NETWORK ANALYSIS OF PAKISTAN STOCK MARKET DURING THE TURBULENCE OF ECONOMIC CRISIS

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Abstract. *Purpose* – the purpose of this study is to analyse the impact of the recent economic crisis on the network topology structure of Pakistan stock market. Since stock market is considered a core financial market for the development of an economy, it is often used as benchmark to measure a country`s progress. Policymakers often forecast tendency of share prices, that is dependent on several foreign and local macroeconomic factors. Therefore, the aim of this study is to investigate how rising inflation, higher interest rates, and trade and budgetary deficits affect the network structure of blue-chip 96 companies listed on the Karachi stock exchange (KSE-100) index of Pakistan stock market.

Research methodology – this study follows the methodology proposed by Mantegna and Stanley and uses cross-correlation in the daily closing price of KSE 100 Index companies to compute Minimum spanning tree (MST) structures. Additionally, we also apply time-varying topological property of average tree length to extract dynamic features of the MST networks.

Findings – we construct eight monthly MSTs that show the instability of the network structure and significant differences in the topological characteristics due to economic crisis of Pakistan. Furthermore, the time-varying topological property of average tree length reveals contraction of the networks due to tight correlation among stocks.

Research limitations – this study focuses on correlation-based network construction of MST. The scope of the study can be widened by constructing partial correlation-based MSTs and comparison of different networks structures accordingly.

Practical implications – the network properties and findings of this paper will help policymakers and regulators in setting right policies, regulatory framework, and risk management for the stock market.

Originality/Value – no previous studies have performed MST based network analysis examining macroeconomic events. Therefore, we fill the research gap and thoroughly analyse structural change and dynamics of Pakistan stock market during the turbulence of current economic crisis of Pakistan.

Keywords: stock market, minimum spanning tree, network topology, macroeconomic indicators, crisis.

JEL Classification: C18, E44, G19.

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Introduction

Stock markets have been considered a significant financial market of a country for centuries. Any uncertainties and crisis spreading among these markets exert partial or significant implications on the economy. Over the past many decades, the world economy absorbed several crises initiated from financial particularly stock markets (Garber, 1990). Therefore, regulators and policymakers critically monitor their local stock exchanges in order to take timely actions against any irregularity.

There are many factors that drive daily fluctuation in stock prices. Among most primary factors that drive daily fluctuations of stock markets are economic and political events (Darrat & Mukherjee, 1986; Kwon & Shin, 1999; Husain & Mahmood, 2001; Yusoff, Salleh, Ahmad, & Idris, 2015; Sajid Nazir, Younus, Kaleem, & Anwar, 2014; Yao & Memon, 2019). Conversely, it is also observed that stock markets are complex in nature and that the investors are not only influenced by direct macroeconomic conditions, external events of financial and economic crisis can exert fear among investors and influence the stock prices (Horta, Lagoa, & Martins, 2014; Anagnostidis, Varsakelis, & Emmanouilides, 2016; Jin, 2016; Memon & Yao, 2019). However, investors are directly affected by country`s macroeconomic determinants, and they take decisions in stock market based on the favourability of economic environment of a country.

In this study, we fill the research gap and thoroughly analyse structural change and dynamics of Pakistan stock market during the current economic crisis of Pakistan. As a result of current economic crisis, Pakistan is experiencing a record inflation[1] level which is ongoing, and shown an increase from 4.19 in the month of May-2018 to 9.41 in the month of March-2019, presented in Figure 1. Conversely, a decline in inflation rate boosts investors' confidence and generates a positive impact on the stock markets (Omran & Pointon, 2001).
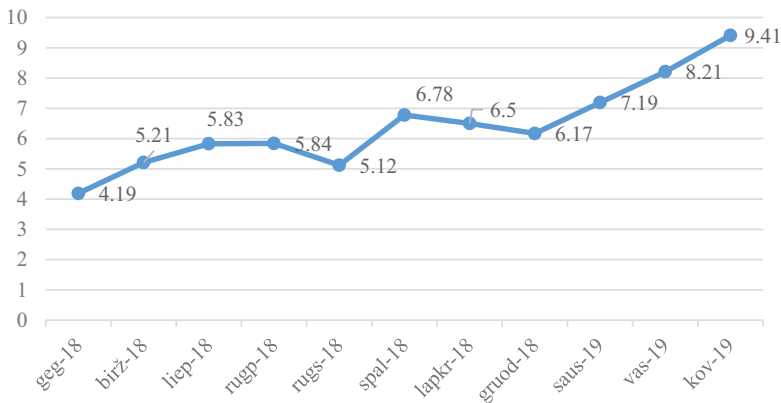

