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Chapter 1

Introduction

1.1 Introduction

Graph theory, a branch of mathematics, provides a rigorous framework for understanding and modeling networks, the intricate webs of connections that underpin our world. In graph theory, entities or individuals are represented by nodes, and their relationships are denoted by edges. This conceptual framework enables the visualization, analysis, and modeling of complex systems, ranging from social networks to transportation networks, and extending to the complex world of International trade.

In the intricate realm of International trade, the dynamics of Dollarization and De-Dollarization play a pivotal role in shaping economic landscapes. Graph theory, a powerful mathematical tool, emerges as an invaluable instrument for analyzing these complex phenomena and their far-reaching impacts. This project thesis delves into the realm of graph theory, harnessing its capabilities to unravel the intricacies of Dollarization and De-Dollarization in the context of Indian International trade economics.

1.2 Origin of Graph Theory

Graph theory is a branch of mathematics, concerned about how networks can be encoded while their properties are measured. It has been enriched in the last decade by growing influence from the study of social networks. Graph theory is the study of graphs in which mathematical structures are used to model pairwise relations between objects. A graph in this context is a combination of vertices, nodes, or points and edges, arcs, or lines that connect them. A graph may be called as undirected, which means that there is no distinction between the two vertices associated with each edge, or its edge maybe directed from one vertex to another. Past three decades graph theory has established itself as a worth while mathematical discipline and there are many applications of graph theory to a wide variety of subjects while including Operation Research, Physics, Chemistry, Economics, Genetics, Linguistics, Engineering, and Computer Science. Graphs serve as mathematical models to analyze many concrete real-world problems successfully. Konigsberg bridge problem, a recreational mathematical puzzle, set in the old Prussian city of Konigsberg - Russia, that led to the development of the branches of mathematics, known as Topology and Graph Theory.

In the early 18th century, the citizens of Konigsberg spent their days walking on the intricate arrangement of bridges across the waters of the Pregel river, which surrounded two central landmasses connected by a bridge. Additionally, the first landmass was connected by two bridges to the lower bank of the Pregel and also by two bridges to the upper bank, while the other landmass was connected to the lower bank by one bridge and to the upper bank by one bridge, for a total of seven bridges. Eventually, a question arose of whether a citizen could take a walk through the town in such a way that each bridge would be crossed exactly once.

It would be nearly 150 years before mathematicians would picture the Konigsberg bridge problem as a graph consisting of nodes (vertices) representing the landmasses and arcs (edges) representing the bridges. The degree of a vertex of a graph specifies the number of edges in-

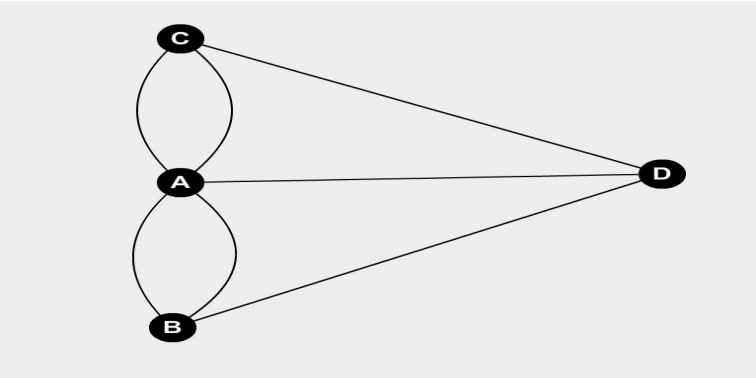

Figure 1.1: Konigsberg Bridge and its Graphical representation

cident to it. In modern graph theory, an Eulerian path traverses each edge of a graph once and only once. Thus, Euler's assertion that a graph possessing such a path has at most two vertices of odd degree was the first theorem in graph theory.

In 1735 a Swiss mathematician Leonhard Euler presented a solution to this problem, concluding that such a walk was impossible. To confirm this, suppose that such a walk is possible in a single encounter with a specific landmass, other than the initial or terminal one here, Two different bridges must be accounted, one for entering the landmass and one for leaving it. Thus, each such landmass must serve as an endpoint of several bridges equaling twice the number of times it is encountered during the walk. Therefore, each landmass with the possible exception of the initial and terminal ones if they are not identical, must serve as an endpoint of an even number of bridges. However, for the landmasses of Konigsberg, A is an endpoint of five bridges whereas, B, C, and D are endpoints of three bridges. Therefore the walk is impossible.

1.3 Development of Graph Theory

After Euler's work for next 100 years nothing more was done in the field. In 1847, **G.R Kirchhoff (1824-1887)** developed the theory of trees in order to solve the system of simultaneous linear equations, which give the current in each branch and around each circuit of an electrical network. Ten years later **Cayley (1821-1895)** discovered the important class of graphs called trees by considering the change of variables in the differential calculus. Later he was engaged in enumerating the isomers of the saturated hydrocarbons C_nH_{2n+2}, with a given number n of carbon atoms. Later **Jordan later (1869)** independently discovered trees as a purely mathematical discipline. Further the game invented by **Sir William** Hamilton in 1859 led to the important concept of Hamiltonian paths and Hamiltonian cycles in graph theory. In 1976, after a long history of failed attempts to prove this, **Kenneth Appel (1932)** and **Wolfgang Haken (1928)** published a computer-assisted proof which many mathematicians were unwilling to accept as valid.

1.4 Definitions

Graph: A graph G is an ordered tuple consisting of a finite set V of vertices and a finite set E of edges where each edge is an unordered pair of vertices. The two vertices associated with an edge e are called the end vertices of e.

Vertices: Nodes represent the objects in the system being modeled. They are represented by points or circles in diagrams.

Edges: Edges represent the relationships between the objects. They are typically represented by lines or curves connecting the nodes.

Directed and Undirected Graphs: In a directed graph, edges have a direction, mean-

ing that they have a starting and an ending point. In an undirected graph, edges do not have a direction.

Weighted and Unweighted Graphs: In a weighted graph, edges have weights, which represent the strength or cost of the connection between the nodes. In an unweighted graph, edges do not have weights.

Adjacent Vertex: A vertex 'u' is adjacent to a vertex 'v' if they are joined by an edge.

Self-Loop: A self-loop is an edge that joins a single endpoint to itself.

Simple Graph: A simple graph is a graph that has no self-loops or multiple edges.

Trivial Graph: A trivial graph is a graph consisting of one vertex and no edges.

Null Graph: A graph without any edges is called a null graph.

Degree of a Graph: If G is a graph, then the number of edges incident at a vertex 'V' of G is called the degree of that vertex in G. It is denoted by d(v).

Regular Graph: A graph G in which all the vertices are of equal degree is called a regular graph.

Isolated vertex: A vertex of degree 0 is an isolated vertex.

Pendant vertex: A vertex of a degree 1 is a pendant vertex.

Pendant edge: The edge incident to a pendent vertex is called a pendant edge.

1.5 Types of Graphs

Complete Graphs: A complete graph is a graph in which every pair of distinct vertices is connected by a unique edge.

Trees: A tree is a connected graph that has no cycles. In other words, it is possible to travel from one node to any other node in the graph without passing through any other node twice.

Bipartite Graphs: A bipartite graph is a graph in which the nodes can be divided into

two sets, such that every edge connects a node from one set to a node in the other set.

Graphs with Special Properties: There are many other types of graphs with special properties, such as planar graphs, chordal graphs, and perfect graphs.

1.6 International Trading

Trade Networks: Trade networks represent the connections between countries or regions engaged in an International trade.

International trading: The exchange or trade of goods and services between different nations.

Export: Goods and services produced in one country but supplied to buyers in another country are known as exports.

Currency: Currency is a medium of exchange for goods and services.

Dollarization: Dollarization refers to the widespread use of the US dollar as a medium of exchange, reserve currency, or unit of account in International trade and financial transactions.

De-dollarization: De-dollarization refers to the process of reducing reliance on the US dollar in International trade and financial transactions.

Bilateral agreement: A bilateral contract is an agreement between two parties in which each side agrees to fulfill their side of bargain.

