses of international trade using radiation theory in section 4.3. In section 4.4 we discuss additional complexities of radiation model in trade. In section 4.5 we consider several functional variations of economic uses across countries and explore the implication of the radiation theory. The importance of this approach is that it allows us to consider a large number of cases where regions or countries in a given set are heterogeneous in mass (size of the gap), and follow a distribution. In addition, the extent of trade flow is dependent on the economic mass of the set which surrounds the trading hubs with the centre lying in region i, but not including the location pair engaged in bilateral trade. We derive the mass of all surrounding countries from the distribution and use that to reflect on the bilateral trade flows. Section 4.6 concludes.

4.2 Particle Radiation Between Locations

Emission and absorption processes for particle radiation are commonly studied as part of physics, defining the Radiation Model [294].

Suppose the location of origin, i, is a source emitting an outgoing flux of identical and independent units (particles). We define the emission/absorption process through the following two steps:

1) We associate to every particle, X, emitted from location$_i$ a number, $z_X^{(i)}$, that represents the absorption threshold for that particle. A particle with large threshold is less likely to be absorbed. We define $z_X^{(i)}$, as the maximum number obtained after m_i random extractions from a preselected distribution, $p(z)$ (m_i is the population of particles in location$_i$). Thus, on average, particles emitted from a highly populated (i.e., dense) location have a

higher absorption threshold than those emitted from a scarcely populated location. We will show below that the particular choice of $p(z)$ does not affect the final results.

2) The surrounding locations have a certain probability to absorb particle X: $z_X^{(j)}$ represents the absorbance of location$_j$ for particle X, and it is defined as the maximum of n_j extractions from $p(z)$ (remember that n_j is the population in location$_j$). The particle is absorbed by the closest location whose absorbance is greater than its absorption threshold. This process will repeat for all emitted particles and we obtain the fluxes across the entire surface.

Now we calculate the probability of one emission/absorption event between any two locations, and obtain the fluxes between them.

Let

i = a location,

j = another location,

m_i = population of particles at location$_i$,

n_j = population of particles at location$_j$,

$r_{i,j}$ = distance between location$_i$ and location$_j$
= radius of a circle with center at i

$s_{i,j}$ = Total population of particles in all locations (except i and j) within a circle of radius $r_{i,j}$ centered at i,

$p(z)$ = probability of event is equal to z

$p(<z)$ = probability of event is less than z

$p(>z)$ = probability of event is greater than z

$P_{m_i}(z)$ = the probability that the maximum value extracted from $p(z)$ after m_i trials is equal to z

$P_{s_{ij}}(<z)$ = the probability that $s_{i,j}$ number of particles extracted from the distribution are all less than z

$P_{m_i}(<z)$ = the probability that m_i number of particles extracted from the distribution are all less than z

$P_{n_j}(>z)$ = the probability that among n_j number of particles extracted from at least one is greater than z.

$P(1|m_i,n_j,s_{ij})$ = probability that a particle emitted from location$_i$ with population m_i is absorbed in location$_j$ with population n_j, with given $s_{i,j}$.

Therefore according to the radiation process, we have

$$P(1|m_i,n_j,s_{ij}) = \int_0^\infty dz P_{m_i}(z) P_{s_{ij}}(<z) P_{n_j}(>z) \tag{4.1}$$

$$\begin{aligned} P_{s_{ij}}(<z) &= p(<z).p(<z).p(<z)\cdots \text{ to } s_{ij} \text{ times} \\ &= p(<z)^{s_{ij}} \end{aligned} \tag{4.2}$$

Similarly we obtain

$$P_{m_i}(<z) = p(<z)^{m_i} \tag{4.3}$$

$$P_{n_j}(<z) = p(<z)^{n_j} \tag{4.4}$$

and

$$P_{n_j}(>z) = 1 - P_{n_j}(<z) = 1 - p(<z)^{n_j} \tag{4.5}$$

Also

$$P_{m_i}(z) = \frac{dP_{m_i}(<z)}{dz} = m_i p(<z)^{m_i-1} \frac{dp(<z)}{dz} \tag{4.6}$$

Now we can write from Eqn. (4.1) using Eqns. (4.2), (4.5) and (4.6)

$$\begin{aligned} P(1|m_i,n_j,s_{ij}) &= \int_0^\infty dz P_{m_i}(z) P_{s_{ij}}(<z) P_{n_j}(>z) \\ &= \int_0^\infty dz m_i p(<z)^{m_i-1} \frac{dp(<z)}{dz} p(<z)^{s_{ij}} \left(1 - p(<z)^{n_j}\right) \\ &= m_i \int_0^\infty p(<z)^{m_i+s_{ij}-1} \left(1 - p(<z)^{n_j}\right) dp(<z) \\ &= m_i \int_0^\infty \left(p(<z)^{m_i+s_{ij}-1} - p(<z)^{m_i+s_{ij}+n_j-1}\right) dp(<z) \\ &= m_i \left(\frac{1}{m_i+s_{ij}} - \frac{1}{m_i+s_{ij}+n_j}\right) \\ &= \frac{m_i n_j}{(m_i+s_{ij})(m_i+s_{ij}+n_j)} \end{aligned}$$

$$\therefore \quad P(1|m_i,n_j,s_{ij}) = \frac{m_i n_j}{(m_i+s_{ij})(m_i+s_{ij}+n_j)} \tag{4.7}$$

This is independent of the distribution $p(z)$ and is invariant under rescaling of the population by the same multiplicative factor.

Given the perspective of the recipient locations,let

T_{ik} = absorptions of k particles emitted at location$_i$,
$(T_{i1}, T_{i2}, \cdots, T_{iL})$ = a sequence of absorptions,
$P(T_{i1}, T_{i2}, \cdots, T_{iL})$ = probability for sequence $(T_{i1}, T_{i2}, \cdots, T_{iL})$
T_i = total number of particles emitted at location$_i$,
$= \sum_{j \neq i} T_{ij}$
p_{ij} $= P(1|m_i, n_j, s_{ij})$

Here the probability $P(T_{i1}, T_{i2}, \cdots, T_{iL})$ for a particular sequence of absorptions, $(T_{i1}, T_{i2}, \cdots, T_{iL})$, of the particles emitted at location$_i$ is given by the multinomial distribution. Therefore

$$P(T_{i1}, T_{i2}, \cdots, T_{iL}) = \Pi_{j \neq i} \frac{T_i!}{T_{ij}!} p_{ij}^{T_{ij}} \tag{4.8}$$

Equation (4.8) is normalized because

$$\sum_{j \neq i} p_{ij} = 1 \tag{4.9}$$

The probability that exactly T_{ij} particles emitted from location$_i$ are absorbed in location$_j$ is obtained by marginalizing probability (4.8):

$$\begin{aligned} P(T_{ij}|m_i, n_j, s_{ij}) &= \sum_{\substack{T_{ik}:k \neq i,j \\ \sum_{k \neq i} T_{ik} = T_i}} P_i(T_{i1}, T_{i2}, \cdots, T_{ij}, \cdots, T_{iL}) \\ &= \frac{T_i!}{T_{ij}!(T_i - T_{ij})!} p_{ij}^{T_{ij}} (1 - p_{ij})^{T_i - T_{ij}} \end{aligned} \tag{4.10}$$

However, this is a binomial distribution with mean

$$< T_{ij} >= T_i p_{ij} = T_i \frac{m_i n_j}{(m_i + s_{ij})(m_i + s_{ij} + n_j)} \tag{4.11}$$

and variance $T_i p_{ij}(1 - p_{ij})$

The above proof is part of the general discussions on radiation theory [294].

4.3 Adopting Radiation Model in Regional and International Trade

Radiation model in regional and cross-country trade can be described by Eqn. (4.12). This is considered from Eqn. (4.11).

$$T_{ij} = T_i \frac{m_i m_j}{(m_i + s_{ij})(m_i + s_{ij} + m_j)} \tag{4.12}$$

where,

i = country$_i$,

j = country$_j$,

m_i = GDP of country$_i$ or regional income of $_i$,

m_j = GDP of country$_j$ or regional income of $_j$,

$r_{i,j}$ = Geographical distance between location $_i$ and location $_j$,

$s_{i,j}$ = Total GDP or income of all countries or locations within the radius $r_{i,j}$ in the trade network except that of $_i$ and $_j$,

T_i = Total export (or import) by country$_i$ in the trade network,

$T_{i,j}$ = Total export (or import) from country$_i$ to country$_j$

4.3.1 Restrictions and Configurations

Based on above descriptions GDP of a country and regional income within a country are used interchangeably for the rest of the paper. Now, suppose that the GDP of country$_i$, m_i; GDP of country$_j$, m_j; and total GDP of all countries within the radius $r_{i,j}$ in the trade network except the GDPs of country$_i$ and country$_j$ $s_{i,j}$, are all positive.

The following cases explore the parametric conditions under which trade models based on radiation theory offers important interpretations.

Case 1: $T_i = 0$

If $T_i = 0$, i.e., total export by country$_i$ in the trade network is zero, then $T_{i,j} = 0$, i.e., the income weighted trade relation between any country$_i$ and country$_j$ collapses to zero. This is a trivial case.

Case 2: $m_i, m_j << s_{i,j}$

Here $m_i, m_j << s_{ij}$ that means $\frac{m_i}{s_{ij}} \to 0$ and $\frac{m_j}{s_{ij}} \to 0$ as s_{ij} is large.

In this situation the relation described in (4.12) can be rewritten as

$$T_{ij} = T_i \frac{m_i m_j}{s_{ij}^2 \left(1 + \frac{m_i}{s_{ij}}\right)\left(1 + \frac{m_i + m_j}{s_{ij}}\right)} \tag{4.13}$$

By taking limit as $\frac{m_i}{s_{ij}} \to 0$ and $\frac{m_j}{s_{ij}} \to 0$ on both sides of Eqn (4.13) we get

$$\lim_{\substack{\frac{m_i}{s_{ij}} \to 0 \\ \frac{m_j}{s_{ij}} \to 0}} T_{ij} = \lim_{\substack{\frac{m_i}{s_{ij}} \to 0 \\ \frac{m_j}{s_{ij}} \to 0}} \left[T_i \frac{m_i m_j}{s_{ij}^2 \left(1 + \frac{m_i}{s_{ij}}\right)\left(1 + \frac{m_i + m_j}{s_{ij}}\right)} \right]$$

$$\therefore T_{ij} = T_i \frac{m_i m_j}{s_{ij}^2} \tag{4.14}$$

Relation (4.14) demonstrates that the income-weighted trade flow between country$_i$ and country$_j$ increases exports from country$_i$, the GDPs in country$_i$ and country$_j$, but falls intensively as the total GDP of the trading bloc or countries within the selected radius, increases. In other words, for any country$_i$ and country$_j$, the trade flow moves in opposite direction as the overall prosperity of the region grows.

Case 3: $m_i << s_{ij} << m_j$

For $m_i << s_{ij} << m_j$ it means that $\frac{m_i}{s_{ij}} \to 0$ as s_{ij} is large. But, $\frac{s_{ij}}{m_j} \to 0$ as m_j is large.

In this situation the relation described in Eqn. (4.12) can be rewritten as

$$\begin{aligned} T_{ij} &= T_i \frac{m_i m_j}{(m_i + s_{ij})(m_i + s_{ij} + m_j)} \\ &= T_i \frac{m_i m_j}{s_{i,j}\left(1 + \frac{m_i}{s_{i,j}}\right) m_j \left(1 + \frac{m_i + s_{i,j}}{m_j}\right)} \\ &= T_i \frac{m_i m_j}{s_{i,j} m_j} \frac{1}{\left(1 + \frac{m_i}{s_{i,j}}\right)\left(1 + \frac{s_{i,j}}{m_j}\left(1 + \frac{m_i}{s_{i,j}}\right)\right)} \\ &\to T_i \frac{m_i m_j}{s_{i,j} m_j} \qquad [\text{As } \frac{m_i}{s_{ij}} \to 0 \text{ and } \frac{s_{ij}}{m_j} \to 0] \\ &= T_i \frac{m_i}{s_{i,j}} \end{aligned} \tag{4.15}$$

Presently, it seems that the overall trade network between country$_i$ and country$_j$ increases trade flow from country$_i$, increases GDP of country$_i$, but decreases if the total GDP of the set of trading countries become larger. In other words, trade between two countries with asymmetric income levels, in particular, those with large gaps might not affect trade flow from the smaller countries. Obviously, it would be similar for all country$_i$, country$_j$ and for the reverse relation.

Case 4: $m_i >> s_{i,j}, m_j$

This is a case, where the source country is very large compared to the destination country or even the total income in the region.