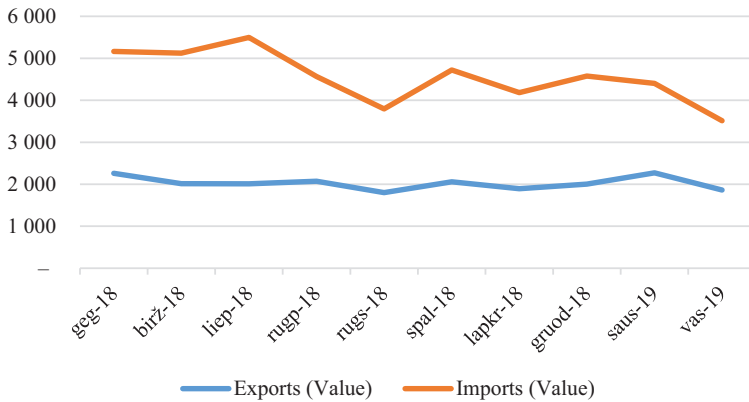Figure 1. Monthly inflation rate of Pakistan

Figure 2. Monthly trade data of Pakistan

In addition, government of Pakistan took additional measures of Pakistan rupee depreciation to curb balance of payment crisis and to maintain its foreign exchange reserves. Figure 2 shows monthly trade data and disparity among imports and exports value[2] of Pakistan.

Pakistan stock market has been an exceptional emerging market and reclassified as Morgan Stanley Capital International (MSCI) emerging markets index in month of May-2017. Presently, there are 559 companies listed on the Pakistan stock exchange[3] (PSX). The Karachi stock exchange (KSE) 100 index (comprises top 100 companies) is the benchmark index of PSX, representing 85% of the entire stock market capitalisation. Since PSX stages a vital role for the expansion of the country, researchers in the past have employed various methods to examine the impact of macroeconomic variables on Pakistan stock market (see e.g. Nishat & Shaheen, 2004; Sohail & Zakir, 2010; Shahbaz, 2013; Ahmed, Vveinhardt, Streimikiene, & Fayyaz, 2017). However, many studies have adopted network science theories to analyse a complex system such as stock market. These theories unfolds many exciting aspects of stock markets, such as: significant influencers, community detections, forecasting future movements, analysis and prediction of an upcoming crisis, and so on (see e.g. Namaki, Shirazi, Raei, & Jafari, 2011; Yang, Li, & Zhang, 2014; Creamer, Ren, & Nickerson, 2013; Nobi, Lee, Kim, & Lee, 2014; Yin, Z. Liu, & P. Liu, 2017; Memon & Yao, 2019). In a typical stock market network, stocks are taken as nodes of the network, and their edges are described by Pearson correlation coefficient (Liu & Tse, 2012; Kazemilari, Mohamadi, Mardani, & Streimikis, 2019; Yao & Memon, 2019). We further employ a useful method of Minimum spanning tree (MST), a filtering tool of extracting relevant information from a stock market network (Mantegna, 1999). Network formed through MST is useful in examining topological properties of the network, and is widely applied in numerous areas of scientific investigations, see e.g. portfolio analysis (Onnela, Chakraborti, Kaski, & Kertiész, 2002), trade network (Maeng, Choi, & Lee, 2012), systematic risk assessment (Song, Ko, & Chang, 2018), commodity market (Lee & Nobi, 2018), Foreign exchange market (Jang, Lee, & Chang, 2011), and so on. It is due to this interest of scientific community MST serve as a prime network mapping tool, and a useful method for event study (Yao & Memon, 2019). Therefore, this paper focuses on

applying MST method to examine structural change and dynamics of Pakistan stock market during economic crisis of Pakistan.

The remaining paper is structured as follows. Section 1 presents relevant literature. Section 2 describes the data and methodology of constructing MST. Section 3 presents empirical results and discussions. Finally, last Section concludes the paper.

1. Literature review

The existing literature offers numerous stock market correlation-based networks to determine its possible structure. The initiating work is suggested by (Mantegna, 1999), who presented a filtering tool to examine stock correlation networks called Minimum Spanning tree (MST). After that, numerous methods have been proposed to study interdependency and dynamics evolution of financial markets, for example, threshold network (CT) (Boginski, Butenko, & Pardalos, 2005), Planar maximally filtered graph (Tumminello, Aste, Di Matteo, & N Mantegna, 2005), etc. (Tse, Liu, & Lau, 2010) studied correlation structure of US stock market by dividing timeline into two periods and found influential role of financial sector for the US stock market, and all stocks obeying a power-law degree distribution. Gilmore, Lucey, and Boscia (2008) applied MST on EU stock markets from the year 1999 to 2006 and found an important central node of French stock market. (Gałązka, 2011) formed correlation network of polish stock market, and after applying MST he found few compelling stocks dominating and influencing the entire stock market.

