Directed Financial Networks using Granger Causality: A Study on Stock Markets of Pakistan and its Major Trading Partners

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ARTICLE INFO	ABSTRACT
	This study is conducted with the aim to construct and analyze directed financial networks of Pakistan and its major trading partners. Five major export partners of Pakistan are USA, China, UK, Germany and UAE. While major import partners are USA, China, Indonesia., Saudi Arabia and UAE. Granger causality test was conducted using the stock returns from each stock exchange. The test was used to detect whether a change in the prices one stock exchange cause a change the prices of others. The results reveal that none of the exporting or importing country's stock exchange cause any change in the Pakistan stock exchange neither does PSX cause any change in other stock exchanges. However, some countries like Shanghai and New York, Shanghai and Frankfurt show a unidirectional causality.

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1. Introduction

Globalization has led to an increased synchronization among international markets. This means that stock markets around the world show similar responses to events. The financial crisis of 2008 is an example of how one event, financial crisis in a single economy, caused disruption in the interconnected economies. Various studies have examined this co-movement among stock markets adducing reasons such as interdependence of economies, leading stock markets influencing other markets, geographical position, trade relations etc. (Husnain, Um-e-Habiba, & Muhammad, 2018). So any event in one country can create a ripple effect, disturbing other markets in an instance. Increased integration among stock markets is due to technological advancements and sophisticated systems of communication (Qarni & Gulzar, 2018). It is already established by the literature that trading partners are integrated to a greater extent (Ullah, Kiani, & Imran, 2019). This study focuses on relation of Pakistan with its major trading partners. The point where our investigations diverges from others is that we analyze and explain the relation using directed networks. A directed network is one where every edge has a point of origin and insertion (Hansen, Shneiderman, Smith, & Himelboim, 2020).

Financial network is defined as those networks where nodes represent different organization (firms, investors, banks etc.) linked through financial interdependencies (Hu, Schwabe, & Li, 2015). A major portion of work done on financial networks is that of undirected networks using correlation. A study performed on Asian financial markets concluded on the existence of heavy interconnectedness among the markets (Chowdhury, Dungey, Kangogo, Sayeed, & Volkov, 2019). This gives us little information about the

causal relationship among variables. Keeping this in view a new trend is seen in the recent years of researchers focusing on studying causality between stock markets. Directed networks help in understanding the direction of causality and so have important policy implications. Like the work of Al-Yahyaee et al. 2019 has examined the causal relation between the stock markets of U.S and some European countries like Italy, Greece, Ireland, Spain and Portugal. The results conclude a causal relation from U.S to Spanish and Greek markets.

In this research study we aim to build directed networks in order to understand the interconnectedness among the major trading partners of Pakistan using them as nodes. While the presence of an edge among two nodes marks the presence of causality. The direction of an edge determines that who granger causes whom. Major trading partners of Pakistan are USA, UK, UAE, China, Indonesia, Saudi Arabia and Germany.

This study focuses on the examination of directed financial network among major trading partners of Pakistan using Granger causality. This research is significant in the sense that it not only contributes to the already existing literature on the study of causality between stock markets of different countries, but it also is one its kind when it comes to the studies performed on Pakistan stock markets with the help of directed networks. It is an effort to bring attention of researchers towards the need of in-dept studies of directed financial networks especially after the financial crisis of 2007-2009 in which the magnitude of damage was huge because of the interconnectedness of the markets. This is why systemic risk (the possibility that an event in one country can affect the global stock market) is being studied extensively using network science. We are also studying directed networks in the hope to get an insight on how Pakistani stock market can be affected by the events happening in other countries and how can changes in Pakistani stock market effect other stock markets. Financial markets, for developing countries, are a backbone of the country and can either make or break their future and so understanding their networks can help us avoid systematic failures like the crisis and will also help us in understanding the complex dynamics of financial networks and their resilience towards systematic risk.

This study is performed with the following objectives:
- To construct and examine directed networks of major trade partners of Pakistan for the existence of Granger Causality.
- To define properties of these networks using statistical measure of average degree.

Global financial system is highly connected and financial event at local level can have global impact. So it is crucial to understand financial networks as they can help us in assessing systematic risk and resilience in them. Despite this there is lack of studies on directed financial network of Pakistan and its major trading partners which can reveal interconnectedness among them and the direction of causality. Therefore, it is crucial to perform a study on directed networks regarding Pakistan and its major trading partners.

2.   Literature Review

A network is a system of similar parts, connected together as to allow these parts to communicate between themselves or with a control center (Cambridge et al., 2021). When studying directed networks certain measures help in understanding the dynamics of the networks. Average degree is an example of such measures. It is simply a comparison between the number of nodes and number of edges. Average degree is the average number of edges per node. It shows how well connected a node is and provides useful insights about the structure of a network. For directed networks, it makes more sense to talk about the in-degree and out-degree. The in-degree measures the sum of inward connection. This means that it measures the number of insertion point it has. While out-degree is the sum of outward connections which means that it measures the number of origins (Papana, Kyrtsou, Kugiumtzis, & Diks, 2017). Directed networks are constructed to reveal casual relationships (Tang, Xiong, Luo, & Zhang, 2019).