Therefore, if $m_i >> s_{i,j}, m_j$ then
$m_i + s_{ij} \approx m_i$ and $m_i + s_{ij} + m_j \approx m_i$
Now Eqn. (4.12) can be rewritten as

$$\begin{aligned} T_{ij} &= T_i \frac{m_i m_j}{(m_i + s_{ij})(m_i + s_{ij} + m_j)} \\ &\approx T_i \frac{m_i m_j}{m_i \times m_i} \qquad \text{[Since } m_i >> s_{i,j}, m_j] \\ &= T_i \frac{m_j}{m_i} \end{aligned} \tag{4.16}$$

Relation (4.16) suggests that the bilateral trade flow between country$_i$ and country$_j$, increases if country$_i$ as the source is the major driver of the trade flow. The income level in country$_j$ positively influences the bilateral trade flow, while that in the source country affects it negatively. Interestingly, the overall income of the region has no impact on the bilateral flow. In relation to radiation theory, it implies that external environment has negligible impact, when the source of radiation emission is considerably bigger than the receptor.

Case 5: $m_i, m_j >> s_{i,j}$

If $m_i, m_j >> s_{i,j}$ then $m_i + s_{ij} \approx m_i$ and $m_i + s_{ij} + m_j \approx m_i + m_j$
Now Eqn. (4.12) can be rewritten as

$$\begin{aligned} T_{ij} &= T_i \frac{m_i m_j}{(m_i + s_{ij})(m_i + s_{ij} + m_j)} \\ &\approx T_i \frac{m_i m_j}{m_i \times (m_i + m_j)} \qquad \text{[Since } m_i, m_j >> s_{i,j}] \end{aligned}$$

$$= T_i \frac{m_j}{m_i + m_j} \tag{4.17}$$

If both trading partners for bilateral trade for all country$_i$ and country$_j$, have income levels bigger than the total income of the region, then bilateral flow is a positive function of the income in the destination (country$_i$ being the source and symmetry assumed), as a share of the total income of the trading partners. If the source country becomes richer, the flow must flow as a sequence.

4.4 Complexity Analysis of Radiation Model in Trade

In this section our objective is to analyze the complexity of radiation model in trade after assuming that the trading mass is statistically distributed as: (1) uniform, (2) exponential, (3) power-law. Here trading mass means export, import or total absolute foreign transactions. First, let us explain a few symbols and notations for the analysis.

Suppose

Λ_{ij} = set of countries, except for country$_i$ and country$_j$, within a circle centered at the country$_i$ with radius r_{ij},

n_{ij} = the number of countries in Λ_{ij}

Now by the use of fractal geometry, we know that a fractal dimension is a ratio providing a statistical index of complexity comparing how the detail in a pattern changes with the scale with which it is measured. For example, the length of a (fractured) coastline increases if the length of a measuring scale falls. Presently, we use the fractal space to accommodate non-uniform regional clusters so that potentially most empirical observations could fit in. We therefore write:

$$n_{ij} = c r_{ij}^{d_f} \tag{4.18}$$

where,

c = a constant, and

d_f = fractal dimension of space.

Therefore the surrounding economic mass can be written as

$$s_{ij} = \sum_{l \in \Lambda_{ij}} m_l = \sum_{k=1}^{n_{ij}} m_k \tag{4.19}$$

where,

$m_k =$ Economic mass (GDP) for the country k.

$k \in \{1, 2, \cdots, n_{ij}\}$

We use the following assumptions for relating bilateral trade to distribution of locations in the set.

Assumptions:

Assumption 1: Suppose the economic masses are sorted as given below

$$m_1 \geq m_2 \geq \cdots \geq m_{n_{ij}}$$

Assumption 2: Assume that m_k is an economic mass (GDP) for the country k and also its rank is k in the sorted sequence of economic mass.

Assumption 3: The economic masses $m_1, m_2, \cdots, m_{n_{ij}}$ are statistically independent of each other.

Assumption 4: The economic masses $m_1, m_2, \cdots, m_{n_{ij}}$ follows a statistical distribution,

Assumption 5: We analyze this problem by using three different probability distributions as:

(1) uniform distribution,

(2) exponential distribution, and

(3) power-law distribution.

4.4.1 Analysis with Uniformly Distributed Economic Mass

The definition of the uniform distribution of economic mass m is given in Eqn. (4.20)

$$P(m) = \frac{1}{b-a} \quad \text{for } a \leq m \leq b \tag{4.20}$$

where,

a = lower bound of GDP i.e., economic mass, and

b = upper bound of GDP i.e., economic mass.

The m_k with its rank k in sorted list of economic masses. Now by using the distribution of economic mass $P(m)$ we can define the probability $\frac{k}{n_{ij}}$ as

$$\begin{aligned}\frac{k}{n_{ij}} &= \int_{m_k}^{b} P(m)dm \\ &= \int_{m_k}^{b} \frac{1}{b-a}dm \\ &= \frac{b-m_k}{b-a}\end{aligned}$$

$$m_k = b-(b-a)\frac{k}{n_{ij}} \tag{4.21}$$

Using Eqn. (4.19) we can compute

$$\begin{aligned}s_{ij} &= \sum_{l\in\Lambda_{ij}} m_l = \sum_{k=1}^{n_{ij}} m_k \\ &= \sum_{k=1}^{n_{ij}} \left(b-(b-a)\frac{k}{n_{ij}}\right) \\ &= bn_{ij} - \frac{b-a}{n_{ij}} \times \frac{n_{ij}(n_{ij}+1)}{2} \\ &= \frac{1}{2}(a+b)n_{ij} - \frac{1}{2}(b-a) \\ &= \frac{1}{2}(a+b)cr_{ij}^{d_f} - \frac{1}{2}(b-a) \quad \text{[Using Eqn. (4.18)]}\end{aligned}$$

$$\therefore \quad s_{ij} \sim r_{ij}^{d_f} \tag{4.22}$$

4.4.2 Analysis with Exponentially Distributed Economic Mass

The definition of the exponential distribution of economic mass m is given in Eqn. (4.23)

$$P(m) = \beta e^{-\beta m} \quad \text{for } m \geq 0 \tag{4.23}$$

The m_k with its rank k in sorted list of economic masses. Now by using the distribution of economic mass $P(m)$ we can define the probability $\frac{k}{n_{ij}}$ as

$$\begin{aligned}
\frac{k}{n_{ij}} &= \int_{m_k}^{\infty} P(m)dm \\
&= \int_{m_k}^{\infty} \beta e^{-\beta m} dm \\
&= e^{-\beta m_k}
\end{aligned}$$

$$\therefore \quad m_k = -\frac{1}{\beta} \log \frac{k}{n_{ij}} \tag{4.24}$$

Using Eqn. (4.19) we can compute

$$\begin{aligned}
s_{ij} &= \sum_{l \in \Lambda_{ij}} m_l = \sum_{k=1}^{n_{ij}} m_k \\
&= \sum_{k=1}^{n_{ij}} \left(-\frac{1}{\beta} \log \frac{k}{n_{ij}} \right) \\
&= \frac{1}{\beta} \sum_{k=1}^{n_{ij}} (\log n_{ij} - \log k) \\
&= \frac{1}{\beta} \sum_{k=1}^{n_{ij}} \log n_{ij} - \frac{1}{\beta} \sum_{k=1}^{n_{ij}} \log k \\
&= \frac{1}{\beta} n_{ij} \log n_{ij} - \frac{1}{\beta} \int_{1}^{n_{ij}} \log k dk \\
&= \frac{1}{\beta} n_{ij} \log n_{ij} + \frac{1}{\beta} \int_{1}^{n_{ij}} dk \\
&= \frac{1}{\beta} n_{ij} \log n_{ij} + \frac{1}{\beta} (n_{ij} - 1) \\
&= \frac{1}{\beta} n_{ij} (1 + \log n_{ij}) - \frac{1}{\beta} \\
&= \frac{1}{\beta} c r_{ij}^{d_f} (1 + \log(c r_{ij}^{d_f})) - \frac{1}{\beta} \quad \text{[Using Eqn. (4.18)]}
\end{aligned}$$

$$\therefore \quad s_{ij} \sim r_{ij}^{d_f} \tag{4.25}$$

4.4.3 Analysis with Power-Law Distributed Economic Mass

The definition of the power-law distribution of economic mass $P(m)$ with the exponent $\beta > 1$ is given in Eqn. (4.26)

$$P(m) = (\beta-1)m_0^{(\beta-1)}m^{-\beta} \quad \text{for } m \geq m_0 \tag{4.26}$$

where,

m_0 = lower bound of economic mass (GDP).

β = parameter of the distribution

The m_k with its rank k in sorted list of economic masses. Now by using the distribution of economic mass $P(m)$ we can define the probability $\frac{k}{n_{ij}}$ as

$$\begin{aligned}\frac{k}{n_{ij}} &= \int_{m_k}^{\infty} P(m)dm \qquad (4.27)\\ &= \int_{m_k}^{\infty}(\beta-1)m_0^{(\beta-1)}m^{-\beta}dm \quad \text{[Using Eqn. (4.26)]}\\ &= (\beta-1)m_0^{(\beta-1)}\int_{m_k}^{\infty} m^{-\beta}dm\\ &= (\beta-1)m_0^{(\beta-1)} \times \left(\frac{m_k^{-\beta+1}}{\beta-1}\right) = \left(\frac{m_k}{m_0}\right)^{-(\beta-1)}\\ \therefore\ m_k &= m_0\left(\frac{k}{n_{ij}}\right)^{-1/(\beta-1)} \qquad (4.28)\end{aligned}$$

Again we get from Eqn. (4.19)

$$\begin{aligned}s_{ij} &= \sum_{k=1}^{n_{ij}} m_k\\ &\approx \int_1^{n_{ij}} m_k dk\\ &= \int_1^{n_{ij}} m_0\left(\frac{k}{n_{ij}}\right)^{-1/(\beta-1)} dk \quad \text{[Using Eqn. (4.28)]}\\ &= \frac{m_0}{n_{ij}^{-1/(\beta-1)}}\int_1^{n_{ij}} k^{-1/(\beta-1)}dk \qquad (4.29)\end{aligned}$$

Since by definition $\beta > 1$ then we consider the following cases

(1)If $\beta \neq 2$ then Eqn. (4.29) can be rewritten with the total economic masses as

$$\begin{aligned}s_{ij} &\approx \frac{m_0}{n_{ij}^{-1/(\beta-1)}}\left.\frac{k^{-\frac{1}{\beta-1}+1}}{-\frac{1}{\beta-1}+1}\right|_1^{n_{ij}}\\ &= \frac{m_0}{n_{ij}^{-1/(\beta-1)}}\frac{\beta-1}{\beta-2}\left[n_{ij}^{\frac{\beta-2}{\beta-1}}-1\right]\end{aligned}$$

$$= m_0 \frac{\beta-1}{\beta-2}\left[n_{ij} - n_{ij}^{\frac{1}{\beta-1}}\right] \tag{4.30}$$

(2) If $\beta = 2$ then Eqn. (4.29) can be rewritten as

$$s_{ij} \approx \frac{m_0}{n_{ij}^{-1}} \ln k\big|_1^{n_{ij}}$$
$$= m_0 n_{ij} \ln n_{ij} \tag{4.31}$$

By Eqns. (4.30) and (4.31) we can rewrite as

$$s_{ij} \approx \begin{cases} m_0 \frac{\beta-1}{\beta-2}\left[n_{ij} - n_{ij}^{\frac{1}{\beta-1}}\right], & \beta \neq 2 \\ m_0 n_{ij} \ln n_{ij}, & \beta = 2 \end{cases} \tag{4.32}$$

By using Eqn. (4.18) and Eqn. (4.32) we get

$$s_{ij} \approx \begin{cases} m_0 \frac{\beta-1}{\beta-2}\left[c r_{ij}^{d_f} - c^{\frac{1}{\beta-1}} r_{ij}^{\frac{d_f}{\beta-1}}\right], & \beta \neq 2 \\ m_0 c r_{ij}^{d_f} \ln\left(c r_{ij}^{d_f}\right), & \beta = 2 \end{cases} \tag{4.33}$$

By analysis of Eqn. (4.33) we get

Option 1. $\beta > 2$

If $\beta > 2$ then $\frac{\beta-1}{\beta-2} \to 1$ and $\frac{1}{\beta-1} \to 0$ as $\beta \to \infty$

$\therefore \quad s_{ij} \to m_0 c r_{ij}^{d_f}$

In this case the term $r_{ij}^{d_f}$ dominates s_{ij} for large r_{ij}.

$$\therefore \quad s_{ij} \sim r_{ij}^{d_f} \tag{4.34}$$

Option 2. $\beta < 2$

If $\beta < 2$ then $1 < \beta < 2$ and $\frac{\beta-1}{\beta-2}$ is a negative quantity.