1.7 Applications of Graph Theory

Graph theory has a wide range of applications in many different fields, including:

- **Computer Science:** Graph theory is used in many areas of computer science, such as algorithm design, network optimization, and social network analysis.
- **Mathematics:** Graph theory is closely related to other areas of mathematics, such as combinatorics, topology, and algebra.

- **Social Sciences:** Graph theory is used to model social networks, such as friendship networks, collaboration networks, and communication networks.
- **Biology:** Graph theory is used to model biological networks, such as protein-protein interaction networks, gene regulatory networks, and metabolic networks.
- **Physics:** Graph theory is used to model physical systems, such as electrical circuits, transportation networks, and communication networks.
- **Economics:** Graph theory and network analysis have emerged as powerful tools to analyze economic systems as networks.

1.8 Applications of Graph Theory in Economics

The applications of graph theory in economics are as diverse as the field itself. Graph theory has proven its utility in analyzing:

- **Social Networks:** Unraveling the structure and dynamics of social networks, identifying influential individuals or communities, and understanding the spread of information and ideas.
- **Transportation Networks:** Optimizing traffic flow, identifying potential bottlenecks, and designing efficient routing strategies in transportation networks.
- **Supply Chains:** Modeling and analyzing supply chains, identifying critical nodes and potential disruptions, and optimizing production and distribution processes.
- **International Trade Networks:** Visualizing trade relationships between countries, analyzing trade patterns, and identifying key trading partners and regions.

1.9 Understanding Dollarization and De-Dollarization

1.9.1 Dollarization

In global trade, the dominance of the US dollar is profound. It goes beyond just preferring the dollar over local currencies; it fundamentally shapes how goods are traded worldwide. For example, products like Indian spices might be sold in US dollars to European buyers, and contracts for Venezuelan oil are settled using American currency. This illustrates the core concept of dollarization in global trade [3]. Imagine it as a coin with two sides. On one side, using the dollar offers stability and ease on the other side. Conducting transactions in USD simplifies international commerce, reducing currency exchange complications and aiding in financial settlements across borders. This can be advantageous for developing economies, attracting investments and strengthening trade relationships. However, there's a downside. Heavy reliance on the dollar makes countries susceptible to changes in US monetary policies. A strong dollar can inflate export prices, affecting competitiveness on the global stage. Moreover, depending on a foreign currency limits a nation's control over its own economy, impacting its ability to manage inflation and shape monetary policies. Dollarization levels vary widely across countries, some, like Ecuador, extensively use the dollar, while others, like India, are working to promote their own currencies. It's not just about convenience versus control, but it's about finding a balance between leveraging the stability of the dollar and preserving economic independence. As global trade progresses, understanding the complexities of dollarization remains vital for nations aiming to succeed in the International market.

1.9.2 De-Dollarization

India is boldly stepping away from its reliance on the US dollar in global trade, a strategy known as de-dollarization [7]. This move aims to reduce India's dependence on the dollar and strengthen the importance of its own currency, the Rupee. By doing so, India seeks greater control over its economy, aiming to minimize vulnerability to fluctuations in US economic

policies that affect its exports and limit its ability to manage its economy independently, To achieve de-dollarization, India is actively promoting the use of the Rupee in International transactions. India is forming agreements with other nations to conduct trade deals in rupees instead of dollars [6]. Additionally, diversifying its foreign exchange reserves by holding currencies other than the dollar, like Euros and Yuan, is part of its strategy to lessen reliance on the dollar's dominance in global trade. However, this transition is not without its challenges. Building trust in the rupee as a global reserve currency takes time. There's a need for significant improvements in its infrastructure and legal frameworks to support this shift. India's ongoing move away from the dollar demonstrates a determined effort to secure greater economic autonomy. Whether the Rupee can significantly diminish the dollar's importance remains uncertain, but India's proactive approach challenges the prevailing economic norms and could potentially reshape the dynamics of the global trade in future.

1.10 MATLAB

MATLAB was chosen for this research due to its powerful capabilities in the creation and manipulation of graphs, which serve as the foundational data structure for the analysis conducted. Additionally, MATLAB's proficiency in machine learning was leveraged to implement and tailor algorithms, crucial for predicting and dissecting intricate relationships within the research scope. Furthermore, the software's process in data visualization was instrumental in generating visually compelling and informative charts and graphs, essential for effectively presenting the research findings.

1.11 Objectives of the analysis

The primary objective of this analysis is to analyze the impact of Dollarization and De-dollarization on the Indian-International trading economy using graph theoretical techniques. The specific objectives include:

- **Quantifying the extent of Dollarization in India's international trade:** Measuring the degree to which the US dollar is used as a medium of exchange, reserve currency, and unit of account in India's international trade transactions.
- **Modeling the impact of Dollarization on network structure:** Developing a graph-based model to simulate the impact of Dollarization on the structure of India's international trade network, including changes in centrality measures, community detection, and network flow patterns.
- **Evaluating the impact of dollarization on network resilience:** Assessing the impact of dollarization on the resilience of India's international trade network to shocks and disruptions, such as financial crises and geopolitical tensions.
- **Analyzing the potential benefits and risks of de-dollarization:** Identifying the potential economic and financial benefits and risks associated with de-dollarization for India's international trade.
- **Developing policy recommendations for de-dollarization:** Proposing policy recommendations for mitigating the potential risks and maximizing the potential benefits of de-dollarization for India's international trade.

Chapter 2

Literature review

2.1 Introduction

Dollarization is the process of a country adopting the U.S. dollar as a parallel or official currency in place of, its domestic currency. This can take different forms:

- Full Dollarization: This entails complete abandonment of the domestic currency in favor of the US dollar for all transactions. El Salvador is an example of a country that adopted full Dollarization in 2001.
- Partial Dollarization: This involves using the US dollar alongside the domestic currency for specific transactions, such as International trade or specific types of contracts. Many countries in Central and South America have adopted partial Dollarization.

De-dollarization is the process by which a country or region reduces its reliance on the US dollar as the dominant currency in its economy.

2.1.1 Factors that contributed to the Dollarization of Indian foreign trade

1. **Widely accepted currency:** The US dollar's status as a global reserve currency often makes Dollarization convenient for Indian businesses. It offers stability and predictability in trade prices, as the dollar is less prone to fluctuations compared to other currencies.

2. **Reduced transaction costs:** Using the dollar can minimize transaction costs associated with currency conversions, especially for trade in commodities often priced in dollars.

3. **Access to global markets:** Dollarization facilitates India's integration into global markets as the dollar is widely used internationally. It can boost trade by simplifying transactions for Indian importers and exporters.

4. **Vulnerability to external shocks:** A high degree of Dollarization makes India's economy more susceptible to external shocks originating in the US economy, such as changes in US monetary policy or fluctuations in the value of the dollar.

5. **Loss of monetary policy control:** With Dollarization, India partially relinquishes its ability to use monetary policy tools for managing its economy as its policies become strongly linked to those of the US.

2.1.2 Factors behind Indian foreign trade focusing on De-dollarization

1. **Increased economic sovereignty:** Reducing reliance on the US dollar can give India greater control over its monetary policy and exchange rate management, bolstering its economic independence.

2. **Reduced vulnerability to external risks:** De-dollarization helps India insulate its economy from the effects of US economic policies and potential volatility in the dollar's value.

3. **Promotion of the rupee:** De-dollarization can support the internationalization of the Indian rupee, increasing its use in global trade settlements. This could reduce transaction costs and enhance India's economic influence.

4. **Potential trade diversification:** De-dollarization can incentivize India to diversify its trading partners and explore the use of other currencies, potentially leading to new trade opportunities.

5. **Challenges:** Implementing De-dollarization can be complex. It requires building confidence in the rupee, establishing trade mechanisms in other currencies, and potentially navigating geopolitical considerations.