Previous research on Pakistan stock market has applied various methods to investigate the impact of economic factors. For example, Butt, ur Rehman, Khan, and Safwan (2010) found influence of major economic factors in influencing stock returns of 32 companies from two industry sectors of Pakistan between 1998 and 2008. Their results suggested significant influence of major economic factors on industry level in comparison with the firm-level stock returns. Besides, they found that Pakistan banking sector is more vulnerable to changes in economic variables compared to textile industry sector. Finally, their results mentioned that rising inflation rate adversely affects the stock returns of Pakistan. Ali, Rehman, Yilmaz, Khan, and Afzal (2010) explored association among macro-economic indicators of inflation, exchange rate, balance of trade, money supply, and industrial production on Karachi stock exchange (KSE) index from the period 1990 to 2008. After applying the Granger causality test, their results found no causal association among macro-economic indicators and KSE.

On the contrary, Nishat and Shaheen (2004) applied Vector error correction model and found cointegration and "causal" relationship among macroeconomic factors and Pakistan stock prices. Additionally, their result also shows inflation as a negative determinant of stock prices in Pakistan. However, this study analyses stock market structural change and dynamics during deteriorating macroeconomic indication and economic crisis of Pakistan.

About country and region-specific economic and political crises, Dimitrios and Vasileios (2015) constructed correlation threshold network of Greek stock market and to study the impact of economic crisis by dividing the timeline into two yearly periods of pre and post-crisis between 2007 and 2012. Their results found a weak stock market that can be manipulated by large investors or economic climate. Dias (2013) applied MST to examine the impact of the
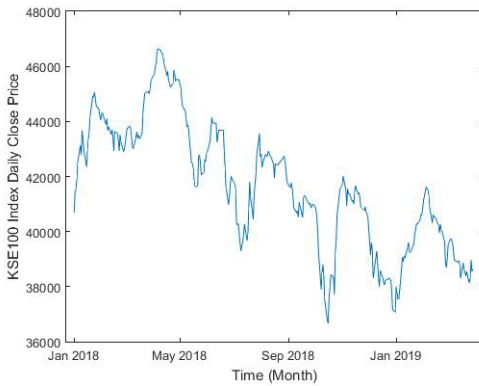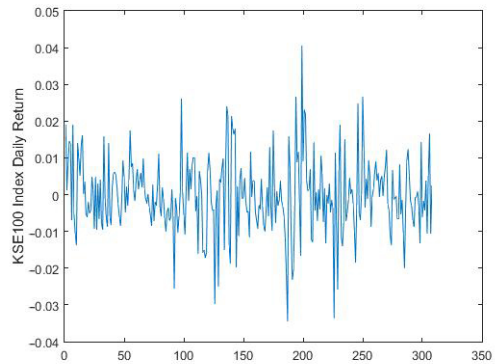
Figure 3. KSE-100 Index value

Figure 4. KSE-100 index return

eurozone crisis and found clear segregation between two groups of countries. Radhakrishnan, Duvvuru, Sultornsanee, and Kamarthi (2016) measured the effect of various crises including Thai currency and Asian financial crisis by comparing correlation-based MST and phase synchronise MST on Thai currency and stock market data. Their results found lower values of mean distance for both MSTs during crises. While analysing the impact of Brexit on London stock market, Yao and Memon (2019) constructed a network of FTSE 100 index companies, and found stable MST and an expansion in the MST during post-referendum period. All of these studies indicate a thorough examination of stock market structural change and evolution due to events of economic and financial crisis from within or outside world.

2. Data and methodology

We thoroughly examine the time series of the daily closing prices of 96 companies of Pakistan stock market blue-chip index, the Karachi stock exchange (KSE) 100 index from August 2018 to March 2019. Pakistan is going through severe economic crisis post general elections of 2018, due to deteriorating Country's foreign exchange reserves, high inflation, and current account deficits were among few factors accumulating a crisis for Pakistan. The international monetary fund (IMF) predicted lowest economic growth rates for Pakistan[4] to 2.4% for the year 2019 and 2.6% until 2023 due to internal macroeconomic, and external challenges. The benchmark KSE-100 index value has witnessed a gradual decline specially from May 2018 onwards and presenting a turbulent market index in Figure 3. Additionally, large fluctuations in the KSE-100 market index returns can be witnessed in Figure 4, showing sign of economic uncertainty.