In this case the term $r_{ij}^{\frac{d_f}{\beta-1}}$ dominates s_{ij} for large r_{ij}.

$$\therefore \quad s_{ij} \sim r_{ij}^{\frac{d_f}{\beta-1}} \tag{4.35}$$

Option 3. $\beta = 2$

$$\therefore \quad s_{ij} \sim r_{ij}^{d_f} \tag{4.36}$$

Therefore we can redefine s_{ij} as in relation (4.37)

$$s_{ij} \sim r_{ij}^{\alpha} \tag{4.37}$$

where,

$$\alpha = \begin{cases} \dfrac{d_f}{\beta - 1}, & \beta \leq 2 \\ d_f, & \beta \geq 2 \end{cases} \tag{4.38}$$

4.5 A Brief Comparison with Gravity Models

The total GDP of all countries within the radius r_{ij} in the trade network except the GDPs of country$_i$ and country$_j$ is s_{ij} which is correlated to r_{ij}, the geographical distance between country$_i$ and country$_j$. The relation between s_{ij} and r_{ij} is analytically derived based on three different statistical distributions of trade mass of trading countries in the trade network. That is

$$s_{ij} \sim r_{ij}^{x} \tag{4.39}$$

where,

$$x = \begin{cases} d_f, & \text{for uniform and exponential distribution} \\ \alpha, & \text{for power-law distribution} \end{cases}$$

and

$$\alpha = \begin{cases} \dfrac{d_f}{\beta - 1}, & \beta \leq 2 \\ d_f, & \beta \geq 2 \end{cases}$$

This result helps to study the relation between radiation model and gravity model in international trade. The gravity model can compute the trade force F_{ij} for the trade masses m_i and m_j as defined in Eqn. (4.40).

$$F_{ij} \propto \frac{m_i \times m_j}{r_{ij}^{\gamma}} \tag{4.40}$$

$$\text{or,} \ \frac{F_{ij}}{m_i m_j} \propto \frac{1}{r_{ij}^{\gamma}} \tag{4.41}$$

By using relation (4.39), we get

$$\frac{F_{ij}}{m_i m_j} \sim \frac{1}{s_{ij}^{\gamma/x}} \tag{4.42}$$

Suppose

$$\begin{aligned} f_{ij} &= \text{ratio between total export from country}_i \text{ to country}_j \text{ and the total} \\ &\quad \text{export by country}_i \text{ in the trade network} \\ &= \frac{T_{ij}}{T_i} \\ &\approx \text{probability of export from country}_i \text{ to country}_j \text{ in the trade network} \\ &= p_{ij} \end{aligned}$$

Here we assume p_{ij} is an indicator of relative trade force between country$_i$ and country$_j$, and direction of flow from country$_i$ to country$_j$.

The radiation model in Eqn. (4.12) can be rewritten as

$$\begin{aligned} T_{ij} &= T_i \frac{m_i m_j}{(m_i + s_{ij})(m_i + s_{ij} + m_j)} \\ p_{ij} \approx \frac{T_{ij}}{T_i} &= \frac{m_i m_j}{(m_i + s_{ij})(m_i + s_{ij} + m_j)} \\ \text{or, } \frac{p_{ij}}{m_i m_j} &\approx \frac{1}{(m_i + s_{ij})(m_i + s_{ij} + m_j)} \\ &= \begin{cases} \frac{1}{s_{ij}^2}, \text{ for } m_i, m_j << s_{ij} \\ \frac{1}{s_{ij}}, \text{ for } m_i << s_{ij} << m_j \end{cases} \end{aligned} \tag{4.43}$$

Now by comparing relations (4.42) and (4.43) we get

$$\begin{aligned} \gamma/x &= \begin{cases} 2, \text{ for } m_i, m_j << s_{ij} \\ 1, \text{ for } m_i << s_{ij} << m_j \end{cases} \\ \text{or,} \quad \gamma &= \begin{cases} 2x, \text{ for } m_i, m_j << s_{ij} \\ x, \quad \text{for } m_i << s_{ij} << m_j \end{cases} \end{aligned} \tag{4.44}$$

where,

$$x = \begin{cases} d_f, \text{ for uniform and exponential distribution} \\ \alpha, \text{ for power-law distribution} \end{cases}$$

and

$$\alpha = \begin{cases} \dfrac{d_f}{\beta - 1}, & \beta \leq 2 \\ d_f, & \beta \geq 2 \end{cases}$$

This strongly implies that it does not necessarily have to be characterized by the single value of the distance exponent. In reality, behavior of international trade depends on the economic masses of the countries.

4.6 Conclusion

The grafting of well-known laws of physics to various topics in economics is not too uncommon in the literature, albeit many parallel sources remain neglected in popular adaptations. The present work shows that the Radiation Theory in physics is capable of explaining bilateral movements of goods and factors in the same spirit as the gravity model. To explain trading patterns, rather several such patterns, we adopt the principles of particle radiation and classify the possibilities according to several country level specifications in terms of income levels, export capacity, share of a country's income in the network of countries it belongs to, geographical distance between countries, etc. We have explained categorically in the introduction and subsequent derivations that in parts it bears strong similarities with the gravity model in international trade. Yet, the choice and adoption of newer parameters akin to radiation theory and further sorted by country level exports, income levels, share of trade in the group, etc., is a clear advantage. In fact, a number of qualifications available under this framework offers a better prediction of bilateral pattern of trade than that regularly upheld by gravity models. Indeed, we do offer a brief comparison with gravity models as well, and highlight that the role of economic masses for trading partners in radiation theory carries greater importance unlike that in earlier studies. In addition, multiple distributions of economic masses for the network of countries have been utilized to predict the volume of exports through case studies. These results based on radiation theory should enable subsequent empirical work and deepen our understanding of how goods and factors flow between countries, with wider categorization of the most powerful determinants beyond those regularly explored in related research.

Chapter 5

Conclusions and Future Research

5.1 Contributions

An introductory concept on contagion of crisis, international trade and welfare is presented in this chapter. This concept gives a motivation to study the topic in-depth through literature survey and review existing works and their improvements. This review process produces one or more research problems in mind and also it guides to find a new or improved solution.

During literature review, these works are classified based on the topics like crisis, international trade, welfare and contagion and then subdivided based on the theory and themes.

This chapter summarize the generations of theoretical currency crisis models starting from first generation to fourth generation. We have also 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 if it goes beyond a certain threshold level of the *bad* signal.

(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 agent-based model explain 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 of 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.

Subsequently, in chapter 2 gravity model is evolved based on Newton's law of gravitation in classical mechanics of physics. So gravity models in international trade is 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, though the geographical location of a country remains unchanged. In trade the distance depends on the mode of transport as well as volume of goods to be transported. In this chapter we have discussed various distances with transport modes. Distances are (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 we have 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 represent a country. And we define the measure of Similarity in Country Size.

Concepts of Multi-Channel Gravity Model of a Trading Network in 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.

In chapter 3, Cross Country Analysis of Gravity Model in the Presence of FTAs is presented. In this connection data is collected from different web sites for the dependent and explanatory variables of the gravity model. Here we have considered the following web sites: (1) COMTRADE data base of UN, (2) CEPII of France, (3) World Bank open data (4) Asia Regional Integration center, (5) International Trade Administration, (6) World Trade Organization (WTO), (7) wikipedia, etc. The variables are: GDP_i, GDP_j, Population_i, Population_j, Distance_{ij}, REER_{ij}, Border_{ij}, $\text{DevelopedCountry}_{ij}$, Colony_{ij}, Language_{ij}, Currency_{ij}, FTA_{ij}, Relegion_{ij}. The estimation techniques such as (1) Between Effect (BE) estimation, (2) GMM (generalized method of moments) are performed by STATA software. The experimental results with analysis of gravity model is presented in the tabular form.

In chapter 4, we have proposed a mathematical model for the analysis of international trade by the theory radiation in physics. Also we have proved that this fact is related with gravity model of international trade where we have considered that economic masses such as GDP of the countries are statistically (1) uniformly distributed, (2) exponentially distributed, and (3) power-law distributed.

Fractal dimension of space (d_f) is a ratio providing a statistical index of complexity comparing how detail a pattern changes with the scale at which it is measured.

The distance exponent of the gravity model plays an important role of spatial cost in determining the trade flows. When this exponent is larger then it leads to the stronger dependence of the trade flows on the distance.

In an international trade, the number of partner countries in a trade network is proportional to r^{d_f}. A higher-dimensional geometry with a large r^{d_f} would provide more possibilities in the trade in the same range of the radius of the circle r from the source country. It implies that an international trader can find a product at a closer country and does not need to transport farther in a higher-dimensional space, leading to a larger distance exponent.

In the radiation model, a country with the larger variations of the product provides more possibilities for trade. An international trader of a country finds a product market at the closest partner countries in the trade network. They will choose a partner country in the trade network for their business. This fact is implying a smaller distance exponent. The international traders of a country will choose a partner country with an extremely large economic mass. They possibly have a larger variation of products and services.

Subsequently,in chapter 5, we have summarized the outcome of each chapters and stated a set of future problems for future research work.

5.2 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 proposed 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.

References

1. Abbas. (2012) Pakistan's Potential Export Flow: The Gravity Model Approach. *The Journal of Developing Areas*, Vol. 49(4), pp. 367 - 388
2. Abbas. (2014) Trade liberalization and its economic impact on developing and least developed countries. *Journal of International Trade Law and Policy*, Vol. 13(3), pp. 215 - 221.
3. Abedini J, & Peridy N. (2018) The greater arab free trade area (GAFTA): an estimation of the trade effects. *J Econ Integr.* 2008; 23(4): 848-72.
4. Abueg, L. (2017) An econometric history of phillippine trade: 1810 - 1899. *DLSU Business and Economics Review*, Vol. 26(2), pp. 125 - 146.
5. Abueg, L. (2018) Survey of gravity models of trade and labour, and a proposed trade-employment gravity model for the Philippines. `https://mpra.ub.uni-muenchen.de/87256/ MPRA Paper No. 87256`
6. ADB (2011) EE Asea's Free Trade Agreements How is Business Responding? *Asian Development Bank*
7. Agenor, P.R., Bhandari, J.S. & Flood, R.P (1991) Speculative Attacks and Models of Balance of Payment Crises, *NBER Working Paper*, 3919
8. Agenor, P.R. & Aizenman, J. (1999) Financial Sector Inefficiencies and Coordinate Failures: Implications for Crisis Management. *NBER Working Paper*, 7446
9. Alba, P., Bhattacharya, A., Claessens, S., Ghosh, S. & Hernandez, L. (1998). Volatility and contagion in a financially - integrated world: lessons from east Asia's recent experience. *Paper presented at the PAFTAD 24 Conference "Asia pacific financial liberalaigation and reform", Chiangmai, Thailand, 20-22 May*
10. Alesina, A., Devleschawuer, A., Easterly, W., Kurlat, S. & Wacziarg, R. (2002) Fractionalization. *Journal of Economic Growth*, Vol. 8, pp. 155-194
11. Alonso, William (1971). The System of Intermetropolitan Population Flows. *Working Paper* No. 155.