2.1.3 Impacts of Dollarization and De-dollarization on India's Import and Export

Dollarization

- Import prices
  - Lower: The stability of the dollar can offer predictability and potentially lower import prices, especially for commodities typically priced in dollars like oil.
  - Higher: A strong dollar relative to the rupee can increase the cost of imports, potentially making them less competitive in the Indian market.
- Export prices
  - Lower: A strong dollar can make Indian exports cheaper and more competitive in the global market.
  - Higher: A weak dollar can make Indian exports less competitive, potentially leading to lower export volumes.

De-dollarization

- Import prices
  - More volatile: The import prices would become more susceptible to fluctuations in the rupee's exchange rate with other currencies used in trade.
  - Potentially lower: If De-dollarization leads to rupee appreciation, import prices could decrease.
  - Potentially higher: If De-dollarization leads to rupee depreciation, import prices could increase.
- Export prices
  - More volatile: Export prices would also become more susceptible to exchange rate fluctuations.
  - Potentially higher: Rupee depreciation could make Indian exports more competitive globally.
  - Potentially lower: Rupee appreciation could make Indian exports less competitive globally.

2.2 Empirical Studies

"The Impact of Dollarization Policy on Zimbabwe Export: A Gravity Model Approach" was an article in the International Journal of Economics and Financial Issues. This paper investigates the impact of Dollarization policy on Zimbabwe's exports over 20 years. The study used panel data for 50 Zimbabwe potential historical trading partners. The random effects model (REM) was applied to estimate the gravity model equation. Panel feasible generalized least squares (FGLS) regression technique corrected for heteroskedasticity and contemporaneous correlation across panels was applied to probe factors that drive Zimbabwe export flows.

The results provide insights into the impact of the Dollarization policy, GDP, bilateral exchange rate, SADC membership status, and population on Zimbabwe exports. If monetary authorities involuntarily re-dollarize the economy owing to monetary autonomy erosion, emphasis should be directed towards internal devaluation which could be attained by measures intended to exert downward pressure on domestic costs, wages, and prices to recuperate export competitiveness. Further, the government has to create an environment that encourages foreign direct investment inflows to ease liquidity challenges probable to be experienced under the Dollarization regime. Nevertheless, macroeconomic fundamentals ought to be addressed with action to spur economic growth. Sufficient resources should be channeled towards increasing the country's productive capacity, and this can enhance the country‘s ability to supply export products to the international market and curb import growth.

"Stock Market Prediction Using Ensemble of Graph Theory, Machine Learning, and Deep Learning Models" was the Master's project, in which a novel approach is proposed using graph theory. This approach leverages temporal relationship information between different stocks by modeling the stock market as a complex network. This graph-based approach is used along with two techniques to create two hybrid models. Two different types of graphs are constructed, one from the correlation of the historical stock prices and the other is a causation-based graph constructed from the financial news mention of that stock over a period. The first hybrid model leverages deep learning convolutional neural networks and the second model leverages a traditional machine learning approach. These models are compared along with other statistical models and the advantages and disadvantages of graph-based models are discussed. Our experiments conclude that both graph-based approaches perform better than the traditional approaches since they leverage structural information while building the prediction model. This helps to understand how Graph theory, Machine learning, and Deep learning models work in the analysis.

2.3 Machine learning

Machine learning has been used widely in the field of economics. The focus of the majority of the studies was to forecast the import and export volumes, analyzing price sensitivity and competitiveness, financial risk assessment and management, trade pattern identification, and policy simulation.

ML models like ARIMA, LSTM networks, or hybrid models can analyze historical data on import/export volumes, exchange rates, global commodity prices, macroeconomic factors, and potentially textual sentiment data surrounding trade policies. These models can forecast how import/export volumes are likely to change under different Dollarization/De-dollarization scenarios. It helps set up counterfactual scenarios to estimate and compare trade volumes if India had pursued a different currency policy (e.g., greater De-dollarization) during a specific historical period.

Machine learning can build complex models to estimate the price elasticities of demand for India's imports and exports. This helps understand how changes in the dollar-rupee exchange rate (due to Dollarization or De-dollarization) would likely impact the prices and competitiveness of Indian goods. Using web scraping techniques combined with ML, researchers could analyze how rivals in the export market price their goods. This helps assess how shifts in exchange rates might impact India's price competitiveness in a dynamic landscape.

Predicting exchange rate volatility machine learning models can forecast fluctuations in the value of the rupee against the dollar and other relevant currencies. This allows businesses and policymakers to better understand and potentially hedge against forex risks in the context of Dollarization or De-dollarization. ML algorithms can assist financial institutions in assessing the creditworthiness of importers and exporters, potentially streamlining the trade financing process and reducing financial risk. Using transaction data, machine learning can map out India's trade networks, identifying key partners and trade flows in terms of prod-

ucts and currencies. De-dollarization could lead to changes in these networks, which could be visualized and evaluated. Machine learning models could simulate the potential impact of different policy scenarios, such as changes in tariffs or promoting the use of specific currencies for settlements.

2.4 Graph Theory Approach

Graph Machine Learning (GML) takes the graph-based analysis of trade networks a step further by applying powerful machine learning techniques directly to graph structures. Here's how GML can enhance the study of Dollarization and De-dollarization impacts on Indian trade:

1. **Node embedding and classification:** Trade partner analysis: GML algorithms can learn representations ("embeddings") for each country (node) in the trade network. These embeddings capture structural information in the graph (trade relationships, currency usage) as well as node attributes (country's economic size, trade specialization).

2. **Classification and prediction:** Using these embeddings, GML models can classify countries into groups based on their trade patterns and potential vulnerability to currency shifts. They could also predict shifts in trade volumes or currency usage patterns following changes in policy.

3. **Link prediction:**Identifying new trade opportunities: GML models can predict which countries are likely to become India's new trading partners or which pairs of countries are likely to increase trade. This could be particularly valuable for exploring diversification strategies during De-dollarization.

4. **Forecasting changes in currency usage:** GML could be used to predict which trade relationships might shift from dollar-denominated settlements to other currencies as a

result of D-dollarization policies.

5. **Community detection and change analysis:**Impact on trade blocs: GML can detect communities or clusters of countries with similar trade patterns and currency preferences. Analyzing how these communities evolve can inform policymakers about the potential ripple effects of India's currency policies on existing trade blocs.

6. **Early warning system:** If a large fraction of India's trade connections start showing early signs of a shift towards different currencies or trade partners, this could signal wider trends impacting trade flows.

7. **Modeling complex interactions:**Combining graph data with other modalities: GML models can seamlessly integrate graph structures (trade network) with time-series data (exchange rates, commodity prices) or textual data (trade agreements, news sentiment). This allows analysis of the complex interplay between currency fluctuations, trade flows, and policy changes.

2.4.1 Represention of Graphs

There are different ways to represent graphs in computer memory, each with its own advantages and disadvantages depending on the specific use case. Here are two common representations:

- **Adjacency Matrix:**

  Creates a two-dimensional matrix where rows and columns represent nodes. Each element in the matrix (i, j) indicates the presence or absence (often using 0 or 1) of an edge connecting node i to node j. This method is efficient for checking connections but might be memory-intensive for sparse graphs (those with few edges compared to the number of nodes).

- **Adjacency List:**

  Uses an array of lists, one for each node. Each element in a list represents a node connected to the corresponding node in the array. This method is more memory-efficient for sparse graphs and easier to implement for adding or removing edges.

2.4.2 Graph Machine Learning algorithms

Some of the Graph Machine Learning algorithms often operate on graphs represented as adjacency matrices or adjacency lists as their underlying data structure. Here are some commonly used GML algorithms and their relationship with adjacency list representation:

- **Community Detection Algorithms:** These algorithms identify groups of nodes (communities) within a graph that are densely connected to each other. Examples include Louvain Modularity, Spectral Clustering, and Label Propagation. While not directly creating an adjacency list, these algorithms can be applied to a graph represented as an adjacency list and output the identified communities, which can be helpful for analyzing the structure and organization of the trade network.
- **Link Prediction Algorithms:** These algorithms predict the likelihood of an edge forming between two nodes in a network based on the existing network structure and node attributes. Examples include Common Neighbors, Adamic/Adar, and Preferential Attachment. While not directly constructing an adjacency list, their predicted edges could be integrated into the existing adjacency list representation of the trade network if those predictions are deemed reliable.
- **Node Classification Algorithms:** These algorithms categorize nodes in the network based on their features and connections. Examples include Logistic Regression, Support Vector Machines (SVM), and Graph Convolutional Neural Networks (GCNs). Again, these algorithms wouldn't directly create an adjacency list, but their classification results

could provide valuable insights into the characteristics of different nodes within the trade network.