We select all the top 96 companies of Pakistan stock market and build correlation network by applying Minimum spanning tree (MST) method on monthly basis. In this way, we construct 8 MST structures and study the dynamic topological evolution of Pakistan stock market during the current economic crisis of Pakistan. We describe daily closing price of stock returns i to be $r_i(t) = \ln(P_i(t)) - \ln(P_i(t-1))$, here $p_i(t)$ and $p_i(t-1)$ are closing prices of stock i on time t and $t-1$. After that, we calculate cross-correlation among all pairs of daily returns of the 96 stocks listed on KSE-100 index. The formula of calculating Pearson correlation between stocks i and j is given below:

$$C_{ij} = \frac{r_i \, r_j - r_i \langle r_j \rangle}{\sqrt{\left(r_i^2 - r_i^2 \right)\left(r_j^2 - r_j^2 \right)}} \, . \tag{1}$$

In the above formula, r_i and r_j are returns of stocks i and j, and $\langle .. \rangle$ is the mean of the period under investigation. In the next, we calculate distances among all the pairs of stocks in the correlation matrix, by following (Mantegna, 1999; Mantegna & Stanley, 2000), and in our case the distance matrix of (96×96) can be obtained using following formula:

$$d_{ij} = \sqrt{2\left(1 - C_{ij}\right)} \, . \tag{2}$$

The MST is formed by combining all the stocks in a graph specified by the shortest distance among stocks; then the graph contains $n-1$ links. We apply (Kruskal, 1956) algorithm to an undirected graph $G = (N, \, E, \, W)$ in formation of MST.

To analyse the dynamics of MST network, we calculate the size of the tree specified by the average tree length (ATL) of the minimum spanning tree. The ATL of MST can be calculated as Nobi, Maeng, Ha, and Lee (2015):

$$L(t) = \frac{1}{N} \sum_{\langle i,j \rangle} d_{ij}^{MST} \, . \tag{3}$$

3. Results and discussions

This section presents eight MSTs (Figures 5 to 12) of sizeable 96 companies[5] listed on the Karachi stock index (KSE-100) of Pakistan stock market. While assessing these MSTs we can notice that companies working in a similar branch of production tend to cluster.

In Figure 5, for the month of Aug-18 when inflation was 5.84%, we identified one key node of International steels (ISL) having 7 number of connections, followed by DG Khan cement (DGKC) having 5 direct number of connections. The most influencing node belonging to the engineering sector and cement sector highlight importance of concentration of KSE-100 index companies in these sectors during this period. The average correlation among all the stocks during this period remains at 0.127. The minimum distance of 0.411 has been observed between Pioneering cement (PIOC) and Maple leaf cement (MLCF). Similarly, the highest distance of 1.125 and subsequent lowest correlation has been observed among Shell petroleum (SHEL) and Pak Suzuki Motors (PSMC).
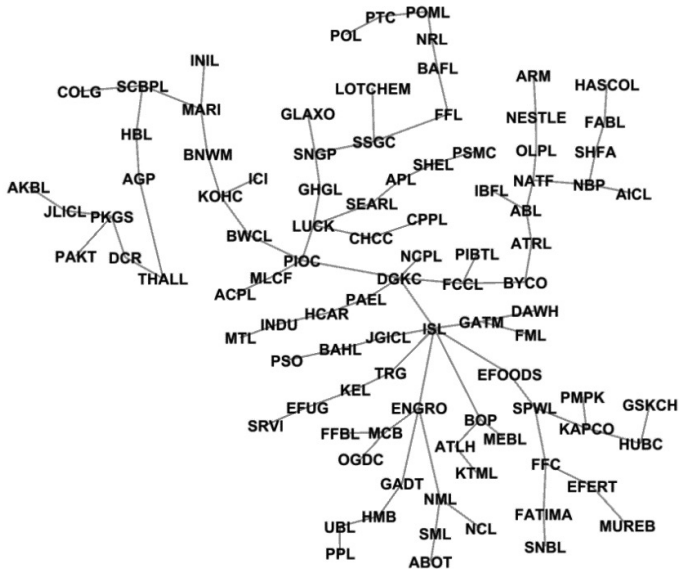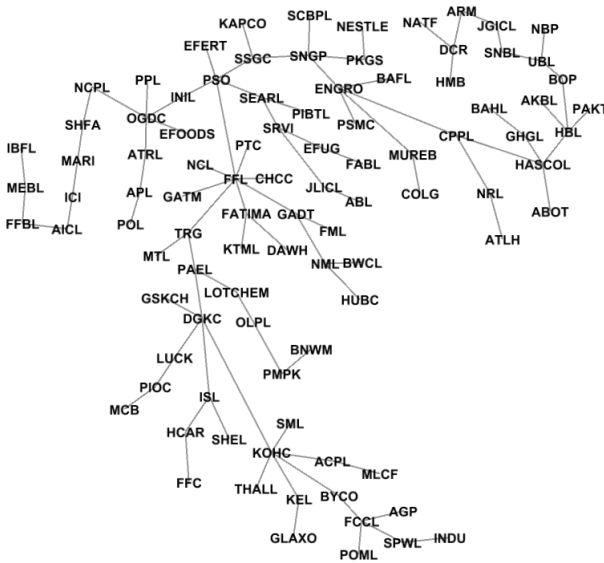
Figure 5. MST map of Pakistan stock market (August 2018)