12. Anderson, J.E. (1979) A theoretical foundation of the gravity model. *American Economic Review*, Vol. 69(1), pp. 106-116.
13. Anderson, J. E. & Wincoop, E.V. (2003) Gravity with Gravitas: A Solution to the Border Puzzle. *American Economic Review*, Vol. 93(1), pp. 170-192.
`doi:10.1257/000282803321455214. hdl:10532/3989`
14. Anderson, J.E. (2010) The gravity model. *NBER Working Paper Series*, Working Paper No. 16576.
`http://www.nber.org/papers/w16576`
15. Anderton, C.H. & Carter, J.R. (2001) The Impact of War on Trade: An Interrupted Time-Series Study. Journal of Peace Research.
`http://doi.org/10.1177/0022343301038004003`
16. Anh, Pham Thi Hoang (2017). Are global shocks leading indicators of a currency crisis in Viet Nam? *Asian Development Bank Institute, ADBI Working Paper Series, No. 686* March 2017.
`https://www.adb.org/sites/default/files/publication/232426/adbi-wp686.pdf`
17. Antonucci D. & Manzocchi S. (2006) Does Turkey have a special trade relation with the EU? A gravity model approach. *Econ Syst.* Vol. 30(2), pp. 157-169.
18. Arellano, M. and S. Bond (1991) Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *Review of Economic Studies*, 2 (58), 277-297
19. Arghyrou M G. (2000) EU participation and the external trade of Greece: an appraisal of the evidence. *Appl Econ*, Vol. 32(2), pp. 151 - 159.
20. Arrow, K. J. (1951). An extension of the basic theorems of classical welfare economics. In *Proceedings of the second Berkeley symposium on mathematical statistics and probability*. The Regents of the University of California.
21. Arrow, K. J. (2012). *Social choice and individual values* (Vol. 12). Yale university press.
22. Asiedu, E. and D. Lien (2011) Democracy, Foreign Direct Investment and Natural Resources. *Journal of International Economics*, Vol. 84, pp. 99-111.
23. Ather-Elahi, M. (2011) Essays on financial fragility. CentER. Center for Economic Research

24. Augier P, Gasiorek M, & Lai Tong C. (2005) The impact of rules of origin on trade flows. *Econ Policy*, Vol. 20(43), pp. 567-624.
25. Baier SL, & Bergsrtand H. (2007) Do free trade agreements actually increase members' international trade? *J Int Econ*, Vol. 71(1), pp. 72-95.
26. Baier, S.L. & J.H. Bergstrand (2009) Bonus vetus OLS: A simple method for approximating international trade-cost effects using the gravity equation. *Journal of International Economics*, Vol.77(1), pp. 77-85.
`doi:10.1016/j.jinteco.2008.10.004`
27. Baig, T. & Goldfajn, I. (1999) Financial Market Contagion in the Asian Crisis. *IMF Staff Papers*, IMF
28. Balcan D, Colizza V, Goncalves B, HuH, Ramasco J J, & Vespignani A. (2009) Multiscale mobility networks and the spatial spreading of infectious diseases. *Proceedings of the National Academy of Sciences*, Vol. 106(51), pp. 21484 - 21489.
`https://doi.org/10.1073/pnas.0906910106`
29. Baltagi BH, Egger P, & Pfaffermayr M. (2003) A generalized design for bilateral trade flow models. *Econ Lett*, Vol. 80(3), pp. 391-397.
30. Barro, Robert J. (1991) Economic Growth in a Cross-Section of Countries. *Quarterly Journal of Economics*, Vol. 106, pp. 407 - 443.
31. Barro, Robert J. (1997) *Determinants of Economic Growth: A Cross-Country Empirical Study*, The MIT Press: Cambridge Mass achusetts, The United States.
32. Barthelemy M. (2011) Spatial networks. *Physics Reports*, Vol. 499(1-3), pp. 1101.
`https://doi.org/10.1016/j.physrep.2010.11.002`
33. Baur, D. & Schulze, N. (2005), Coexceedances in financial markets–a quantile regression analysis of contagion. *Emerging Markets Review*, Vol 6(1), pp. 21-43
34. Bayer, R. & Rupert, M.C. (2004) Effects of Civil Wars on International Trade, 1950-92. Journal of Peace Research.
`http://doi.org/10.1177/0022343304047433`
35. Bchanan M.(2009) Meltdown modelling: could agent-based computer models prevent another financial crisis? *Nature*, Vol. 460(7256).
36. Beirne, John & Gieck, Jana. (2012). Interdependence and Contagion in Global Asset Markets. *Review of International Economics*. Vol. 22.
`10.1111/roie.12116.`

37. Beirne, J., & Fratzscher, M. (2013). The pricing of sovereign risk and contagion during the European sovereign debt crisis. *Journal of International Money and Finance*, Vol. 34, pp. 60-82.
38. Bekaert, G., Harvey, C. R., Lundblad, C. T., & Siegel, S. (2011). What segments equity markets?. *The Review of Financial Studies*, Vol. 24(12), pp. 3841-3890.
39. Berg, A. & Pattillo, C. (1999) Predicting Currency Crises: The Indicators Approach and an Alternative. *Journal of International Money and Finance*, Vol. 18, p. 561-586.
40. Bergstrand, Jeffrey H. (1985). The Gravity Equation in International Trade: Some Microeconomic Foundations and Empirical Evidence. *The Review of Economics and Statistics*, Vol. 67 (3), pp. 474-481.
    `doi:10.2307/1925976. JSTOR 1925976.`
41. Bergstrand, J. (1989) The Generalized Gravity Equation, Monopolistic Competition, and the Factor-Proportions Theory in International Trade. *The Review of Economics and Statistics*, Vol.71, pp. 143-153.
42. Billio, Monica & Caporin, Massimiliano. (2010). Market Linkages, Variance Spillovers, and Correlation Stability: Empirical Evidence of Financial Contagion. *Computational Statistics & Data Analysis*. Vol. 54, pp. 2443-2458.
    `10.1016/j.csda.2009.03.018.`
43. BKF P. K. R. dan B. (2012) Free Trade agreement (FTA) dan Economic Partnership Agreement (EPA), dan Pengaruhnya terhadap Arus Perdagan dan Investasi dengan Negara Mitra. Laporan Hasil Kajian.
44. Blackburn, K. & Sola, M. (1993) Speculative Currency Attacks and Balance of Payments Crises, *Journal of Economic Surveys*, Vol. 7, pp. 119-144
45. Bohl, Martin & Serwa, Dobromil. (2005). Financial Contagion Vulnerability and Resistance: A Comparison of European Stock Markets. *Economic Systems*. 29. 344-362.
    `10.1016/j.ecosys.2005.05.003.`
46. Bond, S. R., Hoeffler, A. and Temple, J. (2001) GMM Estimation of Empirical Growth Models. Discussion Paper No. 2048. London: *Centre for Economic Policy Research*.
47. Bonin, J. & Wachtel, P. (2003) Financial Sector Development in Transition Economies: Lessons From the First Decade, *Financial Markets, Institutions and Instruments*, Vol. 12, pp. 1 - 66.

48. Bookstaber, R.M. (2017). Agent-Based Models for Financial Crises. *Annual Review of Financial Economics*, Vol. 9, pp. 85-100.
`https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3095985`

49. Bordo, Michael D. & Murshid, Antu P. (2000) Are Financial Crises becoming increasingly more contagious? What is the historical evidence on contagion? *National Bureau of Economic Research Working Paper Series*, No. 7900 (Sept 2000)
`doi:10.3386/w7900.`

50. Breuer, J.B. (2004) An Exegesis on Currency and Banking Crises. *Journal of Economic Surveys*, Vol. 18, pp. 293-320.

51. Breuss F. & Egger P. (1999) How reliable are the estimations of east-west trade potentials based on cross-section gravity analyses? *Empirica*, Vol. 26(2), pp. 81-94.

52. Briere, M. & Signori, O. (2012). Inflation-hedging portfolios: Economic regimes matter. *The Journal of Portfolio Management*, Vol. 38(4), pp. 43-58.

53. Brockmann D. & Helbing D. (2013) The Hidden Geometry of Complex, Network-Driven Contagion Phenomena. *Science*, Vol 342(6164), pp. 1337 - 1342.
`https://doi.org/10.1126/science.1245200` PMID: 24337289

54. Buch CM, & Piazolo D. (2001) Capital and trade flows in Europe and the impact of enlargement. *Econ Syst*, Vol. 25(3), pp. 183-214.

55. Buch, C.M. & De Long, G. (2008) Do Weak Supervisory Systems Encourage Banks Risk-Taking?, *Journal of Financial Stability*, Vol. 4, pp. 23-39

56. Bun MJG & Klaassen FJGM. (2007) The Euro effect on trade is not as large as commonly thought. *Oxford B Econ Stat*, Vol. 69(4), pp. 473-496.

57. Bussiere, M. & Mulder, C. (2000) Political Instability and Economic Vulnerability. *International Journal of Finance and Economics*, Vol. 5, pp. 309-330

58. Bussire, M.; Fidrmuc, J. & Schnatz, B. (2008) EU Enlargement and Trade Integration: Lessons from a Gravity Model. *Review of Development Economics*, Vol. 12(3), pp. 562-576.

59. Buyukakin, Figen, & Seda Aydin (2018). Predictability of financial crises by KLR method: Turkey case (Period of 1990:01-2018:09) *Journal of Economics*, Vol. 5(4)
`http://www.kspjournals.org/index.php/JEB/article/view/1800`

60. Cai, M. (2020), Doubly constrained gravity models for interregional trade estimation, *Papers in Regional Science*, 100, 2, p. 455-474.

61. Calvo, Guillermo A., (1987). Balance of Payments Crises in a Cash-in-Advance Economy. *Journal of Money, Credit and Banking*, Vol. 19(1), pp. 19-32.
62. Calvo, Guillermo A.(1995) Varieties of Capital-Market Crises (August 1995). *IDB Working Paper No. 250*.
https://ssrn.com/abstract=1815934 or
http://dx.doi.org/10.2139/ssrn.1815934
63. Calvo, Guillermo A., Leonardo Leiderman, & Carmen M. Reinhart. (1996). Inflows of Capital to Developing Countries in the 1990s. *Journal of Economic Perspective*, Vol. 10 (2), pp. 123-139.
DOI: 10.1257/jep.10.2.123
64. Calvo, Guillermo A., (1998) Varieties of Capital-Market Crises. *The Debt Burden and its Consequences for Monetary Policy, Proceedings of a Conference held by the International Economic Association at the Deutsche Bundesbank*; London: Macmillan
65. Caporale, Guglielmo Maria; Howells, Peter & Soliman, Alaa. (2005). Endogenous Growth Models and Stock Market Development: Evidence from Four Countries. *Review of Development Economics*, Vol. 9, pp. 166-176.
10.1111/j.1467-9361.2005.00270.x.
66. Carrere C. (2006). Revisiting the effects of regional trade agreements on trade flows with proper specification of the gravity model. *Eur Econ Rev* 2006; 50(2): 223-247.
67. CEFTA (2017) CEFTA partners.
http://cefta.int/cefta-parties-2/
68. Cerra, V., & Saxena, S. C. (2002). What caused the 1991 currency crisis in India? *IMF staff papers*, Vol. 49(3), pp. 395-425.
69. Chandran, B.P. Sarath (2018) Trade impact of the india-asean free trade agreement (fta): an augmented gravity model analysis.
https://ssrn.com/abstract=3108804
70. Chaney, T. (2008). Distorted gravity: The intensive and extensive margins of international trade. *American Economic Review*, Vol. 98(4), pp. 1707-1721.
71. Chan-Lau, J. A., Mathieson, D. J., & Yao, J. Y. (2004). Extreme contagion in equity markets. *IMF staff papers*, Vol. 51(2), pp. 386-408.
72. Claessens, Dornbusch & Park, (2000) Spread of market disturbance *Journal of market disturbance*. Prentice-Hall, NY, 2000.

73. Claessens, Stijn & Forbes, Kristin (2001). International Financial Contagion: An Overview of the Issues and the Book. In Claessens, Stijn; Forbes, Kristin (eds.). *International Financial Contagion*. Boston: Kluwer. pp. 3-18. ISBN 978-0-7923-7285-1
74. Claveria, Oscar; Monte, Enric & Torra, Salvador (2015) Self-Organizing Map Analysis of Agents' Expectations. Different Patterns Of Anticipation Of The 2008 Financial Crisis. *Research Institute of Applied Economics, Working Paper 2015/11 1/25* `http://www.ub.edu/irea/working_papers/2015/201511.pdf`
75. Claveria, Oscar; Monte, Enric & Torra, Salvador (2016) A self-organizing map analysis of survey-based agents' expectations before impending shocks for model selection: The case of the 2008 financial crisis. *International Economics*, Vol. 146, pp. 40-58 `www.elsevier.com/locate/inteco` `https://daneshyari.com/article/preview/999163.pdf`
76. Cole, Harold L., & Timothy J. Kehoe (1996) A Self-Fulfilling Model of Mexicos 1994-1995 Debt Crisis, *Journal of International Economics*, pp. 309-330.
77. Colizza V, Barrat A, Barthelemy M, & Vespignani A. (2006) The role of the airline transportation network in the prediction and predictability of global epidemics. *Proceedings of the National Academy of Sciences*. Vol. 103(7), pp. 2015 - 2020. `https://doi.org/10.1073/pnas.0510525103`
78. Collins D. (2018) A new UK-EU Free-Trade Agreement
79. Connoly, M.B. & Taylor, D. (1984) The Exact Timing of the Collapse of an Ecchange Rate Regime and its Impact on the Relative Price of Traded Goods, *Journal of Money, Credit and Banking*, Vol. 16, pp. 192-207.
80. Connolly, R. A., & Wang, F. A. (2003). International equity market comovements: Economic fundamentals or contagion? *Pacific-Basin Finance Journal*, Vol. 11(1), pp.23-43.
81. Cooray, A., N. Dutta and S. Mallick (2016) Does female human capital formation matter for the income effect of remittances? Evidence from developing countries. *Oxford Development Studies*, Vol.44, No. 4, pp. 458-478.
82. Corsetti, G., Pesenti, P. & Roubini, N. (1999) What Caused The Asian Currency and Financial Crisis?, *Japan and The World Economy*, Vol. 11, pp. 305-373
83. Corsetti, G., Pericoli, M., & Sbracia, M. (2005). 'Some contagion, some interdependence: More pitfalls in tests of financial contagion. *Journal of International Money and Finance*, Vol. 24(8), pp. 1177-1199.