- **Graph Neural Networks (GNNs):** These are a class of deep learning models designed specifically for processing graph-structured data. Examples include GCNs, Graph Isomorphism Networks (GIN), and Message Passing Neural Networks (MPNNs). GNNs often operate on graphs represented as adjacency matrices, but some variations might utilize adjacency lists. They are typically used for tasks like node classification, link prediction, and graph generation, not directly generating adjacency lists.

- **Graph Centrality Measures:** Centrality measures are crucial tools in graph theory and network analysis, particularly when applied to trade networks. They help identify the "importance" or "influence" of individual nodes (countries) within a network, providing valuable insights into their trade patterns and potential vulnerabilities. Some algorithms like Degree centrality, PageRank, and Eigenvector centrality are helpful measuring and quantifing the importance or influence of individual nodes within the graph by calculating centrality measures for users and items in the bipartite graph.

2.4.3 Assortativity and Correlation Coefficients Algorithms

The assortativity coefficient is a metric used to quantify the tendency of nodes in a network to connect with other nodes that have similar or dissimilar properties. Here's an overview of calculating the assortativity coefficient for an undirected, weighted graph represented by an adjacency list.

Consider an undirected network N in which each node has a type belonging to a (finite) set T. The assortativity coefficient is defined as

$$r = \frac{\sum_{t \in T} x_{tt} - \sum_{t \in T} y_t^2}{1 - \sum_{t \in T} y_t^2},$$

where x_{st} is the proportion of edges joining nodes of type 's' to nodes of type 't', whereas,

$$y_t = \sum_{s \in T} x_{st}$$

is the proportion of edges incident with nodes of type 't'. The Pearson correlation of adjacent nodes' types is given by

$$\rho = \frac{Cov(t_i, t_j}{\sqrt{Var(t_i)Var(t_j)}},$$

where $t_i, t_j \in T$ are the types of nodes i and j, whereas (co)variances are computed with respect to the frequency at which nodes of type t_i and t_j are adjacent in N.

The assortativity coefficient ranges from -1 to 1, where r = 1 indicates perfect positive assortativity, meaning nodes tend to connect only with others having similar property values, while r = 0 represents no assortativity, and connections are random with respect to the chosen property and r = -1 indicates perfect negative assortativity, meaning nodes tend to connect only with others having dissimilar property values.

This approach utilizes the adjacency list structure to construct the required data, libraries or frameworks might offer more efficient implementations for calculating the assortativity coefficient, especially for larger or more complex graphs.

Chapter 3

Data Set

A data set is a collection of organized information, often in tabular format, used in analysis and modeling. In this project, the data set will be used to analyze the impact of Dollarization and De-dollarization on Indian international trade.

3.1 Data Collection Process

The initial step in the process involves pinpointing the specific trade data needed, such as exports, imports and trade balance. Following this, it is crucial to establish the pertinent time frame for data collection, which might encompass the last decade or coincide with particular events like Dollarization or De-dollarization. Accessing selected data sources comes next, where the aim is to procure the pertinent information in a compatible format like CSV or Excel. To ensure the accuracy and consistency of the data, cross-verification across multiple sources becomes imperative. Additionally, identifying the relevant exchange rates, such as USD/INR or EUR/INR, is mandatory for the analysis. Determining the desired time span for data collection and downloading the information from chosen sources while ensuring compatibility with existing trade data is pivotal. Finally, a thorough check for missing values and inconsistencies should be conducted to ensure the reliability and integrity of the collected

data.

3.2 Data Collection

3.2.1 Trade Value Data

- **Official Government Websites:** Directorate General of Commercial Intelligence and Statistics (DGCI&S) Provides monthly and annual data on India's foreign trade, including exports, imports, and trade balance by country and commodity.
- **Reserve Bank of India (RBI):** Publishes data on India's balance of payments, which includes information on foreign exchange reserves and trade flows.
- **Economic Research Institute National Council of Applied Economic Research (NCAER):** Conducts research on various economic issues, including international trade.
- **Indian Council for Research on International Economic Relations (ICRIER):** Focuses on research related to India's international trade and economic relations.
- **International Trade Databases United Nations Comtrade Database:** Provides data on global trade flows by country and commodity.
- **World Trade Organization (WTO) Trade Statistics Database:** Offers information on trade policies and statistics.

3.2.2 Exchange Rate Data

- **RBI Website:** Provides daily, weekly, and monthly exchange rate data for various currencies, including the US dollar.
- **Bloomberg Terminal:** Offers real-time and historical exchange rate data.

- **Financial Data Providers:** Companies like Reuters and Thomson Reuters offer financial data, including exchange rates.

3.2.3 Economic Indicators

- GDP growth rate
- Inflation rate
- Interest rates
- Foreign Direct Investment (FDI)

In the dataset mentioned, we sourced the data from the official Indian government website, https://tradestat.commerce.gov.in/eidb/default.asp We utilized country-wise import and export data for both Dollars and Rupees. The dataset was conveniently available for download in Excel format, which proved more useful for comprehensive data analysis. The data was obtained directly from the official Indian government website, ensuring its authenticity and reliability. Utilizing country-wise import and export data in both Dollar and Rupees allowed for a comprehensive analysis of trade activities.

A	B	C	D	E	F	G	H	I	J	K	L	M
IND	Country	2021-2022	value	value	value 1	2022-2023	value	value 2	value 2	)23-2024(Apr-Sep)		Value
IND	ANTARTICA	0.07	70000	700000	51753730	0.1	100000	1000000	78604800	0.26	2600000	214442280
IND	ANTIGUA	2.47	2470000	24700000	1826167330	2.9	2900000	29000000	2279539200	10.95	109500000	9031319100
IND	ARGENTINA	1,425.94	1425940000	14259400000	1054253053660	960.4	960400000	9604000000	754920499200	484.55	4845500000	399646179900
IND	ARMENIA	27.47	27470000	274700000	20309642330	61.37	61370000	613700000	48239765760	52.82	528200000	43564773960
IND	ARUBA	6.22	6220000	62200000	4598688580	14.62	14620000	146200000	11492021760	8.76	87600000	7225055280
IND	AUSTRALIA	8,283.13	8283130000	82831300000	6124041051070	6,951.32	6951320000	69513200000	5464071183360	4,896.72	48967200000	4038706928160
IND	AUSTRIA	564.32	5643200000	5643200000	417223784480	1,261.64	1261640000	12616400000	991709598720	516.18	5161800000	425733908040
IND	AZERBAIJAN	36.42	36420000	364200000	26926726380	100.96	100960000	1009600000	79359406080	41.94	419400000	34591189320
IND	BAHAMAS	8.06	8060000	80600000	5959072340	12.76	12760000	127600000	10029972480	7.36	73600000	6070366080
IND	BAHARAIN IS	899.9	8999000000	8999000000	665331166100	965.25	965250000	9652500000	758732832000	292.11	2921100000	240925901580
IND	ANGLADESH P.R	16,156.37	1615637000	1615637000000	11945034439430	12,203.93	12203930000	122039300000	9592874768640	5,040.84	50408400000	4157573933520
IND	BARBADOS	16.19	16190000	161900000	11969898410	24.19	24190000	241900000	19014501120	8.18	81800000	6746684040
IND	BELARUS	65.34	65340000	653400000	48308410260	43.91	43910000	439100000	34515367680	20.82	208200000	17171877960
IND	BELGIUM	10,084.37	1008437000000	100843700000	7455768031430	8,864.09	8864090000	88640900000	6967600216320	4,225.74	42257400000	3485297385720
IND	BELIZE	15.25	15250000	152500000	11274919750	15.93	15930000	159300000	12521744640	7.51	75100000	6194082780
IND	BENIN	716.41	7164100000	7164100000	529669852990	892.81	8928100000	89281000000	7017915148800	513.27	5132700000	423333804060
IND	BERMUDA	5.53	5530000	55300000	4088544670	5.05	5050000	50500000	3969542400	3	30000000	2474334000
IND	BHUTAN	885.81	8858100000	8858100000	654913879590	1,070.37	1070370000	10703700000	841362197760	460.09	4600900000	379472110020
IND	BOLIVIA	117.95	1179500000	1179500000	87205035050	77.34	77340000	773400000	60792952320	41.63	416300000	34335508140
IND	SNIA-HRZGOVIN	17	170000000	170000000	12568763000	17.23	17230000	172300000	13543607040	17.92	179200000	14780021760
IND	BOTSWANA	278.87	2788700000	2788700000	206179466930	171.27	1712700000	17127000000	1346264409600	55.88	558800000	46098694640