One of the most popular method to measure this causal relation is the Granger causality. This statistical concept helps in determining whether a time-series can predict one another or not (Damos, 2016). The economic data usually has a very no experimental

nature and so the cause-and-effect relationship can be proved using statistical tools like Granger causality (Dutta, 2001)**.** First introduced by Sir Clive Granger, a British econometrician, Granger causality makes use of the t-statistic and F-statistic tests and predicts whether a variable X can provide considerable information about the changes in the future values of variable Y (Kolidakis, Botzoris, Profillidis, & Lemonakis, 2019). If X doesn't Granger-cause Y, then X is strictly exogenous to Y (Clarke & Granato, 2005).

The focus towards internationalization of trade has led to a noticeable increment in the goods and services exchanged. The paper of (Pfaffermayr, 1994) has applied Granger causality to analyze the Austrian exports and outward FDI (Foreign Direct Investment). Results revealed a bidirectional causality. Lin (1995) also found a sufficiently great and positive effect of outward FDI on exports. Similarly, a study performed in Spain concluded that the outward FDI and exports have a significant relationship. In the short-run, outward FDI Granger causes exports, but a bidirectional causality was found in the long run (Bajo-Rubio & Montero-Muñoz, 2001).

Trade is undoubtedly seen as a consequential factor in the integration of financial markets. This means that stock markets around the globe are more interconnected due to trade. Even the isolated Chinese market has started to show influence in financial market because of its increasing scope in trade. So, financial strains in the Chinese economy will affect the stock markets of its major trading partners like Japan, Germany, United States of America etc. This effect was seen when in 2015, a stock market bubble was formed due to the encouragement of Chinese government to invest in stocks. In July of 2015, the bubble burst and a sharp decline in valuation caused stock market to crash. This is seen as one of the major economic crisis of the decade in Asia and it has influenced many stock markets throughout the globe (Qarni & Gulzar, 2018).

Another study conducted to investigate integration between the stock markets of Malaysia and its major trading partner (USA, China, Japan and Singapore) using GARCH model (used for predicting volatility of returns) concludes that Japan, China and Singapore have positive while USA has negative effect on stock return of Malaysian market(Phua, Ang, Chua, Hong, & Peng, 2017). Likewise integration between notable trade partners of India and its own stock market in connection with the 2008 crisis is studied by (Patel, 2019). The study concludes that more integration among markets is present after the period of crisis.

(Eswaran, Lal, & Reich, 2019) examined the existence of integration between the Pakistan stock market and its major trade partners. This study also identifies and explains the variation in integration. Results show that integration is not constant throughout the years like notable integration is seen during the years 2002 and 2011 between Japan and Pakistan. Similarly, years 2008 and 2012 show improved integration of Pakistan with Malaysia. It is also revealed that export from one country to another, inflation and real interest rate have negative influence on integration but positive influence on GDP.

Karachi stock exchange's 100 index was one of the best performing index in the initial four years of the twenty-first century. But in 2008 it declined due to bad political environment, inflation and numerous other factors. This shifted the focus of researchers to investigate the interconnection of Pakistan stock market with that of developing and developed countries. Results revealed that no integration exists among Pakistan and developing countries while developed countries like the US, UK, Canada and Germany show relationship with Pakistan which means that Pakistan stock market is affected by events in these countries (Abbas, Farooq, Qureshi, & e Hassan, 2017).

3. Research Methodology
3.1 Sample

We have taken a sample of 8 countries. These countries are Pakistan, United states of America, China, United Kingdom, United Arab Emirates, Germany, Indonesia and Saudi Arabia. These countries are divided into two groups on the basis of major import and export partners. Major trading partners of Pakistan are selected on the basis of volume of trade with them. This data is taken from UN Comtrade database.

The major export partners (benchmark: $1billion) of 2020 are:
1. United States of America ($4.14 billion with a share of 18.6%)
2. China ($1.87 billion with a share of 8.39%)
3. United Kingdom ($1.73 billion with a share of 7.76%)
4. Germany ($1.40 billion with a share of 6.27%)
5. United Arab Emirates ($1.10 billion with a share of 4.93%)

The major import partners (benchmark: $1.5billion) of 2020 are:
1. China ($12.49 billion with a share of 27%)
2. Unites Arab Emirates ($4.47 billion with a share of 9.77%)
3. Unites States ($2.58 billion with a share of 5.64%)
4. Indonesia ($2.41 billion with a share of 5.25%)
5. Saudi Arabia ($1.89 billion with a share of 4.13%)

Table 1
Countries and their respective stock Exchanges

Country	Stock Exchange
Pakistan	Pakistan Stock Exchange
United states of America	New York Stock Exchange
China	Shanghai Stock Exchange
United Kingdom	London Stock Exchange
United Arab Emirates	Abu Dhabi Stock Exchange
Germany	Frankfurt Stock Exchange
Indonesia	Indonesia Stock Exchange
Saudi Arabia	Tadawul Stock Exchange

3.2   Data Collection

The research is on secondary data and the data is collected from the websites of the stock exchanges of each country, Yahoo finance and Investing.com. Monthly closing prices are taken of the last five years, so that we can examine the change in network dynamics before and after Covid-19.

