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A Network Analysis of Shariah-Compliant Stocks across Global Financial Crisis: A Case of Malaysia

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Abstract

Financial network is a complex system in which transaction of securities take place. Due to its complexity, a minimum spanning tree (MST) technique is used to visualize the structure. This paper investigates the topological structure of 125 shariah-compliant stocks traded in Bursa Malaysia from the year 2000 until 2017. Financial networks of the shariah-compliant stocks are constructed using MST for three duration periods namely the pre-crisis, during crisis and post-crisis. To determine the important stocks in the networks, centrality measures are applied such as degree centrality, betweenness centrality, closeness centrality and eigenvector centrality. Lastly, overall centrality measures are computed to identify the overall characteristic of each node. The findings showed that, KUB Malaysia Berhad was the most influential stock in the pre-crisis and crisis periods. While, MK Land Holdings was the main stock in the post-crisis network.

Keywords: financial network, minimum spanning tree (MST), centrality measures, shariah-compliant stocks

1. Introduction

A network can be defined as a set of items, called vertices or nodes and connections between the nodes as links or edges. There are various types of networks such as the Internet, the World Wide Web, social networks, business networks, food webs, distribution networks, technological networks, biological networks and financial market network is one of them. Briefly, a financial market is a trading floor where transaction of securities consists of equities, bonds, currencies, and derivatives take place. Therefore, a financial market network consists of nodes which represent the stocks and the links represent the correlation between stocks. Basically, the correlation between stocks is based on a stock's price. The fluctuation of a stock's price from time to time exhibits a very complicated and complex system since the changes occur in the stock prices will affect other stock prices too. This complexity consequently makes the financial network a fascinating network which attracted much attention from many researchers to further investigate its structures and characterizations. In addition, the complex correlation elements make the financial network difficult to visualize.

Minimum spanning tree (MST) method is a common approach to visualize and simplify stocks correlation network. MST can be defined as a spanning tree with minimum weights. The application of MST is not only in finance, but is also widely used in other fields such as in industry (Sharif & Djauhari, 2012b), transportations (Asrah, Djauhari, & Mohamad, 2017) and politics (Laud, 2015). Furthermore, in finance, MST method has been a very popular method to analyze stocks' correlations since it was introduced by Mantegna (1999). Instead of $N \times N$ correlation elements, it can be reduced to only $N(N\text{-}1)/2$ correlation elements and produce N-1 links where N is the number of stocks. Since decades ago, numerous studies have applied this method to analyze the financial market, for example, Bonanno et al., (2004), Zhuang, Hu and Ye (2008), Jang, Lee and Chang (2011), Djauhari (2012), Cheong et al., (2012), Djauhari and Gan (2013, 2015), Majapa and Gossel (2016) and Coletti (2016). In Malaysian market, Sharif and Djauhari (2012a), Djauhari and Gan (2014), Bahaludin et al., (2015), Yee and Salleh (2018) and Yee et al., (2018) are among the studies investigated a financial network by using MST technique.

All those studies revealed that, there are dominant nodes and also sectors in the network that influence the

topological structures. For instance, in Malaysian market, Gan and Djauhari (2012), Bahaludin et al., (2015), Yee and Salleh (2018) and Yee et al., (2018) studied the top 100 companies based on market capitalization with different time ranges. In the year 2007 until 2009, Gan and Djauhari (2012) found two main clusters with EUMS and BURSA as the key stocks. Later, Bahaludin et al., (2015) obtained three dominant stocks from the year 2011 until 2013, in which two of them are the same stocks found in Gan and Djauhari (2012) and the third stock was UEMS. Recently, Yee and Salleh (2018) continued the study of Bursa Malaysia market performance over the period of 2011 to 2017. They determined four main groups in the network dominated by MALAYAN, AFFIN, MRCB and CIMB.

Moreover, all the authors above used conventional stocks in their studies. Until now, there is no study that analyzes financial market network for shariah-compliant stocks by using MST. Thus, in this perspective, this study aims to investigate the topological structure of shariah-compliant stocks traded in Bursa Malaysia from 28th March 2000 until 29th December 2017 by using MST method. For this purpose, the duration of the study is divided into pre-crisis, crisis and post-crisis periods. In this study, the aim is to determine the most influential shariah-compliant stocks in terms of degree centrality, betweenness centrality, closeness centrality and eigenvector centrality for each period. Lastly, the overall role of the stocks is measured by using the Principal Component Analysis (PCA).