84. Das, U.S., Quintyn, M. & Chenard, K. (2004) Does Regulatory Governance Matter for Financial System Stability? An Empirical Analysis, *IMF Working Paper*, 04/89, Washington: IMF
85. Davies, A. (1995) Local economies and globalization. *Note Book N 20, OECD.*
86. De Nicolo, G., Geadah, S. & Rozhkov, D. (2003) Financial development in the CIS-7 Countries: Bridging the Great Divide, *IMF Working Paper*, 03/205
87. Deardorff, Alan V. (1998) Determinants of Bilateral Trade: Does Gravity Work in a Neoclassical World? In: *The Regionalization of the World Economy, edited by J.A. Frankel. Chicago: University of Chicago Press*.
88. Demirguc-Kunt, A. & Detragiache, E. (1998) The Determinants of Banking Crises in Developing Developed Countries. *IMF Staff Paper*, Vol. 45, pp. 81-109
89. Demirgiic-Kunt, A. & Detragiache, E. (2005) Cross-Country Empirical Studies of Systemic Bank Distress: A Survey. *IMF Working Paper*, Washington: International Monetary Fund, 05/96
90. Dhar, S. & Panagariya A. (1994) Predictions of bilateral trade and the gravity equation. *Working Paper*, International Trade Division, World Bank, Washington, D.C.
91. Diamond, D. W., & Dybvig, P. H. (1983). Bank runs, deposit insurance, and liquidity. *Journal of political economy*, Vol. 91(3), pp. 401-419.
92. Hasan Dincer, Umit Hacioglu, & Serhat Yuksel (2017). A Strategic Approach to Global Financial Crisis in Banking Sector: A Critical Appraisal of Banking Strategies Using Fuzzy ANP and Fuzzy Topsis Methods. *International Journal of Sustainable Economies Management*, Vol. 6(1).
93. Dollar, D. and A. Kraay (2002) Growth is Good for the Poor. *Journal of Economic Growth*, Vol. 7, No. 3, pp. 195-225.
94. Dornbusch, R (1987) Collapsing exchange rate regimes. *Journal of Development Economics*, Vol. 27, pp. 71-83.
95. Dungey, M., Fry, R., Gonzlez-Hermosillo, B., & Martin, V. (2002). The transmission of contagion in developed and developing international bond markets. In Committee on the Global Financial System (ed), *Risk Measurment and Systemic Risk, Proceedings of the Third Joint Central Bank Research Conference* 2002, pp. 61-74.

96. Dungey, M., & Martin, V. L. (2004). A multifactor model of exchange rates with unanticipated shocks: measuring contagion in the East Asian currency crisis. *Journal of Emerging Market Finance*, Vol. 3(3), pp. 305-330.
97. Dungey, M., Fry, R., & Martin, V. L. (2004). Currency Market Contagion in the Asia Pacific Region. *Australian Economic Papers*, 43(4), 379-395.
98. Dungey, M., & Martin, V. L. (2007). Unravelling financial market linkages during crises. *Journal of Applied Econometrics*, Vol. 22(1), pp. 89-119.
99. Dungey, M.; Islam, R. & Volkov, V. (2019). Crisis transmission: visualizing vulnerability *Paper Series N* 2019-07, 2019.
`https://eprints.utas.edu.au/31661/1/2019-07_Dungey_Islam_Volkov.pdf`
100. Dupuit, J. (1995). De la mesure de l'utilite des travaux publics (1844). Revue francaise d'economie, Vol. 10(2), pp. 55-94.
101. Dutta, N. and S. Mallick (2018) Enabling women entrepreneurs: exploring factors that mitigate the negative impact of fertility rates on female entrepreneurship. *Kyklos*, Vol. 71, No. 3, pp. 402-432
102. Dutta, N. and C. Williamson (2016) Aiding Economic Freedom: Exploring the role of Political Institutions. *European Journal of Political Economy*, 45, Supplement, 24-38.
103. Dutta, N. and R. Sobel (2016) Does corruption ever help entrepreneurship? *Small Business Economics*, Vol. 47, No. 1, pp. 179-199.
104. Eaton, J. & S. Kortum (1997) Technology and bilateral trade. NBER *Working Paper* No. W6253, National Bureau of Economic Research, Inc.
105. Eaton, J. & Kortum, S. (2002). Technology, Geography, and Trade, *Econometrica*, Vol. 70(5), pp. 1741 - 1780.
`http://doi.org/10.1111/1468-0262.00352`
106. EC (2006) EIA Notification, 2006
107. Edge R., Kiley M. & Laforte J.P. (2010). A comparison of forecast performance between federal reserve staff forecasts, simple reduced-form and a DSGE model. *Journal of Applied*, Vol. 25(4), pp. 720-754.
108. Edison, H.J. (2003) Do Indicators of Financial Crises Work? An Evaluation of an Early Warning System, *International Journal of Finance and Economics*, Vol. 8, pp. 11-53

109. Edwards, S. (1989) Real Exchange Rates, Devaluation and Adjustment: Exchange Rate Policy in Developing Countries, *Cambridge: MIT Press*
110. Egger P. (2002) An econometric view on the estimation of gravity models and the calculation of trade potentials. *World Econ*, Vol. 25(2): pp. 297-312.
111. Egger P. & Pfaffermayr M. (2003) The proper panel econometrics specification of the gravity equation: a three-way model with bilateral interaction effects. *Empir Econ* Vol. 28(3), pp. 571-80.
112. Egger P. (2004) Estimating regional trading bloc effects with panel data. *Rev World Econ* Vol. 140(1), pp. 151-66.
113. Egger P. (2008) On the role of distance for bilateral trade. *World Econ.* Vol. 31(5), pp. 653-62.
114. Eichengreen, B., Rose, A. & Wyplosz, C. (1994) Speculative Attacks on Pegged Exchange Rates: An Empirical Exploration With Special Reference to the European Monetary System, *NBER Working Paper*, 4898
115. Eichengreen, B., Rose, A. & Wyplosz, C. (1996) Contagious Currency Crises: First Test, *The Scandinavian Journal of Economics*, Vol. 98, pp. 463-484
116. Eichengreet, B. & Arteta, C. (2000) Banking Crises in Emerging Markets: Presumptions and Evidence, *Paper C00'115*, Centre for international and Development Economics Research, Barkely: University of California
117. Elliott, R.J.R. and K. Ikemoto (2004). AFTA and the Asian Crisis: Help or Hindrance to ASEAN Intra- Regional Trade? *Asian Economic Journal*, Vol. 18(1), pp. 1 - 23.
118. Elliott D R. (2007) Caribbean regionalism and the expectation of increased trade: insights from a time-series gravity model. *J Int Trade Econ Dev*, Vol. 16(1), pp. 117-136.
119. Elyasiani, E.; Staikouras, S.K. et al. (2015) Cross-Industry Product Diversification and Contagion in Risk and Return: The Case of Bank- Insurance and Insurance-Bank Takeovers. *Journal of Risk and Insurance*
120. Endoh M. (1999) Trade creation and trade diversion in the EEC, the LAFTA and the CMEA: 1960-1994. *Applied Economics*, Vol. 31(2), pp. 207-216.
121. Endoh, M. (2000) The Transition of Postwar Asia-Pacific Trade Relations. *Journal of Asian Economics*, Vol. 10, pp. 571 - 589.

122. Erlander S. & Stewart NF. (1990) The gravity model in transportation analysis: theory and extensions. VSP; 1990.
`http://www.worldcat.org/isbn/9789067640893.`

123. Esquivel, G. & Larrian, B.F. (1998) Explaining Currency Crises, *Harvard Institute for International Development (HIID) Dev. Disc. Paper*, pp. 666-672

124. Evenett, S.J. & W. Keller (1998) On theories explaining the success of the gravity equation. *NBER Working Papers* 6529, National Bureau of Economic Research, Inc.

125. Farmer, J.D. & Foley, D. (2009) A Model Approach, *Nature*, Vol. 460, pp. 685-686

126. Feenstra, R.C., J.A. Markusen & A.K. Rose (1999) Understanding the Home Market Effect and the Gravity Equation: The Role of Differentiating Goods. *NBER Working Papers* 6804, National Bureau of Economic Research, Inc.

127. Feenstra, Robert C.; Markusen, James R. & Rose, Andrew K. (2001). Using the Gravity Equation to Differentiate among Alternative Theories of Trade. *The Canadian Journal of Economics.* Vol. 34 (2), pp. 431.
`doi:10.1111/0008-4085.00082. JSTOR 3131862.`

128. Filippini C. & Molini V. (2003). The determinants of East Asian trade flows: a gravity equation approach. *J Asian Econ*, Vol. 14(5), pp. 695-711.

129. Flood, R. P., & Garber, P. M. (1984). Collapsing exchange-rate regimes: Some linear examples. *Journal of international Economics*, Vol. 17(1-2), pp. 1-13.

130. Forbes, Kristin, & Roberto Rigobon. (1999). No Contagion, Only Interdependence: Measuring Stock Market Co-movements. *NBER Working Paper* 7267. National Bureau of Economic Research, Cambridge, Mass. *The Journal of Finance*, Vol. 57(5).

131. Forbes, K., & Rigobon, R. (2001). Measuring contagion: conceptual and empirical issues. In *International financial contagion* pp. 43-66. Springer, Boston, MA.,

132. Forbes, Kristin J. & Rigobon, Roberto (2002). No Contagion, Only Interdependence: Measuring Stock Market Comovements. *Journal of Finance*. Vol. 57(5), pp. 2223-2261.
`doi:10.1111/0022-1082.00494.`

133. Franck, Raphael Franck & Aurelien Schmied (2004). *Predicting a Currency Crisis Contagion from East Asia to Russia and Brazil: An Artificial Neural Network Approach* Bar Ilan University, Department of Economics, 52900 Ramat Gan Israel. Available at SSRN

134. Fukao K, Okubo T, & Stern RM. (2003) An econometric analysis of trade diversion under NAFTA. *N Am J Econ Finance*, Vol. 14(1), pp. 2-24.

135. Furman, J. & Stiglitz, J.E. (1998) Economic Crises: Evidence and Insights From East Asia, *Brookings Papers on Economic activity*, Vol. 2, pp. 1-135
136. Gavin, M. & Hausman, R., (1996) The Roots of Banking crises: The Macroeconomic Context, *Banking Crises in Latin America*, Washington, DC.: Inter-American Development Bank, pp. 27-63.
137. Ghosh, S. & Ghosh, A.R. (2002) Structural vulnerabilities and currency crises, *IMF Working Paper No. 02/9*, International Monetary Fund .
138. Glick, R., & Rose, A. K. (1999). Contagion and trade: Why are currency crises regional? *Journal of international Money and Finance*, Vol. 18(4), pp. 603-617.
139. Glick, R., & Rose, A. K. (2002) Does a currency union affect trade? The timeseries evidence. *Eur Econ Rev*, Vol. 46(6), pp. 1125-1151.
140. Goldstein, M., Kaminsky, G. & Reinhart, C.M. (2000) Assessing Financial Vulnerability: An Early Warning System for Emerging Markets. *Institute for International Economics*, Washington, DC
141. Gonzalez MC, Hidalgo CA, & Barabasi AL (2008). Understanding individual human mobility patterns. *Nature*, Vol. 453(7196), pp. 779 - 782. https://doi.org/10.1038/nature06958 PMID: 18528393
142. Gopinath M & Echeverria R. (2004) Does economic development impact the foreign direct investment-trade relationship? A gravity-model approach. *Am J Agric Econ*, Vol. 86(3), pp. 782-787.
143. Grant JS & Lambert DM. (2008) Do regional trade agreements increase members agricultural trade? *Am J Agric Econ*, Vol. 90(3), pp. 765 - 782.
144. Gravelle, H. (2003). Measuring income related inequality in health: standardisation and the partial concentration index. *Health economics*, Vol. 12(10), pp. 803-819.
145. Gravelle, T.; Kichian, M. & Morley, J. (2003) Shift Contagion in Asset Markets. *Bank of Canada Working Paper* 2003-2005.
146. Guimaraes, B. (2007). Currency crisis triggers: sunspots or thresholds? mimeo. CEPR Discussion Papers 6487, C.E.P.R. Discussion Papers. https://ideas.repec.org/p/cpr/ceprdp/6487.html
147. Gulko, L. (2002). Decoupling. *The Journal of Portfolio Management*, Vol. 28(3), pp. 59-66.