3.3   Unit Root test

Financial and economic time-series show trends. If the series is not stationary, it makes predictions about future difficult. A unit root measures stationarity of a time series. In order to test stationarity, two very common tests are, Kwiatkowski-Phillips-Schmidt-Shin test (KPSS test) and Augmented Dickey-Fuller test (ADF Test). We will use the ADF test to check our time series is stationary or not. The ADF is a powerful test more suited for our data as it is most appropriate for complex models. The mathematical representation is as follows:

$$y_t = c + \beta t + \alpha y_{t-1} + \phi_1 \Delta Y_{t-1} + \phi_2 \Delta Y_{t-2} \dots \phi_p \Delta Y_{t-p} + e_t \tag{1}$$

Alpha is the coefficient of the first lag y. So, for null hypothesis alpha should be equal to 1. y_{t-1} is the lag 1 of time series while delta Y is the difference of time series at time (t-1).

3.4. Granger Causality

A statistical method which determines whether time-series can predict one another or not. It tells us whether change in a variable cause change in another variable. Granger causality is a popular and very widely used test which predicts whether one variable say x predicts the changes in another variable say y. Their mathematical relation would be represented as:

$$y_i = \alpha_0 + \sum_{j=1}^{m} \alpha_j y_{i-j} + \sum_{j=1}^{m} \beta_j x_{i-j} + \varepsilon_i \tag{2}$$

Here the terms αj and βj represent the regression coefficients and the term ε_i represents the error term. The symbol m represents the number of lags. If all the values of

β amount to zero this would mean that x does not granger cause y. Of course the test assumes that both the time-series (x and y) are stationary. The Granger Causality test is applied to check for causality between the stock exchanges and whether changes in one of those time-series can be used to predict changes in other.

4.   Results
4.1.   Unit Root Test

The monthly closing prices of each of the 8 stock exchanges was first converted into return and then the Augmented-Dickey-Fuller or the standard unit root test was conducted on the returns. This test discloses the presence or absence of stationarity in the series. The table below shows the result of all unit root tests. It is indicated through these values that there is no unit root and so the data is stationary.

Table 2
ADF Test for Stationarity

Stock Exchange	t-statistic	Probability
Pakistan Stock Exchange	-8.14	0.0000
New York Stock Exchange	-8.57	0.0000
Shanghai Stock Exchange	-8.39	0.0000
London Stock Exchange	-9.90	0.0001
Abu Dhabi Stock Exchange	-8.58	0.0000
Frankfurt Stock Exchange	-10.51	0.0001
Indonesia Stock Exchange	-7.89	0.0000
Tadawul Stock Exchange	-8.10	0.0000