Figure 6. MST map of Pakistan stock market (September 2018)

Figure 6 shows Sep-18 minimum spanning the tree of 96 companies of the KSE-100 index network. We immediately observe a hub node of Fauji Foods (FFL) having eight number of direct connections, followed by important node of Kohat cement (KOHC) with 6 connections. Such configuration of MST has been found by several researchers in the past for emerging markets (Tabak, Serra, & Cajueiro, 2010; Majapa & Gossel, 2016; Memon & Yao, 2019). Additionally, we observe reconfiguration of MST due to replacement of crucial nodes of ISL and DGKC and taken over by hub node of FFL. This reconfiguration possibly reflecting varied investor preferences, due to stock market decline. Figure 7 shows that during the month of Oct-18 the critical node of FFL has dropped from eight number of connections to only one degree of connection, and has been replaced by commercial banks sector node Askari bank (AKBL) with six degrees of connections, highest in the MST network. During this period, MST presents a tree-like flat structure which is common due to crisis-related shocks where index shades its value (Wilinski, Szewczak, Gubiec, Kutner, & Struzik, 2014; Memon & Yao, 2019). The most essential node during this period is Askari bank (AKBL) having six degrees of connections, followed by five other nodes of Allied Bank (ABL), Byco petroleum (BYCO), Dawood Hercules (DAWH), Lucky Cement (LUCK), and Mari Petroleum (MARI) having five degree of connections. Hence, MST during the month of Oct-18 is more concentrated, having more significant linkages among stocks (Brida, Matesanz, & Seijas, 2016).

Figure 8 shows the MST structure of Pakistan stock market for the month of Nov-18. We can observe almost similar configuration in terms of degree of connections. However, key node of commercial banks sector AKBL has dropped from six connection to one degree of connection, similar to node FFL in the previous month. The most important node in-terms
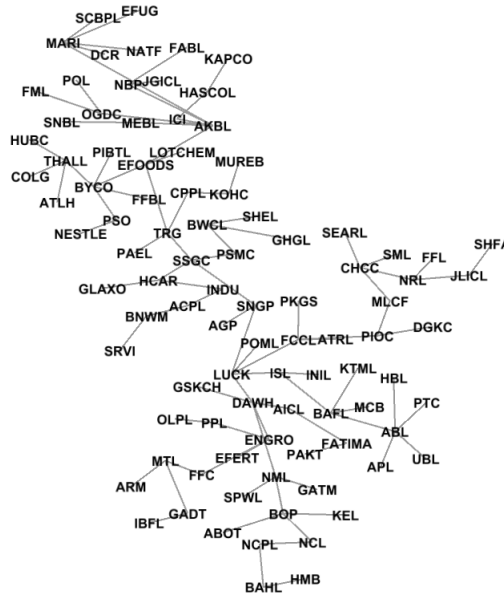

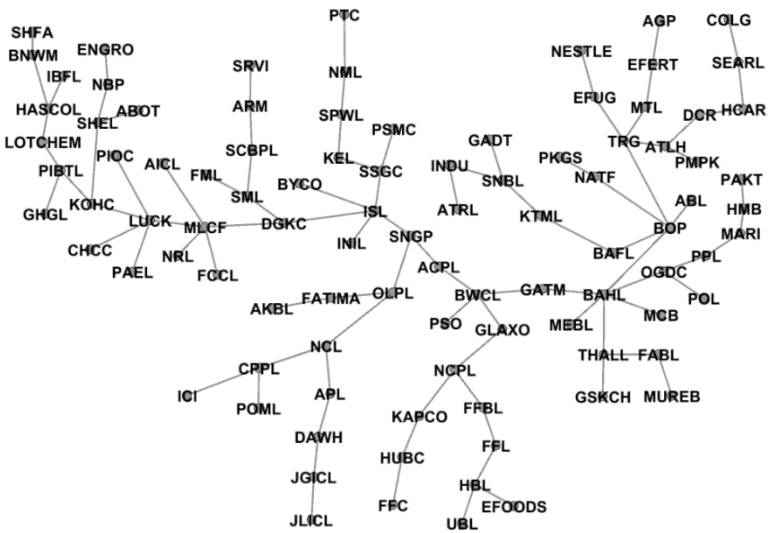Figure 7. MST map of Pakistan stock market (October 2018)