This paper is organized as follows. In the next section, this paper presents the data and methodology followed by a discussion on the findings and analysis in section 3. Finally, in section 4 conclusion was made from the results obtained.

2. Data and Methodology

Data are collected from Eikon Datastream based on the stocks listed in Bursa Malaysia and the Shariah Advisory Council (SAC) from 28th March 2000 until 29th December 2017. Analysis is divided into three periods namely pre-crisis (2000-2006), crisis (2007-2009) and post-crisis (2010-2017). The crisis period is similar to the work of Asmild, Kronborg, Tasmina and Kent (2018). Across all the periods, there are 4,471 daily closing prices for one hundred and twenty-five (125) consistently listed as shariah-compliant companies from the year 2000 until 2017. The list of 125 shariah-compliant companies and their corresponding codes is presented in the Appendix. The next subsection explains shariah-compliant stock, followed by the procedures of the MST and centrality measures.

2.1 Shariah-Compliant Stocks

Securities Commission Malaysia (SC) is a legal organization entrusted with the responsibilities of regulating and systematically developing Malaysia's capital markets by providing a list of securities that has been examined as shariah compliance. In determining the Shariah-compliant status of the listed securities, Securities Commission Malaysia (2018) set up some criteria which need to be fulfilled by companies. The criteria are, the company must be free from interest (riba), gambling (maysir), doubtful transactions or uncertainty (gharar), and forbidden (haram) activities, for example, involvement in alcohol and pig farming. The shariah principles concentrated on the core business activities of the companies. It is worth to note that, if a company comprises halal and non-halal activities, it is shariah-compliant if and only if the non-halal activities are very small compared to the core activities, as well as its images and public perceptions are good. Furthermore, the core activities contribute to the people and the country.

2.2 Minimum Spanning Tree (MST)

MST is a well-known method to simplify the complexity of the correlation networks. There are four simple steps to create MST network. Firstly, logarithmic returns of daily closing prices are calculated and a correlation matrix is computed by using Pearson's correlation coefficient (PCC). Next, the correlation coefficient is transformed into a distance matrix as conducted by Mantegna (1999) and Mantegna and Stanley (2000). In the consequential MST, each node represents a shariah-compliant stock in Bursa Malaysia and their distances are analyzed and taken as their strengths in terms of their correlations between stocks *i* and *j*.

The procedures to construct a network using MST are as follows. If $P_i(t)$ is denoted as the closing stock price of a company *i* (*i* = 1... *N*) at time *t*, then logarithmic return is calculated as:

$$r_i(t) = \ln P_i(t) + \ln P_i(t) \quad (1)$$

Let *C* be a correlation of $N \times N$ matrix, where *N* is the number of stocks. While, ρ_{ij}, is a correlation coefficient between stocks *i* and *j* calculated by using a Pearson's Correlation Coefficient formula:

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

Then, a correlation coefficient, ρ_{ij}, is transformed into a distance matrix, denoted by:

$$d_{ij} = \sqrt{2(1-\rho_{ij})} \tag{3}$$

Lastly, the MST is constructed by using a Kruskal's algorithm as Kruskal's algorithm is one of the standard practice to find MST (Graham & Hell, 1985; Keskin, Deviren, & Kocakaplan, 2011; Mantegna, 1999; Mantegna & Stanley, 2000). The advantages of using the Kruskal's algorithm are that it is mathematically appealing (Malkevitch, 2012), easy to formulate although it is not the fastest algorithm (Nesetril, 1997) and no optimality problem occurs since the result of Kruskal's algorithm is independent of node ordering (Djauhari & Gan, 2013, 2014).

2.3 Centrality Measures

A centrality measure reveals the most influential stocks in the network. There are four commonly used centrality measures in many studies such as degree centrality, betweenness centrality, closeness centrality and eigenvector centrality (Coletti, 2016; Coletti & Murgia, 2016; Yee & Salleh, 2018; Yee et al., 2018). In addition, an overall centrality measure is calculated to determine an overall role of each stock.