4.1   Directed Networks

Each stock exchange was individually tested and the results recorded. Networks were constructed using the results of Granger causality test. Figure 1 represents the network of Pakistan and its major exporting partners. This networks shows that there is no significant relation between Pakistan stock exchange and other stock exchanges (New York, London, Frankfurt, Shanghai and Abu Dhabi).
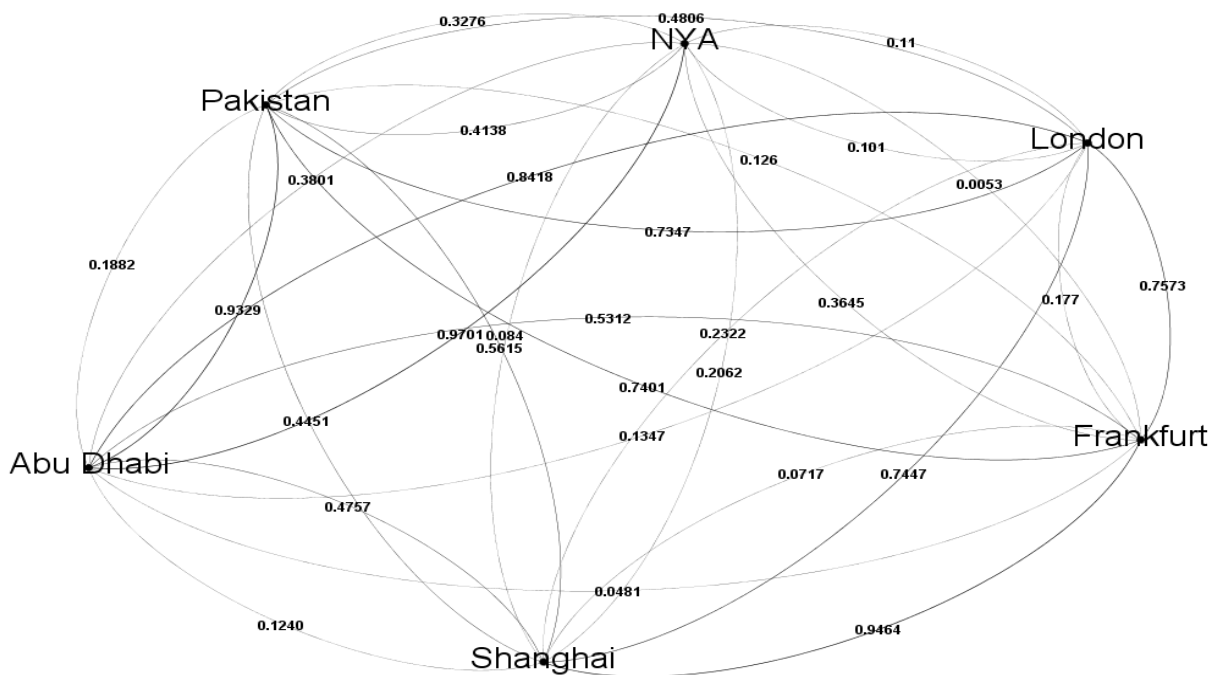

Figure 1: *Directed Network of Pakistan and its Major Exporting Partners*
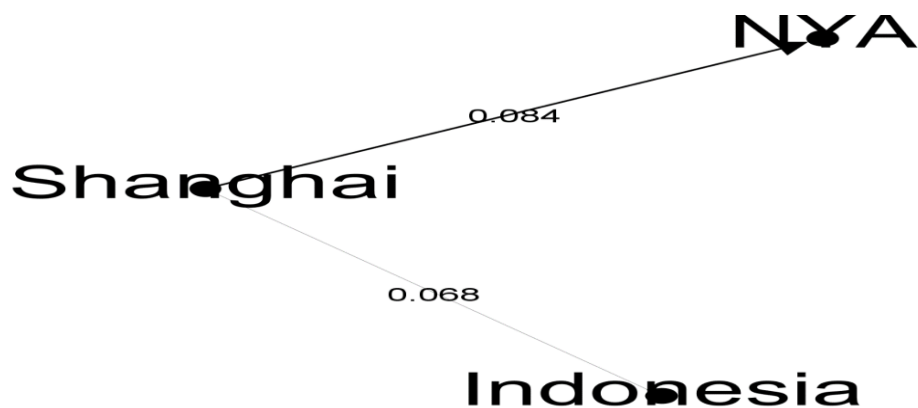
Figure 2: *Directed Network of Linked Countries*

However, in figure 2 we can also see that a significant relation between Frankfurt stock exchange and Abu Dhabi stock exchange which is directed from Frankfurt towards Abu Dhabi. Furthermore, a significant link aslo exists between the New York stock exchange and Frankfurt stock exchange. This link is unidirectional from New York towards Frankfurt. Similarly one-way causality exists between the Shanghai stock exchange and Frankfurt stock exchange. It is directed from Shanghai to Frankfurt. One-way causuality is also found between Shanghai stock exchange and New York stock exchange, directed from Shanghai towards New York.

Figure 3: *Directed Network of Pakistan and its Major Importing Partners*

The same procedure was performed to construct the network represnting relation between Pakistan and its major importing partners. Figure 3 represents the network formed from the results of Granger causality tests done on the Pakistan stock exchnage and its major importing partners. The network indicates that no significant causality exists between Pakistan stock exchange and the stock exchanges of its major import partners (New York, Shanghai, Indonesia, Abu Dhabi, Tadawul).

But there are some countries that show unidirectional relation with each other. The network in figure 4 shows that a one way causality is present between Shanghai stock exchange and Indonesia stock exchange, directed from Shanghai to Indonesia. Similarly, a significant link is also found between Shanghai stock exchange and New York stock exchange, directed from Shanghai to New York. Other than that there is no significant causality observed between between Pakistan and its major importing partners or among the partners themselves.