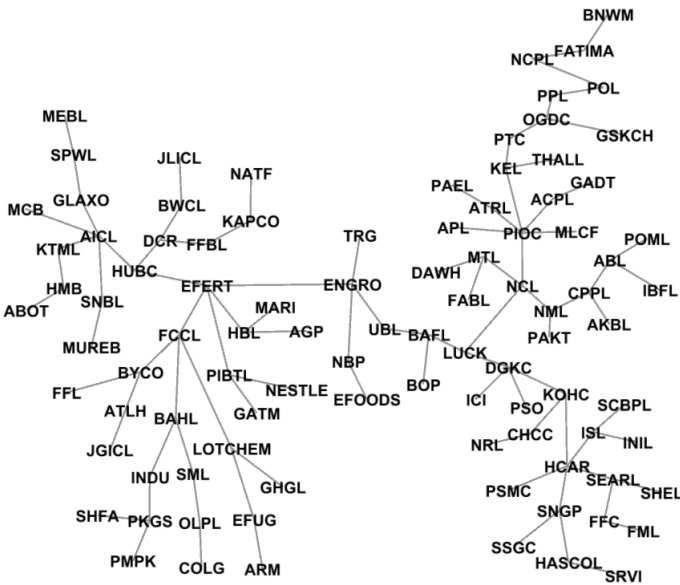Figure 8. MST map of Pakistan stock market (November 2018)

Figure 9. MST map of Pakistan stock market (December 2018)

of connectivity for the month of Nov-18 is Bank Al-Habib (BAHL) with six direct connections, followed by four nodes of Bank of Punjab (BOP), International steels (ISL), Lucky Cement (LUCK), and Maple leaf cement (MLCF) having five degree of connections. The lowest distance and maximum correlation during this period are observed between two cement sector nodes of MLCF and DGKC. The MST for the month of Dec-18 is presented in Figure 9. The KSE-100 index value continued to decline during this time period and closed at a low value of 37,066.67 on last trading day of Dec-18. Similar, reflection has been witnessed in the MST structure that is showing a weak structure during this time. In terms of connectivity, Pioneering cement (PIOC) remained as key node with six degrees of connections, followed by only three stocks of Adamjee insurance (AICL), Engro fertilisers (EFERT), and Honda Atlas Cars (HCAR) having five degrees of connections each. It is also observed that significant nodes of commercial banking sector of Pakistan are scattered throughout MST and does not form a cluster, such as Habib bank (HBL), National bank (NBP), Muslim Commercial bank (MCB), Allied bank (ABL), Askari bank (AKBL) and so on, are connected with companies of other sectors.

Figure 10 shows a fragile MST structure of Pakistan stock market for the month of Jan-19. The most important node in the MST is Pak Elektron (PAEL) with only five degrees of connections. We observed a significant decrease in the degree of connections per node, and MST again presents a tree-like structure. However, Figure 11 shows slight difference in the MST structure, due to an increase in the degree of connections per node, and appearance of key
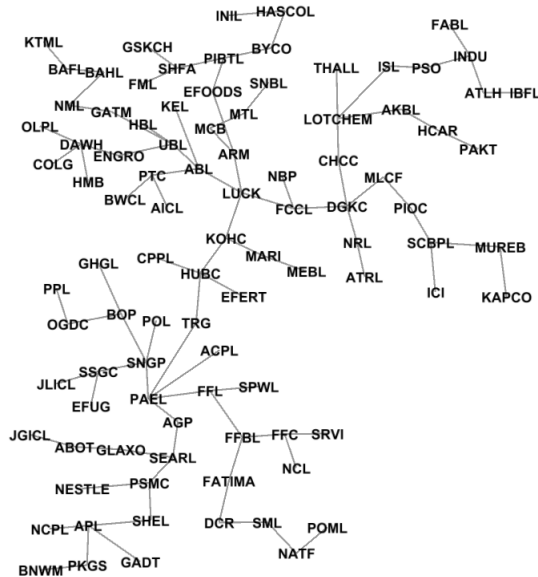

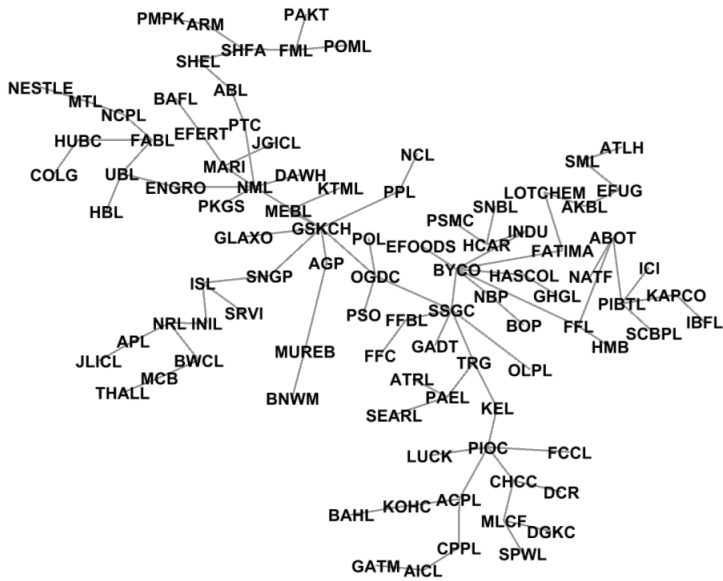Figure 10. MST map of Pakistan stock market (January 2019)