148. Helbing D. (2001) Traffic and related self-driven many-particle systems. *Reviews of Modern Physics*, Vol. 73(4), pp. 1067 - 1141.
`https://doi.org/10.1103/RevModPhys.73.1067`
149. Helble M. (2006) On the influence of world religions on international trade. *Journal of Public and International Affairs*, Vol. 17(11), pp. 278-288.
150. Helpman, E. (1987) Imperfect competition and international trade: evidence from fourteen industrial countries. *Journal of the Japanese and International Economies*, Vol. 1(1), pp. 62-81.
151. Helpman, E., Rubinstein, Y. & Melitz, M.J. (2008). Estimating trade flows: trading partners and trading volumes *Quterlerly Journal of Economies*, Vol. 123(2), pp. 441-487.
`DOI: 10.1162/qjec.2008.123.2.441`
152. Henderson DJ & Millimet DL. (2008) Is gravity linear? *J Appl Econ*, Vol. 23(2), pp. 137-172.
153. Hernandez L. (2005) International reserves crises, monetary integration and the payments system during the international gold standard. *Macroeconomic Dynamics*, Vol. 9(4), pp. 516-541.
154. Haryadi (2009) Impact of trade Liberalization on the Developing and Developed Country Economies. *Dissertation*. Bogor Agriculture University, Bogor.
155. Haryadi (2012) *International Economics. Theory and Aplication*, Biografika, Bogor
156. Haryadi (2015) The Impact of the Change in the Rupiah Exchange Rate on Exports, Imports, GDP, and Inflation in Indonesia. *unpublished*. Faculty of Economics and Business, Jambi University, Jambi.
157. Hong, Inho; Jung, Woo-Sung & Jo, Hang-Hyun (2019) Gravity model explained by the radiation model on a population landscape. *PLoS ONE*, Vol. 14(6): e0218028.
`https://doi.org/10.1371/journal.pone.0218028`
158. Honohan, P. (1997) Banking System Failures in Developing and Transition Countries: Diagnosis and Prediction. *Bank for International Settlements Working paper*, No. 39.
159. Hossein, A. & Nossman, M. (2011) Risk contagion among international stock markets. *Journal of International Money and Finance*, Vol. 30(1), pp. 22-38.
160. Hummels, D. L. (1999). Toward a geography of trade costs. SSRN 160533.

161. Hutchinson, M.M. & Mc Dill, K. (1999) Are All Banking Crises Alike? The Japanese Experience in International Comparison, *Journal of the Japanese and International Economies*, Vol. 13, pp. 155-180

162. Hutchinson, M.M. (2002) European Banking Distress and EMU: Instittional and Macroeconomic Risks, *Scandinavian Journal of Economics*, Vol. 104, pp. 365-89

163. Isard, Walter (1954). Location Theory and Trade Theory: Short-Run Analysis. *Quarterly Journal of Economics*. Vol. 68(2), pp. 305-320. doi:10.2307/1884452. JSTOR 1884452.

164. Hidehiko, Ishihara (2007) *Understanding Krugman's Third-Generation Model of Currency and Financial Crises* in Chapter 2, Hisayuki Mitsuo ed., Financial Fragilities in Developing Countries, Chosakenkyu-Hokokusho, IDE-JETRO, 2007.

165. Ito, T., & Hashimoto, Y. (2005). High-frequency contagion of currency crises in Asia. *Asian Economic Journal*, Vol. 19(4), pp. 357-381.

166. Iwanow T. & Kirkpatrick C. (2007) Trade facilitation, regulatory, quality and export performance. *J Int Dev*, Vol. 19(6), pp. 735-753.

167. Jeanne, O., & Masson, P. (2000) Currency Crises, Sunspots and Markov-Switching Regimes, *Journal of international economics*, Vol. 50, pp. 327-350

168. Kalirajan K. (1999) Stochastic varying coefficients gravity model: an application in trade analysis. *J Appl Stat*, Vol. 26(2), pp. 185-193.

169. Kalirajan K. (2007) Regional cooperation and bilateral trade flows: an empirical measurement of resistance. *Int Trade J*, Vol. 21(2), pp. 85- 107.

170. Kaminsky, G., Lizondo, S. & Reinhart, C. (1998) Leading Indicators of Currency Crises, *Staff Papers, International Monetary Fund*, Vol. 45, pp. 1-48

171. Kaminsky, G. & Reinhart, C. (1999) The Twin Crises: The Causes of Banking and Balance-of-Payments Problems, *American Economic Review*, Vol. 89, pp. 473-500

172. Kaminsky, G. (2000) Currency and Banking Crises: The Early Warning of Distress, *Presented at the workshop on Early warning system modeling and joint regional monitoring jointly organized by the Asian development bank and Korea center for international finance, Korea*.

173. Kandogan Y. (2005) Evidence for the natural trade partners theory from the Euro-Mediterranean region. *Working paper series,* No.2005-01, University of Michigan-Flint School of Management.

174. Kang H. & Fratianni M. (2006) International trade, OECD membership, and religion. *Open Econ Rev*, Vol. 17(4-5), pp. 493-508.

175. Kangas K. & Niskanen A. (2003) Trade in forest products between European Union and the Central and Eastern European access candidates. *Forest Policy Econ*, Vol. 5(3), pp. 297-304.

176. Kepaptsoglou K, Tsamboulas D, Karlaftis MG, & Marzano V. (2009) Analyzing free trade agreements effects in the mediterranean region: a sure gravity model based approach. *Transp Res Rec*, Vol. 2097, pp. 88-96.

177. Kepaptsoglou K.; Karlaftis M. G. & Tsamboulas, D. (2010). The Gravity Model Specification for Modeling International Trade Flows and Free Trade Agreement Effects: A 10-Year Review of Empirical Studies. *The Open Economics Journal*, Vol. 3, pp. 1-13.

178. Kindleberger, C. P. (1986). *The world in depression*, 1929-1939 (Vol. 4). Univ of California Press.

179. King, Mervyn A. & Wadhwani, Sushil (1990). Transmission of volatility between stock markets. *Review of Financial Studies*. Vol. 3 (1), pp. 5-33.
`doi:10.1093/rfs/3.1.5.`

180. Kinsella S. (2019) Visualising economic crises using accounting models. *Accounting, Organizations and Society journal*
homepage: `www.elsevier.com/locate/aos`
`https://fardapaper.ir/mohavaha/uploads/2019/05/Fardapaper-Visualising-economic-crises-using-accounting-models.pdf`

181. Kiprop J. (2018) Economics: What is CEFAT.
`http://www.worldatlas.com/articles/what-is-the-central-european-free-trade-agreement.html`

182. Kong C., Liu Y. & Duo Qin K. (2015) A generalized radiation model for human mobility: spatial scale, searching direction and trip constraint. *PLoS ONE*, Vol. 10(11)
`10.1371/journal.pone.0143500`

183. Korobeinikov, A. (2009) Financial Crisis: An Attempt of Mathematical Modeling, *Applied Mathematics Letters*, Vol. 22, pp. 1882-1886

184. Kouri, P.J.K. (1976) The Exchange Rate and the Balance of Payments in The Short Run and in Tthe Long Run: A Monetary Approach. *The Scandinavian Journal of Economics*, Vol. 78, pp. 280-304

185. Koutmos, G., & Booth, G. G. (1995). Asymmetric volatility transmission in international stock markets. *Journal of international Money and Finance*, Vol. 14(6), pp. 747-762.
186. Krugman P. (1980) Scale economies, product differentiation, and the pattern of trade. *Am Econ Rev*, Vol. 70(5), pp. 950-959.
187. Krugman P. (1979) Scale economies, product differentiation, and the pattern of trade. *Am Econ Rev*. Vol. 70(5), pp. 950-959.
188. Krugman, P. & Rotemberg J.J. (1992) Speculative Attacks on Target Zones, In Target Zones and Currency Bands, *ed. By Krugman, P. and Miller, M.*, Cambridge: Cambridge Uty. Press, pp. 117-132
189. Krugman, Paul, (1999), Balance Sheets, the Transfer Problem, and Financial Crises, *International Tax and Public Finance*, Vol. 6, pp. 459-472.
190. Krugman, P. (2001). Crises: the next generation. In *Conference Honoring Assaf Razin, Tel Aviv.*, 2001, March
191. Krugman P.R., Obstfeld M. & Melitz M. (2012) *International Economics: Theory and Policy*. Pearson.
192. Kucera D. & Sarna R. (2006) Trade union rights, democracy, and exports: a gravity model approach. *Rev Int Econ*, Vol. 14(5), pp. 859-882.
193. Kurihara Y. (2003) APEC: International trade and output. *Pac Econ Rev*, Vol. 8(3), pp. 207-217.
194. Lampe M. (2008) Bilateral trade flows in Europe, 1857-1875: a new dataset. *Res Econ Hist*, Vol. 26(1), pp. 81 - 155.
195. Lattimore D., Baskin O., Heiman S.T. & Toth E.L. (2009) *Public Relations: The profession and the Practice*, McGraw Hill.
196. Lee, S. B., & Kim, K. J. (1993). Does the October 1987 crash strengthen the co-movements among national stock markets?. *Review of Financial Economics*, Vol. 3(1), pp. 89-102.
197. Lee H. & Park I. (2007) In search of optimized regional trade agreements and applications to East Asia. *World Econ*, Vol. 30(5), pp. 783-806.
198. Lerner, A. P. (1944). *Economics of control: Principles of welfare economics*. Macmillan and Company Limited, New York.

199. Lerner, A. (1995). The concept of monopoly and the measurement of monopoly power. In *Essential readings in economics* (pp. 55-76). Palgrave, London.

200. Lerner, A. P. (1997). The Concept of Monopoly and the Measurement of Monopoly Power. *J. Reprints Antitrust L. & Econ.*, Vol. 27, pp. 471.

201. Lin, J., & Granger, C.W. (1994) Forecasting from non-linear models in practice. *Journal of Forecasting*, Vol. 13(1), pp. 1-9.

202. Linders G.J. & de Groot H.L.F. (2006) Estimation of the Gravity Equation in the Presence of Zero Flows. Tinbergen Institute Discussion Paper No. 06-072/3, 31 Pages

203. Lindholm, Christer K. & Liu , Shuhua (2003). Fuzzy Clustering Analysis of the Early Warning Signs of Financial Crisis, No 472, *Working Papers, IAMSR*, 2003 `http://iamsr.abo.fi/publications/ openFile.php?pub_id=472` (application/pdf)

204. Linneman, H. (1966) *An Econometric Study of International Trade Flows*. Amsterdam: North-Holland Publishing Co. 1966.

205. Liu, Shuhua & Lindholm , Christer K. (2005). The portfolio balance model as a tool for predicting currency crises. *Ekonomiska Samfundet Finland-Economic Society Finland*, Vol. 58(1), pp. 37.

206. Liu, Shuhua & Lindholm , Christer K. (2006). Assessing early warning signals of currency crises: a fuzzy clustering approach. *Intelligent Systems in Accounting, Finance & Management: International Journal*, Vol. 14(4), pp. 179-202.

207. Liu, Shuhua; Eklund, Tomas; Collan, Mikael & Sarlin, Peter (2010) A visualization and clustering approach to analyzing the early warning signals of currency crises. *Business Intelligence in Economic Forecasting: Technologies and Techniques*, pp. 65-81, IGI Global. 2010

208. Lomakin, A., & Paiz S. (1999). Measuring Contagion in the Face of Fluctuating Volatility. MIT-Sloan Project, 15.

209. Longo R. & Sekkat K. (2004) Economic obstacles to expanding intra-african trade. *World Dev*, Vol. 32(8), 1309-1321.

210. D Marghescu, S Liu, & P Sarlin (2010). Evaluation of a Fuzzy C-Means Model in Currency Crisis Prediction. *TUCS Technical Report*, No 970, April 2010.