NYA

0.084

Shanghai

0.068

Indonesia

Figure 4: *Directed Network of linked countries*

4.2   Average Degree

Shanghai

NYA

0.084

0.0053

0.0717

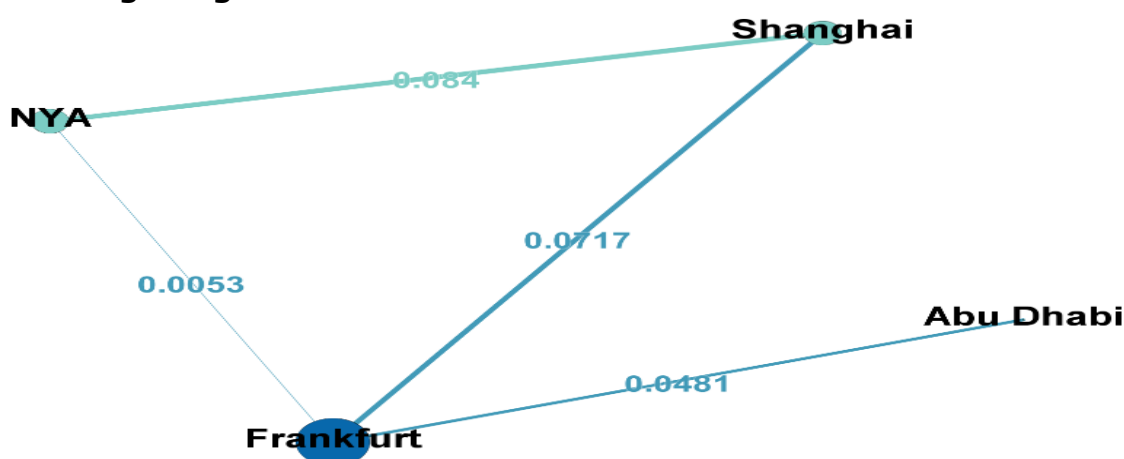Abu Dhabi

0.0481

Frankfurt

Figure 5: *The Average Degree for Exporting Partners*

The average degree is a mathematical property of a network which specifies the number of edges per node. This helps us in determining which node is more involved in the network and which are more isolated. We ran the average degree test on the directed network of partner which were granger causing each other.

Table 3
Indegree and OutDegree for Major Exporting Partners

Stock Exchange	Indegree	Outdegree	Degree
Frankfurt	2	1	3
NYA	1	1	2
Shanghai	0	2	2
Abu Dhabi	1	0	1

The figure 5 and the table 3 show the results for the test of average degree ran on major exporting partners of Pakistan which show a significant relation with other stock exchanges. The results show that in this network of 4 nodes (NYA, Shanghai, Frankfurt and Abu Dhabi), Frankfurt stock exchange is the most well connected node with a total of 3 degree in which 2 are indegree and 1 is outdegree. This means that Frankfurt is connected to three stock exchanges. Out of these three relationships 2 are directed towards Frankfurt while one is directed away. After Frankfurt, New York stock exchange and Shanghai stock exchnage are more well-connected in the network. Both have 2 degress. New York has 1 indegree and 1 outdegree. Which indicates that one relationship is directed towards New York while one goes away from it. Similarly, Shanghai stock exchange also has two degree but in this case both are outdegrees, which means that both connection go away from Shanghai one towards Frankfurt and the other towards the New York.

The figure 6 and table 4 show the results for the test of average degree ran on major importing partners of Pakistan which show a significant relation with other stock exchanges. The network has 3 nodes with significant relation among each other. The most well connected node among these 3 is that of Shanghai stock exchange. It has a degree of

2. Both of them move away from the node representing Shanghai. So both nodes are outdegree. The rest of 2 nodes representing Indonesia and New York stock exchange, both have 1 degree and both are indegrees.
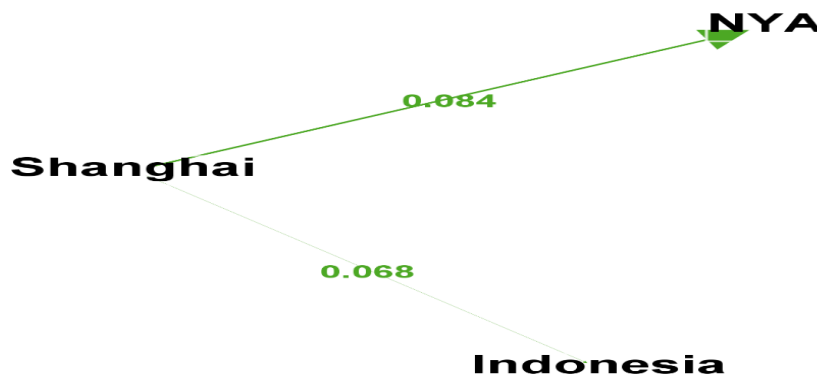

Figure 6: *The Average Degree for Importing Partners*

Table 4
Indegree and Outdegree of Major Importing Partners

Stock Exchange	Indegree	Outdegree	Degree
Shanghai	0	2	2
Indonesia	1	0	1
NYA	1	0	1