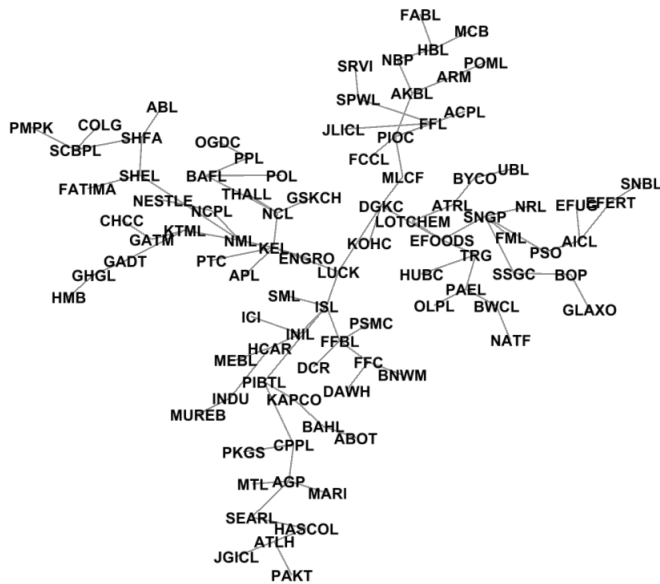Figure 11. MST map of Pakistan stock market (February 2019)

Figure 12. MST map of Pakistan stock market (March 2019)

nodes. The most essential nodes during the month of Feb-18 are Byco petroleum (BYCO) and GlaxoSmithKline consumer health (GSKCH) belonging to refinery and pharmaceutical sector, both having seven degrees of connections in the MST. Simultaneously, lowest distance of 0.257 and highest correlation of 0.967 during this period is observed among cement sector nodes of MLCF and DGKC (Similar to Nov-18 month). The inflation during the first month of year 2019 was recorded at high level of 7.19%, which continuously climbed and reached the highest level of 9.41% in the month of Mar-19. The uncertainty and crisis are well translated given the fragile MST structures of Pakistan stock market. The most influential company for the month of Mar-19 is Karachi electric company (KEL) belonging to power generation and distribution sector, directly connecting with 6 other companies in the network, presented in Figure 12. Moreover, we observed that stocks do not mostly tend to form a cluster, but arbitrarily link with the stocks of other sectors.

The frequency of degree distribution of the dynamic MSTs is presented in Figure 13. We observed varied topological characteristics of Pakistan stock market in almost all of the MST structures. Mainly, there is no single dominant stock, as the configuration of key nodes changes with time. Highest connectivity in the MST of a single node is observed during the month of Sep-18, but most of the nodes have a degree equals to one and two. This is common phenomena of scale-free networks as described by (Barabási & Albert, 1999), that have a great extent of nodes with low degrees but limited and few nodes with higher degree of connections. Such nodes that have higher degree of connections is referred to as hub nodes. However, appearance of major hub nodes in the Pakistan stock market during the current economic crisis of Pakistan is not evident, and the structure of Pakistan stock market change massively. Such phenomena of frequent change in the network structure of stock market are common during the crisis period (Nobi et al., 2015).
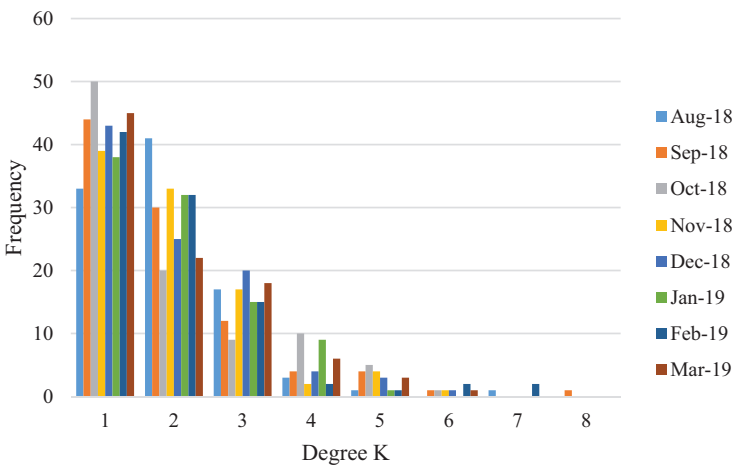
4. Average tree length