To begin with, degree centrality, $C_D(i)$, is to identify the most important node (stock) with respect to the number of linked nodes (Freeman, 1978). It is calculated using the following formula:

$$C_D(i) = \frac{\sum_j^N A_{ij}}{N-1} \tag{4}$$

where $A_{ij} = 1$ if the stock *i* and stock *j* are linked and 0 otherwise. According to Freeman (1977), betweenness centrality, $C_B(i)$ shows the ability of a particular node to control others by controlling the information flows between them. It is computed as follows:

$$C_B(i) = \sum_{j<k} \frac{g_{jk}(i)}{g_{jk}} \tag{5}$$

where, $g_{jk}(i)$ is the number of shortest paths from stock *j* to stock *k* that pass-through stock *i*. Meanwhile, g_{jk} is the total number of shortest paths from *j* to *k*, where $j \neq i$ and $k \neq i$. The value of closeness centrality, $C_C(i)$ reveals the nearest distance between stock *i* and stock *j*, relatively. The closeness centrality of stock *i*, $C_C(i)$ is mathematically defined as:

$$C_C(i) = \left[\sum_{j=1}^{N} d(i,j)\right]^{-1} \tag{6}$$

where $d(i,j)$ is the shortest path from stock *i* to stock *j*. Lastly, the concept of eigenvector centrality is to determine a node's importance in a network by asserting links to another node that are themselves influential (Bonacich, 1987). Eigenvector centrality is denoted as:

$$e(i) = \lambda^{-1} \sum_{j=1}^{N} A_{ij} x_j \text{ for } i = 1,2,...N. \tag{7}$$

Additionally, the expression is also can be written as

$$A_{ij} e(i) = \lambda e(i) \tag{8}$$

where A_{ij} is an adjacency matrix and $e(i)$ is an eigenvector of a largest eigenvalue, λ.

2.4 Overall Centrality Measures

In order to identify the overall role of each stock, an overall centrality measure is calculated by using principal component analysis (PCA), similar to the seminal work of Lee and Djauhari (2012), Pasini (2017) and Yee and Salleh (2018).

The investigation of an overall role of each stock produces a very large and complex data set since a matrix of $N \times 4$ is computed where N is the number of stocks and 4 is denoted as the four centrality measures of stock i. In order to reduce this complexity and minimizes the information loss, PCA method is applied (Jolliffe, 2002). In general, the correlated variables are transformed into a new set of uncorrelated variables which is called as principal components (PCs). The PCs are arranged in a sequence in which the PC with the largest eigenvalue is considered. Then, its eigenvector is computed in which each element of the eigenvectors is a linear combination of the original variables.

Firstly, matrix of $N \times 4$ and a covariance matrix of S are computed. Secondly, eigenvector, $\mathbf{v} = (v_1, v_2, v_3, v_4)$ associated with the largest eigenvalue, $\theta_{\max}$ is calculated by using the formula $S\mathbf{v} = \theta_{\max}\mathbf{v}$. Then, the overall centrality measure score of stock i is determined by

$$O(i) = v_1 C_D(i) + v_2 C_B(i) + v_3 C_C(i) + v_4 e(i) \tag{9}$$

3. Results and Discussions

In this section, the examining of the MST of shariah-compliant companies in Malaysian market for the three durations which are pre-crisis (2000-2006), during crisis (2007-2009) and post-crisis (2010-2017). The data collected consists of 125 stocks which are consistently classified in eight economic sectors based on SAC's list traded since the year 2000 until 2017. However, during crisis period, only 124 companies are used since Teo Guan Lee Construction (9396) from the consumer sector is removed due to the unavailability of data.