Figure 3.1: Dataset

3.3 Data Cleaning Process

- **Identify and address missing values:** Addressing missing values in the dataset is a critical step that involves two primary strategies imputation and exclusion. Firstly, identification of missing values is crucial, and employing imputation techniques becomes necessary to fill in these gaps within the dataset. Various imputation methods, such as mean, median, or predictive modeling, can be used to estimate and replace missing values, enhancing the comprehensiveness of the data. However, in cases where missing information significantly impacts the dataset's integrity, exclusion of those particular data points might be warranted to maintain accuracy in subsequent analyses.

- **Check for outliers and inconsistencies** Another vital aspect of data cleaning involves the detection and management of outliers and inconsistencies. Analyzing the distribution of data aids in identifying potential outliers that lie beyond the expected range. Employing techniques like winsorization can help address outliers by capping extreme values, ensuring a more balanced dataset. Additionally, inconsistencies among various data sources require thorough investigation and resolution to harmonize conflicting information, thereby ensuring the coherence and reliability of the dataset.

- **Standardize the data format:** Standardizing the data format is pivotal for a consistent and coherent analysis. Ensuring uniformity in units, time periods, and data types across the dataset helps in facilitating accurate comparisons and meaningful interpretations. Converting the data into a suitable format, particularly a numerical format, enhances its compatibility for statistical analysis and modeling purposes.

- **Document the data cleaning process:** Documenting the entire data cleaning process is essential for transparency and reproducibility. Keeping a detailed record of the cleaning steps undertaken, along with justifications for each decision made, ensures a clear trail of actions taken. This documentation aids in replicating the results and allows for better understanding and validation of the data cleaning procedures followed, thereby enhancing trust and confidence in the subsequent analyses.

3.4 Data Set Structure

The structure of the final dataset is integral to its usability and comprehension, necessitating a clear and consistent organization. This involves careful consideration of several key factors. Firstly, organizing entities within the dataset involves categorizing countries, commodities, and distinct time periods systematically. Secondly, the attributes within the dataset, such as trade values, exchange rates, economic indicators, and political factors, need to be structured in a coherent manner, ensuring ease of analysis and interpretation. Lastly, establishing relationships within the dataset is crucial, encompassing trade flows between countries, the correlation between exchange rates and trade dynamics, and the impact of political factors on various economic indicators. This structured arrangement of entities, attributes, and relationships not only enhances the accessibility and organization of the dataset but also facilitates comprehensive analyses and insights into the intricate interplay between different factors affecting trade and economics.

3.5 Additional Considerations

In addition to structuring the dataset, several additional considerations are vital for its effective utilization and ethical handling. First and foremost, ensuring data quality is imperative, requiring meticulous attention to source selection and rigorous data cleaning processes to guarantee accuracy and reliability. Secondly, prioritizing data security is crucial, necessitating secure storage and management practices while adhering to ethical guidelines and data privacy regulations to safeguard sensitive information. Lastly, contemplating data availability is essential, as sharing the dataset publicly can significantly contribute to broader research and analysis endeavors, fostering collaboration and advancements in various fields. Prioritizing these considerations not only enhances the integrity and utility of the dataset but also promotes responsible and beneficial use of data for societal and scientific progress.

By following the process we can create a comprehensive and well-organized data set that will support the effective analysis of dollarization and de-dollarization in Indian international trade using graph theory models.

Chapter 4

Modeling Data into a Graph

This chapter describes the process of modeling the trade data in a graph format for analysis. This approach allows us to leverage the power of graph theory and graph algorithms to understand the relationships between countries and analyze the impact of Dollarization and De-dollarization.

4.1 Graph Model Design

The design of the graph model revolves around two fundamental components, namely nodes and edges. Nodes within this model serve as representations of the various countries engaged in trade activities with India. These nodes encapsulate the distinct entities participating in trade relationships. On the other hand, the edges in this graph signify the connections or trade links between these countries. These edges embody the trade relationships, illustrating the interactions and exchanges between respective nations. What distinguishes these edges is the associated weight, which signifies the trade value between connected countries. Notably, this weight factor can be further delineated based on the currency employed for trade transactions, whether in USD or INR. This design allows for a comprehensive depiction of the trade landscape, capturing both the relationships between countries and the varying trade values

based on currency specifics.

4.2 Model Implementation

The implementation of the graph model was executed through the MATLAB Graph Toolbox, involving distinct steps for seamless execution.

4.2.1 Data Preparation

Firstly, the process commenced with data preparation. Trade data sourced from Excel spreadsheets underwent meticulous cleaning and preprocessing. This critical phase ensured the data's uniformity and precision, facilitating reliable analysis. Organizing the data into separate tables, categorized by both year and currency, streamlined subsequent operations.

```
% Load the data from the Excel file
% export $ 96-97
format bank
data = readtable('export $ 96-97.xlsx');

% Extract the 'from', 'country', and 'value' columns
from96 = data.IND;
country96 = data.Country;
value96 = data.Value;
```

Figure 4.1: Upload Data

4.2.2 Graph Creation

Subsequently, the graph creation ensued. For each specific year and currency, a weighted bipartite graph was generated using the versatile graph function. This process utilized the

'from' and 'country' columns to create nodes within the graph. The 'value' column contributed to defining the edges' weights, showing the trade values more precisely. Additionally, labels were assigned to nodes and edges, enhancing the graph's clarity and facilitating easier identification.

```
% Create a weighted bipartite graph
G96 = graph(from96, country96, value96);

% Plot the graph
figure;
plot(G96, 'Layout', 'force');
title('export $ 1996');
```

Figure 4.2: Graph Creation

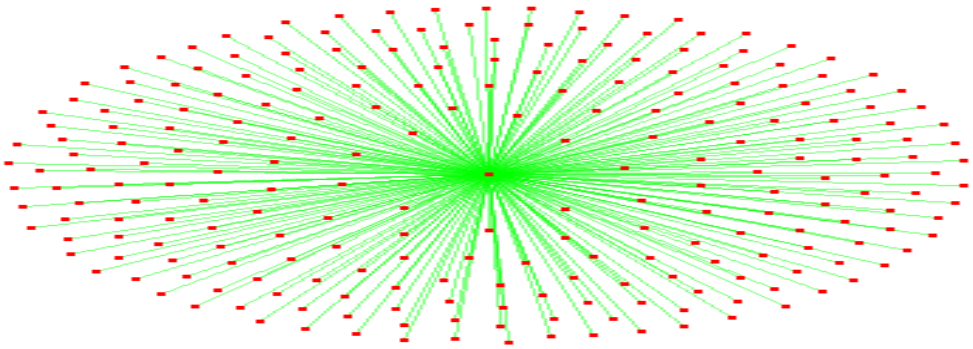

Figure 4.3: Example

4.2.3 Adjacency List

In addition to the graph creation described earlier, an alternative data structure used for efficient representation and analysis is the adjacency list. This structure maintains a list

```
% Extract the weight, country, and from data from the graph
X96 = G96.Edges.Weight;
Y96 = G96.Edges.EndNodes;
T96 = table(Y96,X96);
disp(T96);

% Check for NaN values in the weight array
nanIndices = isnan(X96);
X96(nanIndices) = 0;
```

Figure 4.4: Adjacency List

of connected edges for each node in the graph, including the destination node and associated weight. It offers advantages in terms of memory efficiency and specific analysis tasks compared to the adjacency matrix.