211. Marghescu, D. & Sarlin, P. (2010) Early-warning analysis for currency crises in emerging markets: A revisit with fuzzy clustering. *Intelligent Systems in Accounting Finance*

& Management Vol 17(July), pp. 143165.
DOI: 10.1002/isaf.317

212. Marimoutou, V.; Peguin, D. & Peguin-Feissolle A. (2010) The ”distance-varying” gravity model in international economics: is the distance an obstacle to trade?
`https://halshs.archives-ouvertes.fr /halshs-00536127/document`
213. Markusen, J.A. (1986) Explaining the volume of trade: an eclectic approach. *American Economic Review* Vol. 76(3), pp. 1002 - 1011.
214. Martinez-Zarzoso I. & Suarez-Burguet C. (2005) Transport costs and trade: empirical evidence for latin american imports from the European union. *J Int Trade Econ Dev*, Vol. 14(3), pp. 353-371.
215. Mason, R. S. (1998). *The economics of conspicuous consumption: Theory and thought since 1700.* Edwar Elgar
216. Masueci A.P., Serras J., Johansson A. & Batty M. (2013) Gravist vs radiation model: on the importance of scale and heterogeneity in commuting flows. *Physical Review E*, 88(2), p.022812.
`10.1103/PhysRevE.88.022812`
217. McKinnon, R. & Pill, H. (1996) Credible Liberalization and International Capital Flows: The Over borrowing Syndrome, *In Financial Deregulation and Integration in East Asia*, ed. Takatoshi Ito and Anne Krueger, Chicago: Chicago University press, pp. 7 - 42
218. McPherson,M. A., M. R. Redfearn & M. A. Tieslau (2000). A Re-examination of the Linder Hypothesis: a Random-Effects Tobit Approach. *Working Paper* from the website of the Department of Economics; University of North Texas.
219. Melitz J. (2007) North, South and distance in the gravity model. *Eur Econ Rev*, Vol. 51(4), pp. 971-991.
220. Melnikas, B. (2008) The knowledge-based economy in the European Union: Innovations, networking and transformation strategies, *Trans. in Business and Economics*, vol. 7(3), pp. 170-192.
221. Jozsef Mezei & Peter Sarlin (2017) Possibilistic clustering for crisis prediction: Systemic risk states and membership degrees, Proceedings of the 50th *Hawaii International Conference on System Sciences*, 2017
`https://core.ac.uk/download/pdf/77239634.pdf`

222. Misra, R. & Choudhry, S. (2020) Trade War: Likely Impact on India. Foreign Trade Review. http://doi.org/10.1177/0015732519886793

223. Modekurti, Kameshwar Rao V.S. (2015) *Early Warning Signals for Currency Crisis in India*. SSRN.
https://ssrn.com/abstract=2942575 or
http://dx.doi.org/10.2139/ssrn.2942575

224. Morgenstern, O. (1959). *International financial transactions and business cycles*, Vol. 8, Princeton: Princeton University Press.

225. Musila JW. (2005) The Intensity of trade creation and trade diversion in COMESA, ECCAS and ECOWAS: a comparative analysis. *J Afr Econ*, Vol. 14(1), pp. 117-141.

226. Nag, Ashok, and Amit Mitra (1999) Neural Networks and Early Warning Indicators of Currency Crisis. *Reserve Bank of India Occasional Papers* Vol. 20(2), pp. 183-222.

227. Mauro Napoletano, Eric Guerci & Nobuyuki Hanaki (2018). Recent advances in financial networks and agent-based model validation. *Journal of Economic Interaction and Coordination*, Vol. 13, pp. 1 - 7.
https://link.springer.com/article/10.1007/s11403-018-0221-z

228. Nasira S. & Kalirajan K. (2014) Modern services export performances among emerging and developed Asian economics. *ADB Working Paper Series on Regional Economic Integration*, No. 143, November 2014.

229. Nickell, S. (1981) Biases in Dynamic Models with Fixed Effects. *Econometrica*, Vol. 49, No. 6, pp. 1417-1426

230. Nitsch V. (2000) National borders and international trade: evidence from the European Union. *Can J Econ*, Vol. 33(4), pp. 1091-1105.

231. Ng, Y.C., & Li, S. K. (2000). Measuring the research performance of Chinese higher education institutions: an application of data envelopment analysis. *Education Economics*, Vol. 8(2), pp. 139-156.

232. Nowak-Lehmann F, Herzer D, Martinez-Zarzoso I. & Vollmer S. (2007) The impact of a customs union between turkey and the EU on Turkeys exports to the EU. JCMS. *J Common Market S*, Vol. 45(3), pp. 719 - 743.

233. Obstfeld, M. (1994) Evaluating risky consumption paths: The role of intertemporal substitutability. *European economic review*, Vol. 38(7), pp. 1471-1486.

234. Obstfeld, Maurice & Kenneth Rogoff (1995). The Mirage of Fixed Exchange Rates, *Journal of Economic Perspectives*, Vol. 9, pp. 73-96.

235. Obstfeld, M. (1996) Models of currency crises with self-fulfilling features. *European economic review*, Vol. 40(3-5), pp. 1037-1047.

236. Paas T. & Tafenau E. (2005) Regional trade clusters in promoting eastward enlargement of European union. *Trans Stud Rev*, Vol. 12(1), pp. 77-90.

237. Pal I. & and Kar S. (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

238. Papazoglou C. (2007) Greeces potential trade flows: a gravity model approach. *Int Adv Econ Res*, Vol. 13(4), pp. 403-414.

239. Pareto, V. (1909) *Manuel dEconomie Politique* Trans. A. Bonnet. Paris: Giard & Briere.

240. Park I. & Park S. (2008) Reform creating regional trade agreements and foreign direct investment: applications for East Asia. *Pac Econ Rev*, Vol. 13(5), pp. 550-566.

241. Pelletiere D. & Reinert KA. (2004) Used automobile protection and trade: Gravity and ordered probit analysis. *Empir Econ*, Vol. 29(4), pp. 737- 751.

242. Peng, D. & Bajona, C. (2008) China's vulnerability to currency crisis: A KLR signals approach. *China Economic Review*, Vol. 19, pp. 138 - 151.

243. Peridy N. (2005) The trade effects of the Euro-mediterranean partnership: what are the lessons for ASEAN countries?. *J Asian Econ*, Vol. 16(1), pp. 125-139.

244. Peridy N. (2005) Toward a Pan-Arab free trade area: assessing trade potential effects of the Agadir agreement. *Dev Econ*, Vol. XLIII-3, pp. 329-345.

245. Pigou, A.C. (1912) *Wealth and Welfare*, London: Macmillan

246. Pigou, A.C. (1920) *The Economics of Welfare*, London: Macmillan.

247. Pigou, A.C. (1947) *A Study in Public Finance*. London: Macmillan.

248. Pinheiro, Leonardo dos Santos & Coelho, Flavio Codeco (2017) An Agent-based Model of Contagion in Financial Networks.
https://www.researchgate.net/publication/315514618
_An_Agent-based_Model_of_Contagion_in_Financial_Networks
arXiv.org/abs/1703.07513

249. Porojan A. (2001) Trade flows and spatial effects: the gravity model revisited. *Open Econ Rev*, Vol. 12, pp. 265-280.

250. Poyhonen, P. (1963) A tentative model for the volume of trade between countries. *Weltwirschaltliches Archiv.*, Vol. 90, pp. 93 - 100.

251. Pritsker, M. (2001). The channels for financial contagion. In *International financial contagion*, pp. 67-95. Springer, Boston, MA.

252. Dorina Rajanen Marghescu, Shuhua Liu & Peter Sarlin (2010). Evaluation of a Fuzzy C-Means Model in Currency Crisis Prediction, *TUCS Technical Report*, No. 970, 2010 `https://www.researchgate.net/publication/42800848`

253. Reinert, K. (2013) *Gravity Models*. In K. Reinert and R. Rajan. The Princeton encyclopedia of the world economy. Massachusetts. USA: Princeton University Press

254. Ren Y., Ercsey-Ravasz M., Wng P., Gonzalez M. & Toroczkai Z. (2014) Predicting commuter flows in spatial networks using a radiation model based on temporal ranges. *Nature Communications* Vol. 5 `10.1038/ncomms6347`

255. Ricardo D. (1817) *On the principles of political economy and taxation*. John Murray Publication.

256. Rigobon, R. & Forbes, K. (2000) Contagion in Latin America: Definitions, measurement, and policy implications (No. w7885). *National Bureau of Economic Research*.

257. Rigobon, R. (2001) Does contagion exist?. In *Risk Management: The State of the Art*, pp. 163-166, Springer, Boston, MA.

258. Rigobon, R. (2002) Contagion: how to measure it? In *Preventing currency crises in emerging markets*, pp. 269-334). University of Chicago Press.

259. Rigobon, R. (2003). On the measurement of the international propagation of shocks: is the transmission stable?. *Journal of International Economics*, Vol. 61(2), pp. 261-283.

260. Roberts B. A. (2004) A gravity study of the proposed China-Asean free trade area. *Int Trade J*, Vol. 18(4), pp. 335-353.

261. Roodman D. (2009) How to do xtabond2: An introduction to difference and system GMM in Stata. *The Stata J.*, Vol. 9(1), pp. 86-136.

262. Rose A. K. (2000) Currency unions-one money, one market: the effect of common currencies on trade. *Econ Policy*, Vol. 15(30), pp. 7-45.

263. Rose & Spiegel (2002) A Gravity Model of Sovereign Learning: Trade, Default and Credit, Working Paper 9285, NBER, National Bureau of Economic Research.
`DOI: 10.3386/w9285`

264. Arciniegas Rueda, I. E., & Arciniegas, F. A. (2009). SOM-based data analysis of speculative attacks' real effects. *Intelligent Data Analysis*, Vol. 13(2), pp. 261-300.
`https://www.viscovery.net/scientific-articles/economics`

265. Salam Al-Augby, Sebastian Majewski, Agnieszka Majewska & Kesra Nermend, (2015). A Comparison of K-Means and Fuzzy C-Means Clustering Methods for a Sample of Gulf Cooperation Council Stock Markets. *Folia Oeconomica Stetinensia*, 2015.
`DOI: 10.1515/foli-2015-0001`

266. Salant, S. & D. Henderson (1978) Market anticipations of government policies and the price of gold, *Journal of Political Economy*, Vol. 86, pp. 627-648.

267. Sapir A. (2001) Domino effects in Western European regional trade, 1960- 1992. *European J Polit Econ*, Vol. 17(2), pp. 377-388.

268. Sarker R. & Jayasinghe S. (2007) Regional trade agreements and trade in agri-food products: evidence for the european union from gravity modeling using disaggregated data. *Agric Econ*, Vol. 37(1), pp. 93-104.

269. Sarlin, P., & Marghescu, D. (2010). Visual predictions of currency crises: a comparison of self-organizing maps with probit models.
`https://www.viscovery.net/scientific-articles/economics`

270. Sarlin, P. & Marghescu, D. (2011). Neuro-Genetic Predictions of Currency Crises. *Intelligent Systems in Accounting, Finance and Management*, Vol. 18(4), pp. 145-160.

271. Sarlin, P. & Marghescu, D. (2011). Visual predictions of currency crises using self-organizing maps. *Intelligent Systems in Accounting Finance & Management*, Vol. 18(1), pp. 179-202.
`DOI: 10.1002/isaf.321`

272. Sarlin, P., & Eklund, T. (2011). Fuzzy clustering of the self-organizing map: some applications on financial time series. In *International Workshop on Self-Organizing Maps*, pp. 40-50. Springer, Berlin, Heidelberg.
`https://www.viscovery.net/scientific-articles/economics`

273. Sarlin, P. (2012). Visualizing indicators of debt crisis in a lower dimension: a self-organizing maps approach. *In Handbook of Research on Computational Science and Engineering: Theory and Practice*, pp. 414-431. IGI Global.
`https://www.viscovery.net/scientific-articles/economics`

274. Sarlin, P. (2012). On Biologically Inspired Predictions of the Global Financial Crisis. *Proceedings 26th European Conference on Modelling and Simulation, Klaus G. Troitzsch, Michael Mhring, Ulf Lotzmann* (Editors) ISBN: 978-0-9564944-4-3 / ISBN: 978-0-9564944-5-0 (CD)
`http://www.scs-europe.net/conf/ecms2012/ecms2012 %20accepted%20papers/fes_ECMS_0065.pdf`

275. Sarlin, P. (2013). Exploiting the self-organizing financial stability map. *Engineering Applications of Artificial Intelligence*, Vol. 26(5-6), pp. 1532-1539.
`https://www.viscovery.net/scientific-articles/economics`

276. Siliverstovs B. & Schumacher D. (2008) Estimating gravity equations: to log or not to log?. *Empir Econ*, Vol. 36(3), pp. 645-69.

277. Santos Silva, J.M.C. & Tenreyro, Silvana (2006). The Log of Gravity. *The Review of Economics and Statistics*, Vol. 88 (4), pp. 641-658.
`doi:10.1162/rest.88.4.641.`

278. Simini F, Gonzalez MC, Maritan A & Barabasi AL. (2012) A universal model for mobility and migration patterns. *Nature*. Vol. 484(7392), pp. 96 - 100.
`https://doi.org/10.1038/nature10856`
PMID: `22367540, https://barabasi.com/f/363.pdf`

279. Smith, A. (1876/1986) *The Wealth of Nations*, Books I-III, Reprinted as Penguin Classic 1986.

280. Sohn C-H. (2005) Does the gravity model explain South Koreas trade flows? *Japanese Econ Rev*, Vol. 56(4), pp. 417-430.