4.2.   Pre-Covid and Post-Covid Analysis

To examine the network dynamics before and after the pandemic, we divided the data into pre-covid and post-covid era. Figure 7 shows the network of Pakistan and its major exporting partners before Covid-19 happened. The granger causality test run on the data shows that there is no significant relation between Pakistan and its major exporting partners. This shows that changes in the prices of Pakistan stock exchange will not cause any change in the stock exchanges of other countries (Shanghai, Abu Dhabi, New York, Frankfurt, London). Furthermore, there are no significant relation among the other countries as well.
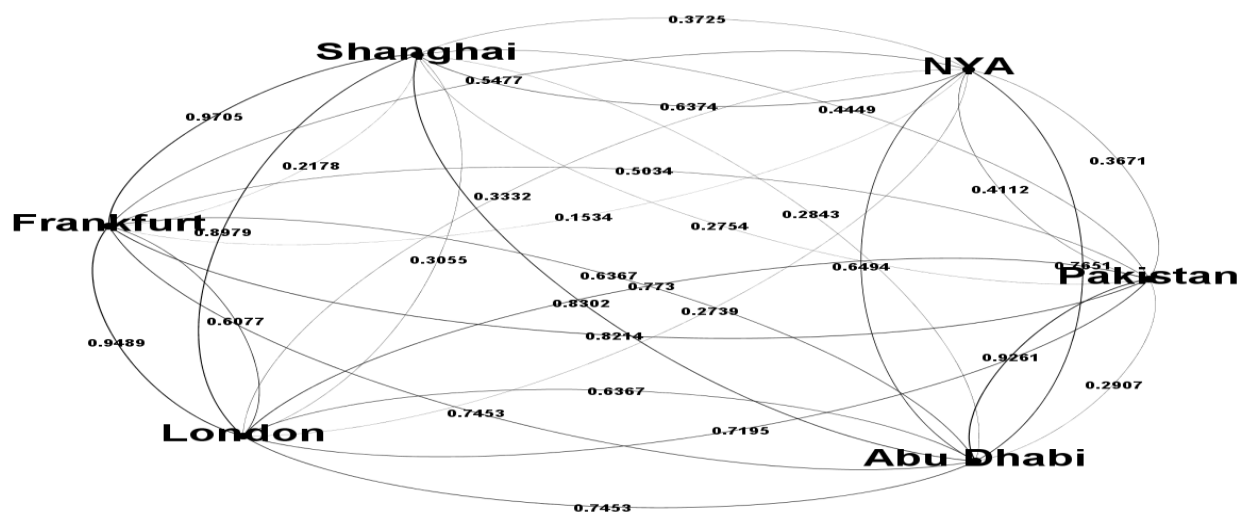

Figure 7: Network of Pakistan and its Major Export Partners Before Covid-19

Figure 8 shows the network of Pakistan and its major importing partners before the pandemic. This network shows a unidirectional relationship between Pakistan and Tadawul. The direction of this causality is from Pakistan to Tadawul. This means that any changes in Pakistan stock exchange will granger cause changes in the Tadawul stock exchange. Other than that there is no significant relation between Pakistan and its major importing partners.
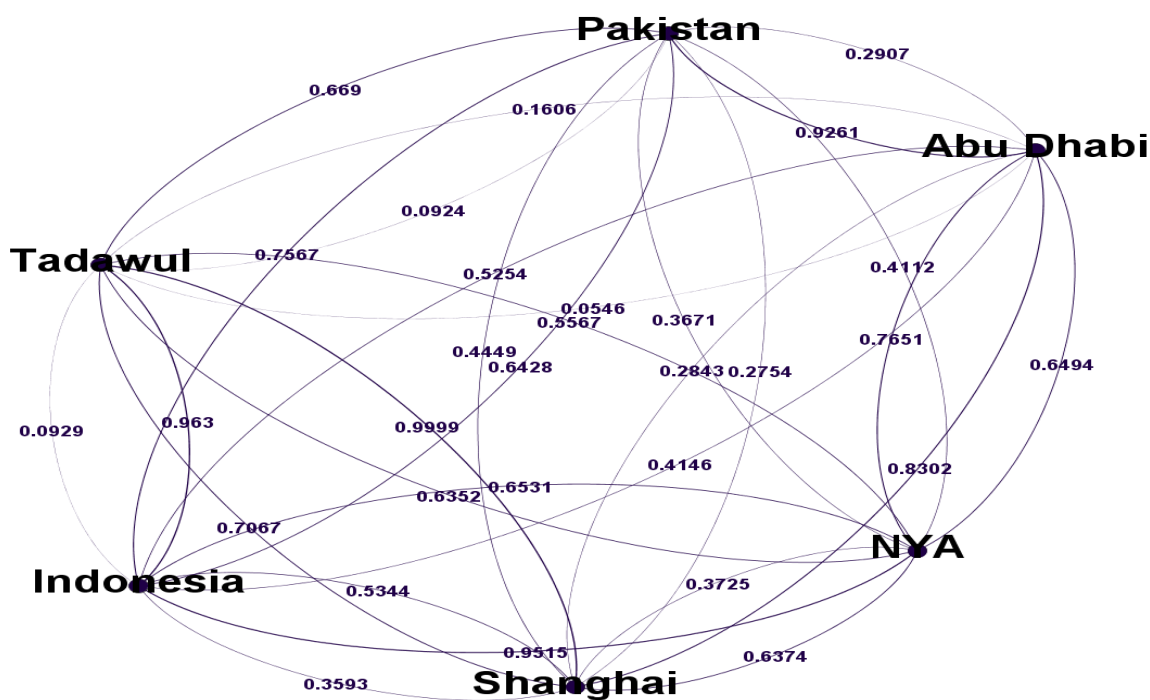
Figure 8: Network of Pakistan and its Major Import Partners Before Covid-19