In our implementation, we created an adjacency list for each node in the graph, containing a list of connected edges with their respective destination nodes and edge weights. This facilitated efficient calculations of metrics such as betweenness, centrality and shortest paths, which are crucial for understanding the influence and connectivity of individual countries in the trade network.

Furthermore, the adjacency list representation proved beneficial for analyzing specific trade flows. By iterating through the list of edges for a selected node, we were able to identify its direct exports or imports and visualize the corresponding trade routes. This provided a detailed view of specific trade relationships and enabled the identification of key trade corridors.

4.2.4 Visualization

The implementation phase progressed to Visualization, where the plot function, leveraging the force layout, was instrumental in graph visualization. This visualization technique offered insights into the intricate relationships between countries, illuminating potential clusters or communities within the trade network. The force layout's dynamic depiction aided in comprehending the connections between nodes and identifying patterns or groupings that might exist within the trade landscape.

```
% creating the column chart
x = categorical({'1996-1997', '2021-2022', '2022-2023', '2023-2024'});
bar_1 = [percentage96,percentage22, percentage23,percentage24];
bar_2 = [percentage96_1, percentage22_1, percentage23_1, percentage24_1];

figure;
bar(x, [bar_1; bar_2]);
xlabel('years');
ylabel('Values');
legend('Dollar', 'Rupees');
title('Chart');

% Displaying values in each column
text(x, bar_1, num2str(bar_1'), 'HorizontalAlignment', 'center', 'VerticalAlignment',
text(x, bar_2, num2str(bar_2'), 'HorizontalAlignment', 'center', 'VerticalAlignment',
```

Figure 4.5: Visualisation

4.3 Analysis using Graph Model

The graph model facilitates the following analyses:

- **Total Trade Value:** The graph model serves as a versatile tool enabling several crucial analyses. One of its primary functions involves determining the Total Trade Value. By summing up the edge weights associated with a specific currency and year, it provides an aggregate view of the trade activities within India. This metric acts as a comprehensive indicator, offering insights into the overall trade engagement involving the country.

- **Trade Relationships:** The graph model facilitates an in-depth examination of Trade Relationships. Through an analysis of the presence and weight of edges linking particular countries, it unveils the intensity and directionality of trade associations. Additionally, by identifying clusters or communities within the graph structure, researchers can uncover regional trade patterns, shedding light on interconnected trade dynamics across different geographical regions.

- **Dollarization and De-Dollarization:** The graph model enables a nuanced assessment of Dollarization and De-Dollarization trends. By comparing the total trade value and edge weights attributed to USD and INR across various years, it allows for an evaluation of the relative prominence of each currency in Indian trade. This analysis proves instrumental in recognizing shifts or tendencies towards either Dollarization or De-dollarization within the trade landscape, offering valuable insights into currency preferences and their implications.

4.4 Advantages of Graph Model

The graph model presents numerous advantages in analyzing trade data. Firstly, it offers a visually intuitive representation, offering a clear depiction of trade connections among different countries. This visual approach facilitates an easy-to-understand comprehension of the complex web of trade relationships. Secondly, the model's utilization of network analysis allows for the application of diverse graph algorithms. This capability enables the extraction of deeper insights from the data, aiding in the identification of crucial trading partners and communities within the network. Thirdly, the model exhibits scalability, as it can be readily adjusted to manage larger datasets and integrate supplementary information, including trade agreements or geographical distances. This adaptability enhances its utility by accommodating additional layers of complexity in the analysis process, thereby augmenting the model's effectiveness in comprehensively understanding and interpreting trade dynamics.

4.5 Limitations of Graph Model

Despite its advantages, the graph model also has some limitations:

- **Complexity:** Depending on the data size and chosen analysis techniques, the model can become complex and computationally expensive.
- **Data limitations:** The model's accuracy depends on the quality and completeness of the underlying data.
- **Interpretation:** Extracting meaningful insights from the model requires expertise in graph theory and analysis techniques.

The graph model provides a powerful and versatile approach to analyze international trade data. It facilitates the visualization of trade relationships, enables network analysis, and helps assess the impact of Dollarization and De-dollarization. While there are limitations to consider, the benefits of this approach make it a valuable tool for researchers and policymakers studying international trade dynamics. This chapter provides a basic framework for the analysis. We can further enhance it by including specific details in upcoming chapters.

Chapter 5

Results for Export

India's export journey has undergone significant transformations. Initially, exporting raw materials under British rule, the focus shifted inwards after independence. However, 1991 marked a turning point, with economic liberalization prioritizing export-led growth. Devaluing the rupee, reducing trade barriers, and establishing Special Economic Zonesez fueled a rise in exports, diversifying beyond traditional textiles and garments to include pharmaceuticals, engineering goods, and IT services.

The US dollar plays a complex role in this equation. A strong dollar can make Indian exports cheaper for foreign buyers, potentially boosting volume, but it can also lead to imported inflation and potentially decrease demand due to higher costs. Beyond the dollar's direct influence, domestic policies, global economic conditions, trade agreements, and India's own competitiveness significantly shape the landscape of Indian exports.

5.1 Dollarization

As we know after the Second World War the impact of the dollar on the global economy was abnormal and it is the same in the Indian economy too. After freedom India started to

focus on international trade. In 1950, the GDP of India was hard to determine due to changing methodologies and inflation adjustments. However, estimates are around 133.7 billion rupees, and currently (2023) the GDP of India is 230 trillion rupees, which has a growth of roughly 172,484% between 1952 and 2023, at the same time, the impact of the dollar did not change.

The below graphs deal with Indian International exports in 1996 for both USD and INR and compare the differences.

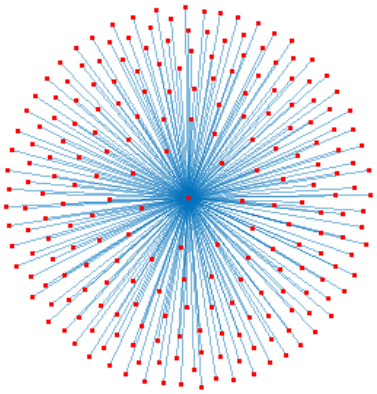

Figure 5.1: Export in $ 1996

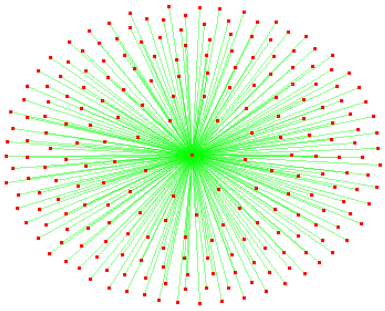

Figure 5.2: Export in Rs. 1996

Our 90% of exports in 1996 were done using USD, The reliance on the dollar for international trade made India's economy vulnerable to fluctuations in exchange rates. A stronger dollar meant Indian exports became more expensive for foreign buyers, impacting trade volume and earnings.

The below graphs deal with Indian International exports in 2023 for both USD and INR and compare the differences.

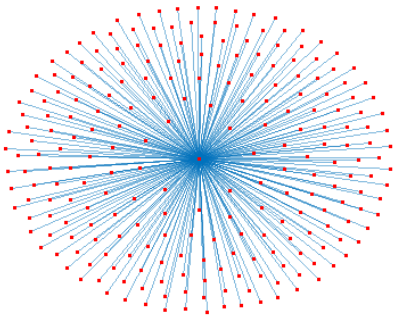

Figure 5.3: Export in $ 2023

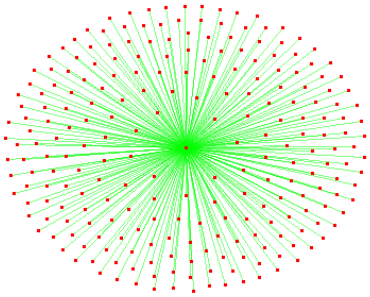

Figure 5.4: Export in Rs. 2023

The fact that 90% of India's exports were conducted in USD in both 1996 and 2023 is indeed striking. A stronger dollar still poses challenges for Indian exports, making them more expensive for foreign buyers and potentially leading to decreased trade volume and earnings.