281. Soloaga I. & Winters A. (2001) Regionalism in the Nineties: What Effect on Trade? *N Am J Econ Finance*, Vol. 12(1), pp. 1-29.

282. Song C, Koren T, Wang P. & Barabasi AL. (2010) Modelling the scaling properties of human mobility. *Nature Physics*, Vol. 6(10), pp. 818 - 823.
`https://doi.org/10.1038/nphys1760`

283. Song C, Qu Z, Blumm N, & Barabasi AL. (2010) Limits of Predictability in Human Mobility. *Science*, Vol. 327 (5968), pp. 1018 - 1021. https://doi.org/10.1126/science.1177170 PMID: 20167789

284. Stefanouli M. & Polyzos S. (2017) Gravity vs radiation model: two approaches on commuting in Greece, *Transportation Research Procedia*, Vol. 24, pp. 65-72.

285. Tang D. (2005) Effects of the regional trading arrangements on trade: evidence from the NAFTA, ANZCER and ASEAN Countries, 1989-2000. *J Int Trade Econ Dev*, Vol. 14(2), pp. 241-65.

286. Taningco A. & Hernandez J. (2010) Behind-the-border determinants of bilateral trade flows in East Asia. *Asia-Pacific Research and Training Network on Trade* (ARTNET) Working Paper Series, No 80.

287. Teresa M. Sorrosal-Forradellas, Lisana B. Martinez, & Antonio Terceno (2017). Are European sovereign bond spreads in concordance with macroeconomic variables evolution? *Emerald Insight*, ISSN: 0368-492X, Vol. 46(1), 9 January 2017.

288. Thurner, S., Farmer, J.D. & Geanakoplos, J. (2009) Leverage Causes Fat Tails and Clustered Volatility, *Quantitative Finance Paper*, 0908.1555

289. Tinbergen, J. (1962) *Shaping the World Economy: Suggestions for an International Economic Policy*, New York, The Twentieth Century Fund.

290. Thorpe M, Zhang Z. (2005) Study of the measurement and determinants of intra-industry trade in East Asia. *Asian Econ J*, Vol. 19(2), pp. 231 - 247.

291. Tularam, G. & Bhuvaneswari Subramanian (2013) Modeling of Financial Crises: A Critical Analysis of Models Leading to the Global Financial Crisis, *Global Journal of Business Research*, Vol. 7(3), pp. 101 - 124.

292. Tzouvelekas V. (2007) Accounting for pairwise heterogeneity in bilateral trade flows: a stochastic varying coefficient gravity model. *Appl Econ Lett*, Vol. 14(12), pp. 927-930.

293. Van Rijckeghem, C., & Weder, B. (2001). Sources of contagion: is it finance or trade?. *Journal of international Economics*, Vol. 54(2), pp. 293-308.

294. Varga, L., Toth, G., and Neda, Z. (2016), An improved radiation model and its applicability for understanding commuting patterns in Hungary. *Regional Statistics*, 6,2, pp. 27-38.

295. Walras, L. (1874-77) *Elements Economique Pure*. Lausanne: Rouge (Reprint 1900).

296. Wilson J.S., Mann C.L. & Otsuki T. (2003) Trade facilitation and economic development: a new approach to quantifying the impact. *World Bank Econ Rev*, Vol. 17(3), pp. 367-389.

297. Wlti, S. (2003) Testing for contagion in international financial markets: which way to go? *Trinity College Dublin*, 44 pages
www.ted.ie

298. Worthington, A., & Higgs, H. (2004). Transmission of equity returns and volatility in Asian developed and emerging markets: a multivariate GARCH analysis. *International Journal of Finance & Economics*, Vol. 9(1), pp. 71-80.

299. WTO (2015) Regional trade agreements by WTO member, diakses April 2017.
http://www.wto.org

300. Yotov, Y.V., Piermartini, R., Monteiro, J.A. & Larch M. (2016). *An advanced guide to trade policy analysis: The structural gravity model.* ISBN 9789287043689.
`DOI: 10.30875/abc0167e-en.`

301. Zhuang, J (2005) Nonparametric EWS Models of Currency and Banking Crises for East Asia. Chapter 4 in *Early Warning Systems of Financial Crises: Applications to East Asia*. Palgrave MacMillan.

302. Zipf GK (1946) The P1 P2/D Hypothesis: On the Intercity Movement of Persons. *American Sociological Review*, Vol. 11(6), pp. 677-686.
`https://doi.org/10.2307/2087063`

Appendix A

Popular Abbreviations in Economics

Abbreviation	Description
ABB	Activity Based Budgeting
ACFTA	ASEAN-China FTA
ADB	Asian Development Bank
AF	After Effects
AFTA	ASEAN Free Trade Area
AI	Artificial Intelligence
AIFTA	ASEAN-India FTA
AIHD	ASEAN Institute for Health Development
AKFTA	ASEAN-Korea FTA
ANN	Artificial Neural Networks
ANND	Average Nearest-Neighbor Degree
ANNS	Average Nearest-Neighbor Strength
ANP	Analytic Network Process
ANZCER	Austratia-New Zealand Closer Economic Relations
APEC	Asia Pacific Economic Cooperation
APEP	Armour Piercing Enhanced Performance
APO	Asian Productivity Organization
ARC	ASEAN Research Centre
	Asia Research Center
ARIMA	Autoregressive integrated moving-average
ASEAN	Association of Southeast Asian Nations

Abbreviation	Description
BE	Between Effects
BEA	Bureau of Economic Analysis
BLS	U.S. Bureau of Labor Statistics
BLUE	Best Linear Unbiased Estimation
BNI	Bad news indicator
BP M5	Balance of Payments Manual, Fifth Edition
BPS	Central Statistics Bureau
BRICS	Brazil, Russia, India, China, and South Aferica Countries
CARICOM	Caribbean Community and Common Market
CEFTA	Central European Free Trade
CES	Elasticity of Substitution
CFA	Chartered Financial Analyst
CEPII	Centre d'etudes prospectives et d'informations internationales
CI	Computational Intelligence
c.i.f.	Cost-Insurance Freight
CIF	Cost-Insurance Freight
CLMVT	Combodia, the Lao P.D.R., Myanmar, Vietnam and Thailand
CMEA	Council for Mutual Economic Assistance
COMESA	Common Market for Easand Southern Africa
COMTRADE	United Nations Commodity Trade Statistics Database
COD	Commercial Operation Date
COVID-19	Coronavirus
DiD	Difference-in-Differences
DOL	Degree of Operating Leverage
DOLS	Dynamic Ordinary Least Squares
DoT	Direction of Trade
DoTS	Direction of Trade Statistics

Abbreviation	Description
ECCAS	Economic Community of Central African States
ECM	Error Component Model
ECOWAS	Economic Community of West African States
EEC	European Economic Community
EFTA	European Free Trade Association
ELG	ELG Hypothesis
EMFTA	Euro-Mediterranean Free Trade Area
EPA	Economic Partnership Agreement
Eqn.	Equation
ERM	European Exchange Rate Mechanism
EU	European Union
EU12	the 12 Member States of the European Union
EU15	the 15 Member States of the European Union
EU25	the 25 Member States of the European Union
EUC	European Economic Community
EUO	Offices in Europe (IMF)
EUR	Euro
EWS	early warning systems
EY	Ernst & Young
FANP	Fuzzy Analytic Network Process
FANP	Fuzzy Analytic Network Process
FCM	Fuzzy c-means
FDI	Foreign Direct Investment
FE	Fixed Effects
FEVD	Fixed Effect with Vector Decomposition
FEPI	Final Expenditure Price Index
FII	Foreign Institutional Investment
FIPI	Fixed-Input-output Price Index

Abbreviation	Description
FISIM	Financial Intermediation Services Implicitly Measured
FL	Fuzzy Logic
FLS	Flexible Least Squares
FOIPI	Fixed-Output input Price Index
FPI	Final uses Price Index
FTA	Free Trade Agreement
GA	Genetic Algorithm
GAAP	Generally Accepted Accounting Principles
GAFTA	Grain and Feed Trade Association
	Greater Arab Free Trade Area
GATT	General Agreement on Tariffs and Trade
GCC	Gulf Cooperation Council
GDP	Gross Domestic Product
GFC	Global Financial Crisis
GLS	General Ledger System
	Generalized Least Squares
GM	Gravity Model
	Geometric Mean
GMED	Gravity Model Estimation Debate
GNI	Gross National Income
GNI	Good News Indicator
GNP	Gross National Product
GPI	Global Price Index
	Government Price Index
HBS	Household Budget Survey
HICPs	Harmonized Indices of Consumer Prices (Eurostat)
H.M.	Harmonic Mean
HM	Harmonic Mean

Abbreviation	Description
HPI	Household Consumption Price Index
HRD	Human Resources Development
HTM	Heideck Team Member (Oilfield, oil, gas)
ICP	Implicit Characteric Price
ICPI	Intermediate Consumption Price Index
IFRS	International Financial Reporting Standards
IFS	International Financial Statements
iid	independent and identically distribution
i.i.d.	independent and identically distribution
ILO	International Labour Office
	International Labour Organization
IMF	International Monetory Fund
I/O	Input/Output
IPP	International price Program
ISO	International Standards Organization
ITN	International Trade Network
IWGPS	Inter-Secretariat Working Group on Price Statistics
KLR	Kaminsky – Lizondo – Reinhart
KPI	Fixed capital formation Price Index
LAFTA	Latin American Free Trade Association
LSDV	Least Squares Dummy Variable
LTCM	Long-Term Capital Management
MEA	Midwest Economics Association
MENA	Middle East and North Africa
MERCOSUR	Mercado Comun del Sur
MLE	Maximum Likelihood Estimation
MMPI	Money Market Pressure Index
MNC	Multinational Corporations
MoFA	Ministry of Foreign Affairs

Abbreviation	Description
MoU	Memorandum of Understanding
MPI	Import Price Index
NAFTA	North American Free Trade Agreement
NAICS	North American Industrial Classification System
NBPML	Negative Binomial Pseudo Maximum Likelihood
NDMO	National Disaster Management Office
NG	Neuro-Genetic
NGO	Non-Governmental Organization
NN	Neural Network
NPI	Inventory Price Index
NPISH	Nonprofit Institution Serving Households
NPO	National Productivity Organization
OECD	Organization for Economic Co-operation and Development
OLS	Ordinary Least Square
PAFTA	Pacific Alliance Free Trade Area
PBM	Portfolio Balance Model
PBV	Price-to-Book Value
PCA	Principal Component Analysis
PCGDP	per capita Gross Domestic Product
PDM	Project Design Matrix
PDR	Price Dividend Ratio
PER	Pacific Economic Review
PFE	Panel Fixed Effects
PO	Plan of Operation
POLS	Pooled OLS (a method of estimation)
PPI	Producer Price Index
PPML	Poisson Pseudo-Maximum Likelihood models
PPP	Purchasing Power Parity

Abbreviation	Description
PPS	Probability Proportional to Size
PQML	Poisson Quasi Maximum Likelihood
PR	Price Relative
	Pattern Recognition
PROBIT	A Regression method
PTA	Preferential Trade Agreement
RE	Random Effects
REER	Real Effective Exchange Rate
RMSE	Root Mean Square Error
RoO	Rules of Origin
RTA	Regional Trade Agreement
SAA	Stabilization and Association Agreement
SAFTA	South Asian Free Trade Area
SC	Softcomputing
SMC	Simple Matching Coefficient
SNA	System of National Accounts
SNR	Signal-to-Noise Ratio
SOM	Self-Organizing Maps
SPI	Supply Price Index
SVM	Support Vector Machine
SVR	Support-Vector Regression
TOBIT	To bit Regression
	Tobin's probit
TOPSIS	Technique for Order Preference by Similarities to Ideal Solution
TPP	Trans-Pacific Partnership
UFE	Unit Fixed Effects
U.K.	United Kingdom
UK	United Kingdom
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nation Development Programme

Abbreviation	Description
UNECE	UN Economic Commission for Europe
U.S.	United State
US GAAP	United States Generally Accepted Accounting Principles
USA	United State of America
USD	U.S. dollar
VAT	Value Added Tax
VIF	Variance Inflation Factors
VPI	Valuables Price Index
WHO	World Health Organization
WITS	World Integrated Trade Solution
	World Integrated Trade System
WLS	Weighted Least Squares
WPI	Whole Sale Price Index
WTO	World Trade Organization
XPI	Export Price Index
YPI	Output Price Index
ZI	Zero-Inflated
ZINB	Zero-Inflated Negative Binomial
ZIP	Zero-Inflated Poisson
ZIPML	Zero-Inflated Pseudo Maximum Likelihood

Index