However, other importing countries do have significant connection with each other. There are two other relations. The first is a one way causality from Abu Dhabi to Tadawul. There is also a significant relation between Indonesia and Tadawul. The direction of this causality is also from Indonesia stock exchange to Tadawul stock exchange. The Tadawul stock exchange is relatively new (established in 2007) and so is extremely volatile and fluctuations in prices are a result from changes in both domestic and foreign economies.

The granger causality test and the subsequent network formation was also done on the post-covid data to analyse how networks have changed in the aftermath of Covid-19. The results are represented in the form of networks. Figure 9 shows the network of Pakistan and its
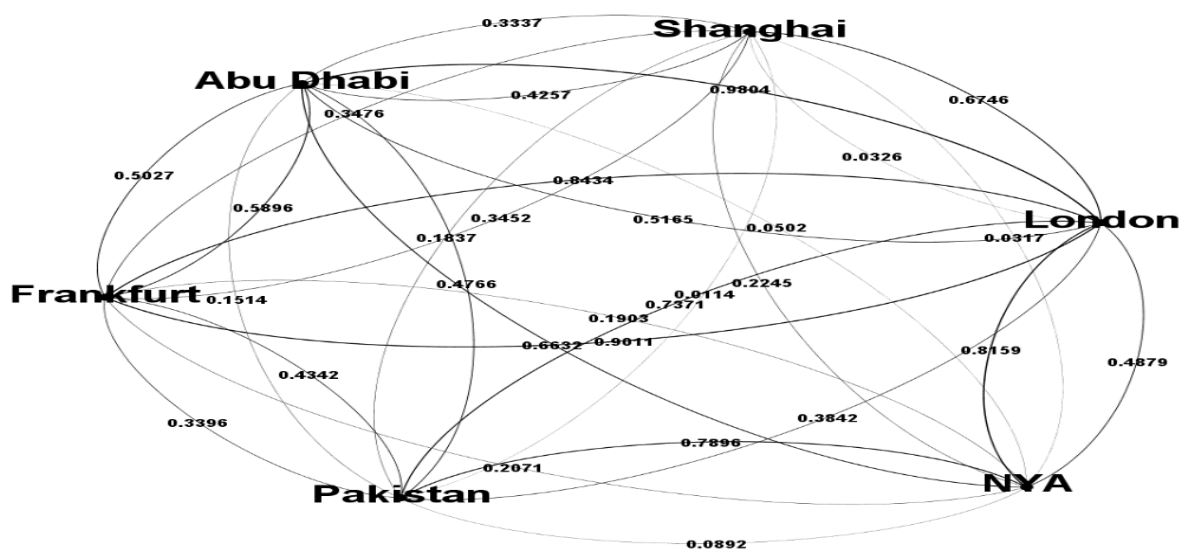

Figure 9: Network of Pakistan and its Major Export Partners After Covid-19

major exporting partners after the pandemic. The results reveal that there is unidirectional causality between New York stock exchange and Pakistan stock exchange. This causality is directed from New York to Pakistan. Furthermore, unidirectional causality also exists from Shanghai stock exchange to Pakistan stock exchange. Other than these, there are no significant relation among Pakistan and major exporting partners. Significant