Despite India's impressive economic growth, its international trade remains heavily reliant

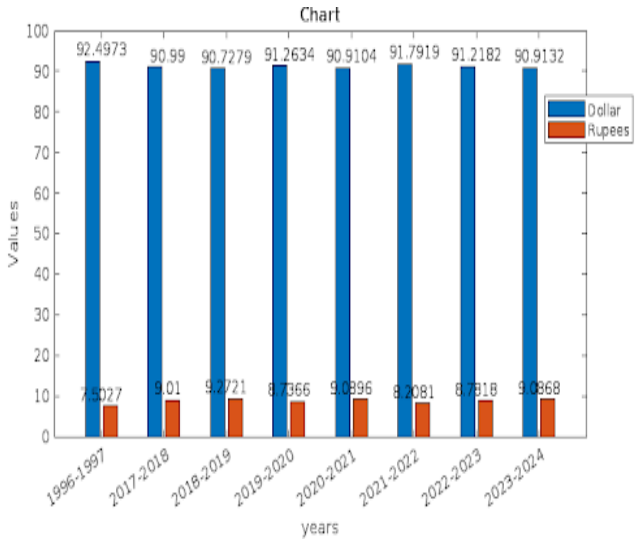

Figure 5.5: Result for Dollarization

on the USD. Surprisingly, the proportion of exports conducted in USD has remained remark-

ably consistent at around 90% between 2017 and 2023.
This dependence on the USD exposes the Indian economy to the vulnerabilities of fluctuating exchange rates. A stronger dollar makes Indian exports more expensive for foreign buyers. This impedes India's ability to fully capitalize on its potential for export growth. By remaining tied to a single currency, Indian exporters face an additional hurdle in competing with other countries in the global market.

5.2 De-Dollarization

In 2023, India was the fifth largest economy country in the world whose GDP was party dependency on the US Dollar was inevitable So the Indian government planned to sign a bilateral agreement with their training partners to encourage trade in INR a strategic move. By creating a framework for direct INR-INR settlements, these agreements can reduce conversion costs, and transaction risks associated with exchange rates, and potentially increase trade volume. Currently, India has signed 20 agreements with 20 countries some of which are the leading trading partners with India like United Arab Emirates (UAE), Mauritius, Sri Lanka etc.

The upcoming graph says what if the export trade between India and 20 countries was completely done by using INR.

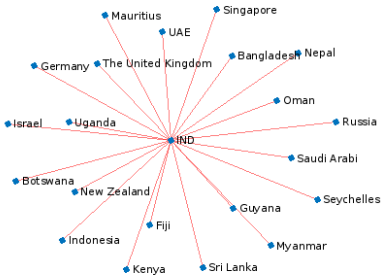

Figure 5.6: Bilateral Export in $

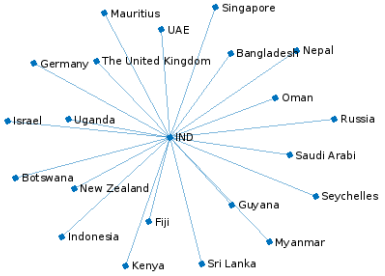

Figure 5.7: Bilateral Export in

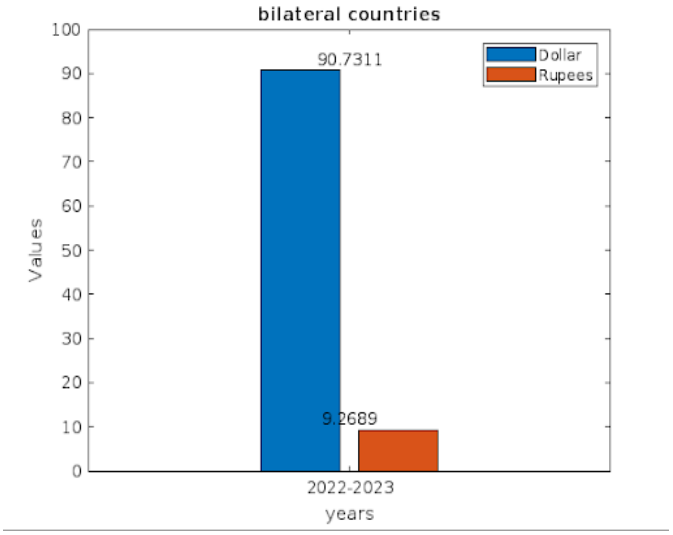

Figure 5.8: Result for De-Dollarization

The current scenario shows the limited impact of the bilateral agreements, that represent a promising starting point for reducing India's dependence on USD. Continued efforts to expand, incentivize, and streamline INR-based trade could eventually lead to significant economic benefits for India and its trading partners.

Chapter 6

Results for Import

India's import landscape has evolved alongside its export journey. In the pre-liberalization era, import substitution policies aimed to reduce dependence on foreign goods, often with strict controls and high tariffs. However, the 1991 economic reforms ushered in a shift towards a more open economy.

Trade liberalization and global market participation facilitated easier access to foreign goods, fulfilling domestic needs and fueling industrial growth. India's heavy reliance on energy imports makes it vulnerable to global price fluctuations, while the need for advanced technology often necessitates imports for various sectors. Foreign direct investment can also lead to increased imports of essential components. The US dollar's strength can have opposing effects, making imports costlier or cheaper depending on its value against the rupee. Ultimately, India's import decisions are shaped by a complex interplay of domestic production capacity, government policies, global economic conditions, and the ever-present influence of the US dollar.

6.1 Dollarization

As we have seen in the previous chapters, the impact of the US dollar after the Second World War didn't change. The upcoming graph shows Indian imports in 1996 for both USD and INR.

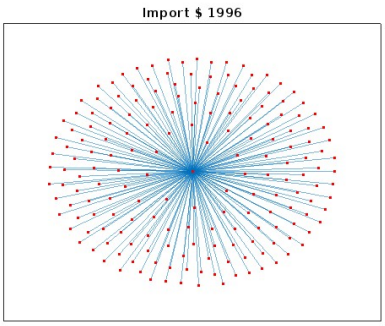

Figure 6.1: Export in $ 1996

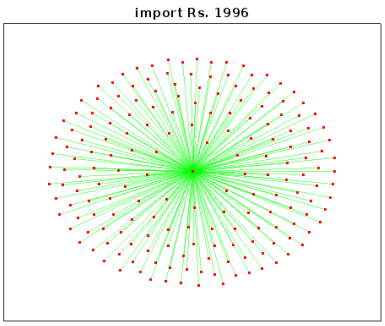

Figure 6.2: Export in Rs. 1996

Here 51 % of imports in 1996 were done by using USD. The US dollar has been the dominant global reserve currency for a long time, and a significant portion of international trade was likely denominated in USD even back then.

The below Graphs deal with Indian International imports in 2023 for both USD and INR and compare the differences.

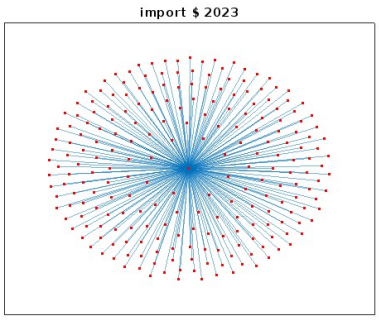

Figure 6.3: Export in $ 1996

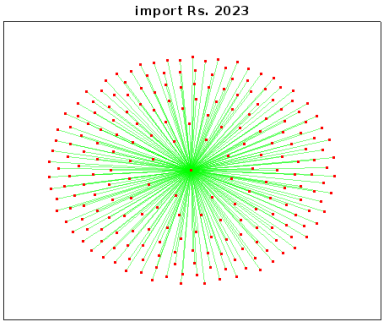

Figure 6.4: Export in Rs. 1996

While the US dollar (USD) remains a dominant currency in international trade, it shows that 51% of all Indian imports in 2023 were conducted in USD.