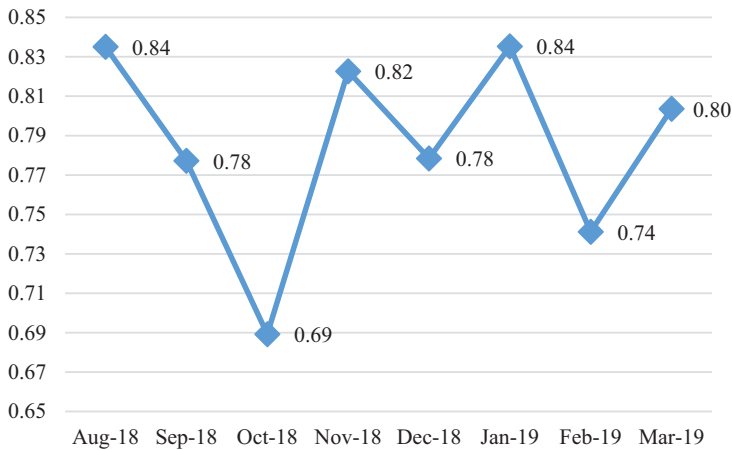Figure 13. Frequency of Degree Distribution of dynamic MSTs

Figure 14. Time-varying average tree length (ATL) of MSTs

In order to assess the dynamics of Pakistan stock market network, the topological property of Average tree length (ATL) of the eight MSTs is presented in Figure 14. The results show an overall network contraction, with the lowest being in the month of Oct-18. However, the ATL is recorded at 0.84 during two months of Aug-18 and Jan-19, in comparison with a shrink in the MST networks for the rest of months. The average ATL for all the periods is recorded at 0.79. The lower ATL values of Pakistan stock market for majority of time represents tight correlation among stocks, which has been observed during economic or financial crises (Wang, Xie, & Stanley, 2018; Yao & Memon, 2019). The micro and macro-economic indicators of Pakistan have witnessed a decline during economic crisis of Pakistan, the currency has been devalued exerting chaos among investors, and this behaviour was transmitted to Pakistan stock market that resulted in higher correlation among stocks.

Conclusions

In this study, the behaviour of 96 top stocks belonging to KSE-100 index of Pakistan stock market are thoroughly examined through network analysis approach. By using daily closing prices of stocks, we formed the correlation matrices for eight sub-sample sliding windows. The main aim of this paper was to analyse the impact of economic crisis of Pakistan on the network structure; therefore we obtained eight different MSTs and discussed their properties. We also presented frequency of degree distribution and average tree length of these MSTs. Our results revealed inconsistency in the key nodes of all the MSTs, and structural change is visible showing sign of severe economic crisis hit for the stock market. The eight key stocks that appeared in the dynamic MSTs of Pakistan stock market with a high degree of connections are ISL, FFL, AKBL, BAHL, PIOC, PAEL, BYCO, and KEL. Among these nodes only FFL was connected directly with eight nodes during September, highest degree of connection during entire period of study. Therefore, all the MSTs present tree-like flat structures due uncertainty and panic among investors that lead to varied preferences in their stock positions.

Moreover, stocks from same economic sector do not tend to cluster but connect mostly with stocks of other industry sectors. Which is a reflection of different reactions of the stock market participants to the risks posed by negative macroeconomic factors in the form of rapid increase in the inflation level on monthly basis, rupee depreciation, and depleting foreign exchange reserves of Pakistan? Furthermore, time-varying topological property of average tree length (ATL) reveals network contraction and tight correlation among stocks due to economic crisis of Pakistan. To sum up, the results show that Pakistan stock market remains structurally vulnerable due to economic crisis of Pakistan. This vulnerability is mostly a consequence of the reduced investor confidence in the prospects of Pakistan's economy. However, it can be averted by devising policies conducive to sustainable long-term growth that will restore business and consumer confidence, and bring regularity to the stock market. The information about structural changes and topological properties revealed in this study might assist regulators and practitioners in right trading strategies about stock markets formation. Further work may explore impact of macroeconomic indicators on the network topology structure of developed country's stock markets.

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Author contributions

Conceptualization, B.A.M.; methodology, B.A.M.; software, B.A.M, and R.T; validation, B.A.M., F.A, and H.Y.; formal Analysis, B.A.M..; investigation, B.A.M.; resources, B.A.M. and H.Y.; data curation, B.A.M.; writing – original draft preparation, B.A.M.; writing – review and editing, H.Y., F.A, R.T, and B.A.M.; visualization, B.A.M. and R.T.; supervision, H.Y.

Disclosure statement

The authors declare that they have no competing financial, professional, or personal interests from other parties.

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