relationships exist among other exporting partners, like a unidirectional relation from Abu Dhabi stock exchange to the New York stock exchange. One-way causality between Shanghai and New York stock exchange also exists which is directed from Shanghai to New York. A unidirectional relation also exists from London stock exchange to Shanghai stock exchange.
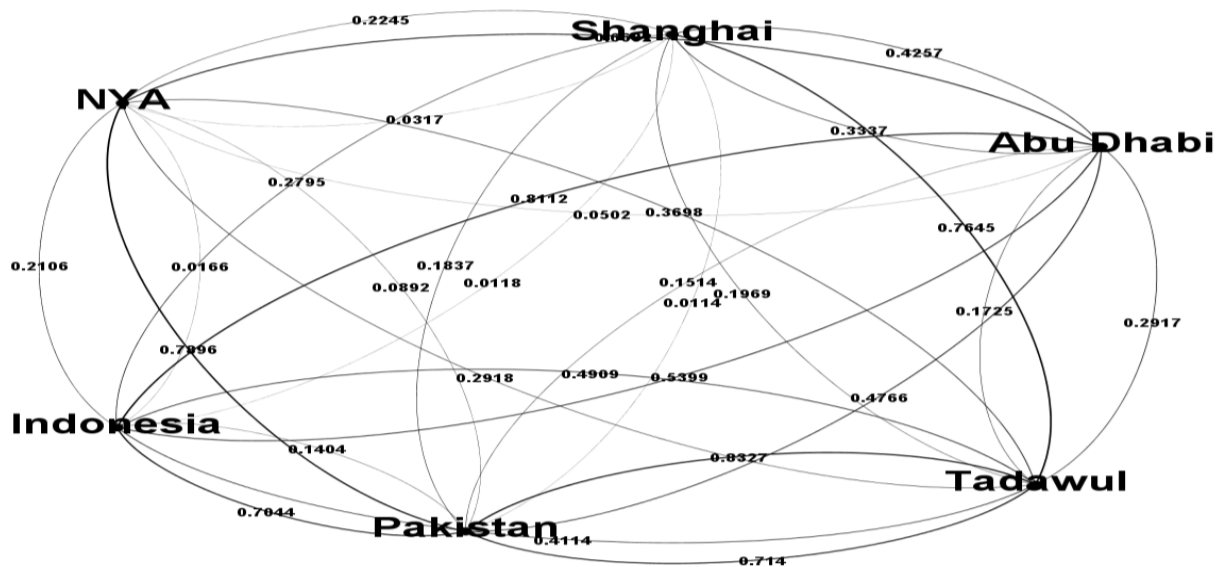

Figure 10: *Network of Pakistan and its Major Import Partners After Covid-19*

Figure 10 represents the network of Pakistan and its major importing partners after the advent of Covid-19. The network reveals a one-way causality from Shanghai to Pakistan stock exchange. Unidirectional causality exists between New York stock exchange and Pakistan stock exchange. The direction of this relation is from New York to Pakistan. There are no other significant relations between Pakistan and its major importing partners. However, causal relation exist between other countries. Abu Dhabi stock exchange has a unidirectional causal relation with the New York stock exchange, directed from Abu Dhabi to New York. One-way causality also exists from New York stock exchange to Indonesia stock exchange. And Indonesia also has a unidirectional relation with Shanghai stock exchange. This relation is directed from Shanghai to Indonesia. Apart from these, there are no significant relations among the major importing partners of Pakistan.

5.   Conclusion and Policy Recommendations

This study aimed at analyzing and constructing a directed network to depict the presence of granger causality between Pakistan and its major trading partners. For this purpose the monthly stock exchange prices were taken and then converted into returns to establish stationarity in data. These returns were then subjected to the Granger Causality test. The results of granger causality show that none of the major exporting partners of Pakistan can be used to predict the future values of Pakistan stock exchange. Similarly PSX cannot be used to predict the future stock values of its major export partners. The same is true for the relation between Pakistan and its major importing partners, that neither can be used to predict one another. So we can conclude that the investors in Pakistan can invest in the stocks of all of its major trading partners. Similarly the investors in all of the major trading partners of Pakistan (New York, Shanghai, Abu Dhabi, Frankfurt, Tadawul, Indonesia and London) can invest in the stocks being traded in the Pakistan stock exchange. Furthermore the Granger causality test also revealed unidirectional relation between different countries like Shanghai and New York, Shanghai and Indonesia, Frankfurt and Abu Dhabi etc. The investors in these countries should not invest in the other countries' stocks. For instance an investor from Shanghai should not invest in the stocks being traded in New York Stock Exchange, but the opposite is not true, i.e. an investor from New York can invest in the stocks being traded in the Shanghai Stock exchange. This happens because the causality is only in one direction, from Shanghai to New York.

This research study has shown that Pakistan is not well integrated with the financial world. Where this isolation has reduced risks to our markets, it has also reduced the foreign investment flowing in our country. To counter this, policy makers and the competent authorities should construct and implement policy which are friendly and favorable for the foreign investor. Furthermore, the major hurdle in the way of foreign investments is the unstable economic and political conditions of the country. Policy makers should work together to remove these impediments so Pakistan can come out from this state of isolation.

The study can be extended further by adding more trading partners. Geographically close countries can also be taken into account. Other methods of connectivity analysis can also be used to analyze networks. One such example is of partial mutual information on mixed embedding (PMIME). Adding countries from the Islamic world can also prove to be a good direction for further research.

Authors Contribution
Ayesha Latif: Conceived of the presented idea and write up.
Nadir Khan: Collected the data and verified the analytical methods.
Saffiullah: edited the citation and references and final review write up.

Conflict of Interests/Disclosures
The authors declared no potential conflicts of interest w.r.t the research, authorship and/or publication of this article.

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