This shows that moreover 51% of Indian imports were done using the US Dollar for the years 1996 and 2023. This indicates a consistent preference or reliance on the US Dollar for international trade transactions over this period. The following graph shows the details of Indian imports for the past 5 years.

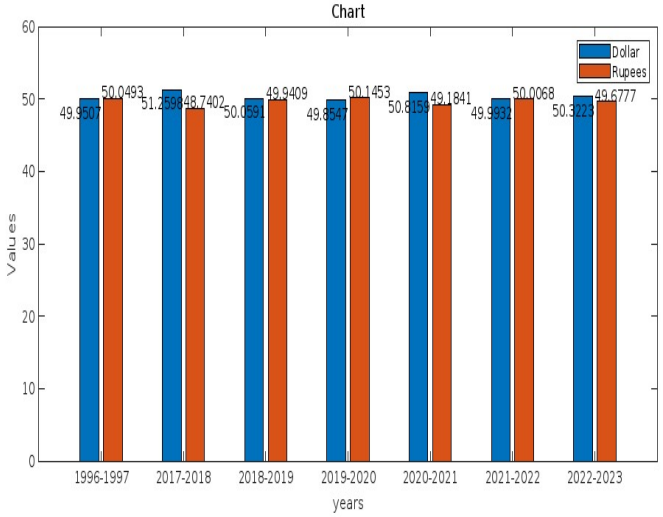

Figure 6.5: Result for Dollarization

Over the past five years, half of India's imports have been consistently conducted in US Dollars, signaling a steadfast reliance on the currency for international trade transactions. This enduring trend underscores India's integration into the global economy, with many of its trading partners, including major economies, predominantly using the US Dollar for trade. The stability and convenience offered by the US Dollar, along with potential influences from exchange rate dynamics and trade policies, contribute to its continued prevalence in Indian imports, reflecting its pivotal role in facilitating India's trade relationships and transactions on the global stage.

6.2 De-Dollarization

The Indian government planned to sign a bilateral agreement with their training partners to encourage trade in INR, a strategic move. By creating a framework for direct INR-INR settlements, these agreements can reduce conversion costs, and transaction risks associated with exchange rates, and potentially increase trade volume. Currently, India has signed 20 agreements with 20 countries some of which are the leading trading partners with India like the United Arab Emirates (UAE), Mauritius, Sri Lanka, etc.

The upcoming Graph says what if the import trade between India and 20 countries was completely done by using INR.

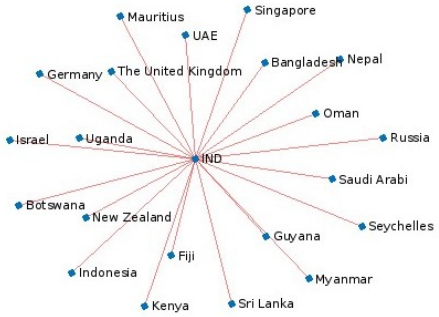

Figure 6.6: Bilateral import in $

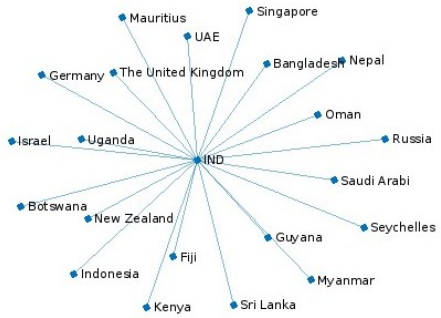

Figure 6.7: Bilateral import in rupee

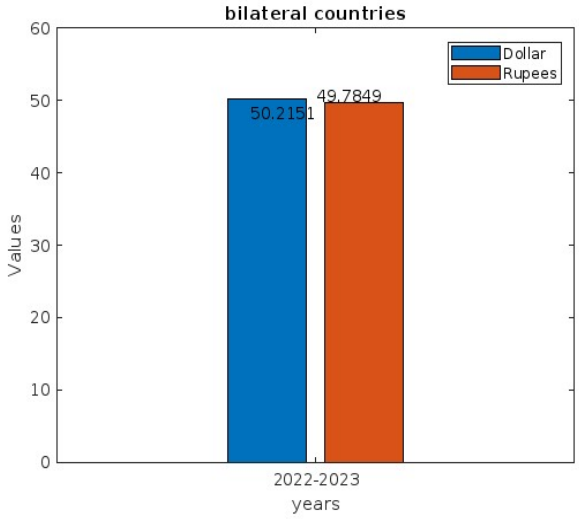

Figure 6.8: Result for De-Dollarization

The current scenario shows the limited impact of the bilateral agreements, they represent a promising starting point for reducing India's dependence on USD. Continued efforts to expand, incentivize, and streamline INR-based trade could eventually lead to significant economic benefits for India and its trading partners.

Chapter 7

Conclusion

The historical context of India's international trade, particularly its reliance on the US dollar since its independence, underscores a persistent vulnerability in the nation's economy. Despite substantial growth in GDP over the decades, the dominance of the dollar in India's export transactions has remained remarkably consistent, hovering around 90%. This reliance exposes India to the fluctuations of the dollar, where a stronger dollar escalates the cost of Indian exports to foreign markets, potentially dampening trade volumes and earnings. This phenomenon highlights the need for a nuanced understanding of the impact of dollarization on India's trade dynamics.

Approximately 50% of India's import transactions are denominated in US dollars. This reliance exposes India to the fluctuations of the dollar, where a stronger dollar escalates the cost of imported goods, potentially increasing the trade deficit and impacting domestic prices. This phenomenon highlights the need for a nuanced understanding of the impact of dollarization on India's import dynamics.

India's strategic shift towards bilateral agreements for INR-based trade signifies a proactive approach to mitigate the adverse effects of dollar dependency on its GDP. While the initial impact of these agreements appears limited, they lay a promising foundation for future

endeavors. By fostering direct INR settlements, India aims to curtail conversion costs and transaction risks associated with fluctuating exchange rates. With 20 agreements already in place, including with key trading partners. India demonstrates its commitment to diversifying trade channels. However, to fully realize the potential benefits, sustained efforts are needed to expand and incentivize INR-based trade. Such initiatives not only reduce India's vulnerability to external currency fluctuations but also foster stronger economic ties with partner nations. As India solidifies its position as the fifth-largest economy globally, these strategic measures mark significant steps towards a more resilient and sustainable trade framework.

In conclusion, India has relied heavily on the US dollar in global trade, showing the importance of diversification. Now, India is making deals directly with other countries using its currency, the rupee, to lower risks and make its economy stronger. While these new agreements might not have big effects at first, they're setting the stage for a stable and growing economy in the future. It's crucial to keep pushing for more deals like this to protect against ups and downs in currency values and to build stronger connections with important trade partners.

Bibliography

[1] Abdul Majeed, Ibtisam Rauf - "Graph Theory: A Comprehensive Survey about Graph Theory Applications in Computer Science and Social Networks." Inventions Publishing 2020.

[2] Claudio, Aldo Marzullo, Enrico Deusebio - "Graph Machine Learning", Packt Publishing 2021.

[3] Kurt Schuler, "Some Theory and History of Dollarization", Cato J., 2005.

[4] Lilian Tomu, Tinashe Chuchu, Eugine Tafadzwa Maziriri - "The Impact of Dollarization Policy on Zimbabwe Exports: A Gravity Model Approach", International Journal of Economics and Financial Issues, 2021.

[5] Pratik Patil, "Stock Market prediction using ensemble of Graph theory, Machine Learning and Deep Learning Models", 2019.

[6] Talwar Huleppa, "The Statuses of De-Dollarization in the Indian Economy", JETIR 2023.

[7] Jiahua Zhang, "Research on De-dollarization and RMB Development in Central Asian Countries during 2010-2021", Frontiers in Business, Economics and Management, 2022.

[8] `https://tradestat.commerce.gov.in/eidb/default.asp`

[9] `https://tradingeconomics.com/india/currency`