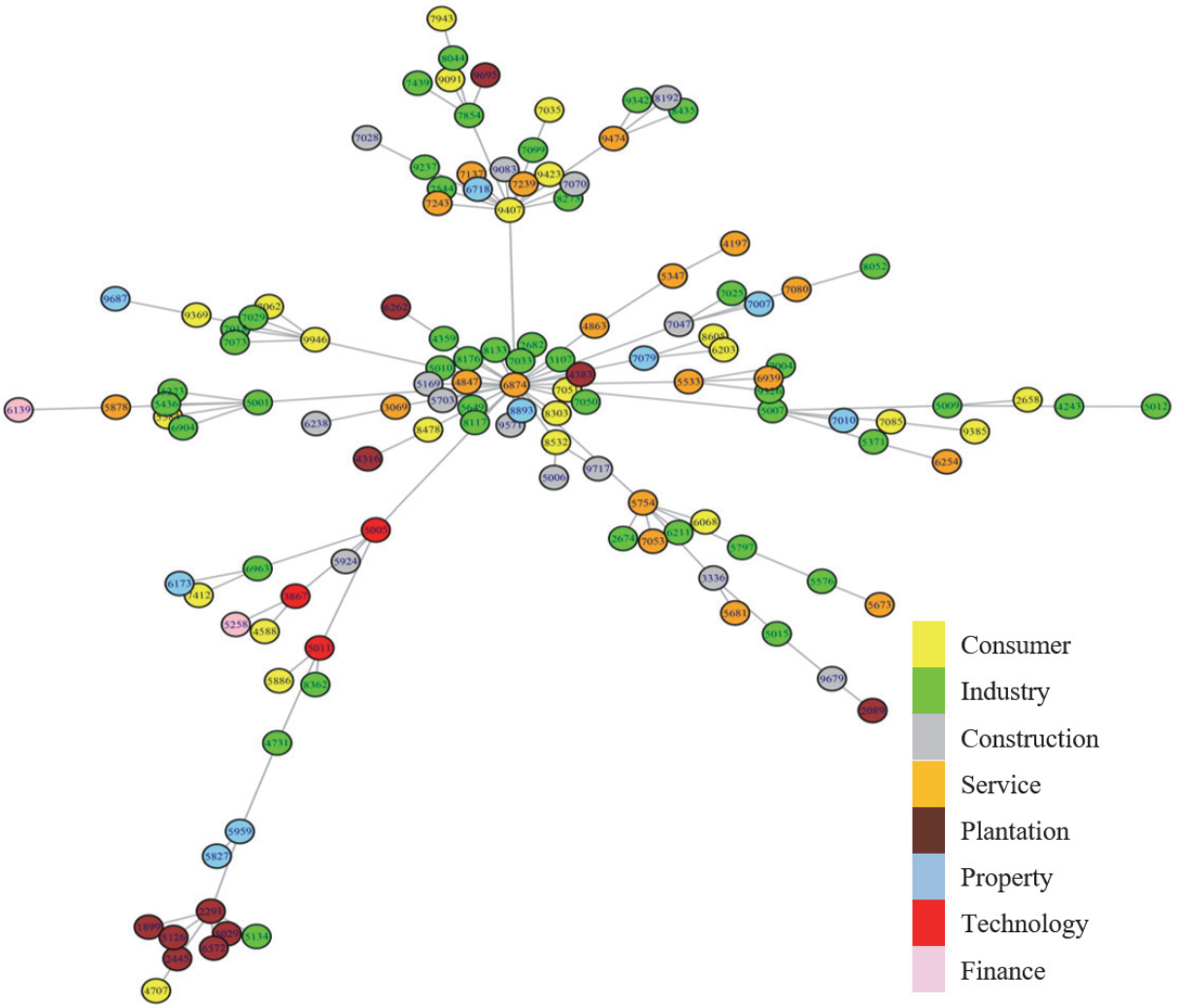

Figure 1. Minimum Spanning Tree (MST) of a pre-crisis period from the year 2000 until 2006

3.1 Minimum Spanning Tree (MST)

Figure 1 until Figure 3 present the evolution of MST from the three periods (pre-crisis, during crisis and post-crisis). Figure 1 portrays that, there were seven main clusters during the pre-crisis period and was dominated by KUB Malaysia Berhad (6874) with 31 stocks connected to it. Next is Paragon Union (9407) with a number of links of 14, Utusan Melayu Malaysia (5754) and Genting Plantation (2291) shared the same number of links which is 7, while Rex Industry (9946) and Mieco Chipboard (5001) have the same number of links which is 6. Lastly, Unisem (5005) has 5 stocks linked to it.

Figure 2 presents three main groups in the crisis period network in which KUB Malaysia Berhad (6874) was the key node with 28 stocks linked to it. Then, with 13 links, Batu Kawan (1899) was the second group. The third goup was Muhibbah Engineering (5703) having 8 stocks connected to it. The crisis period network shows that the stocks had low connections with other stocks compared to the pre-crisis period.

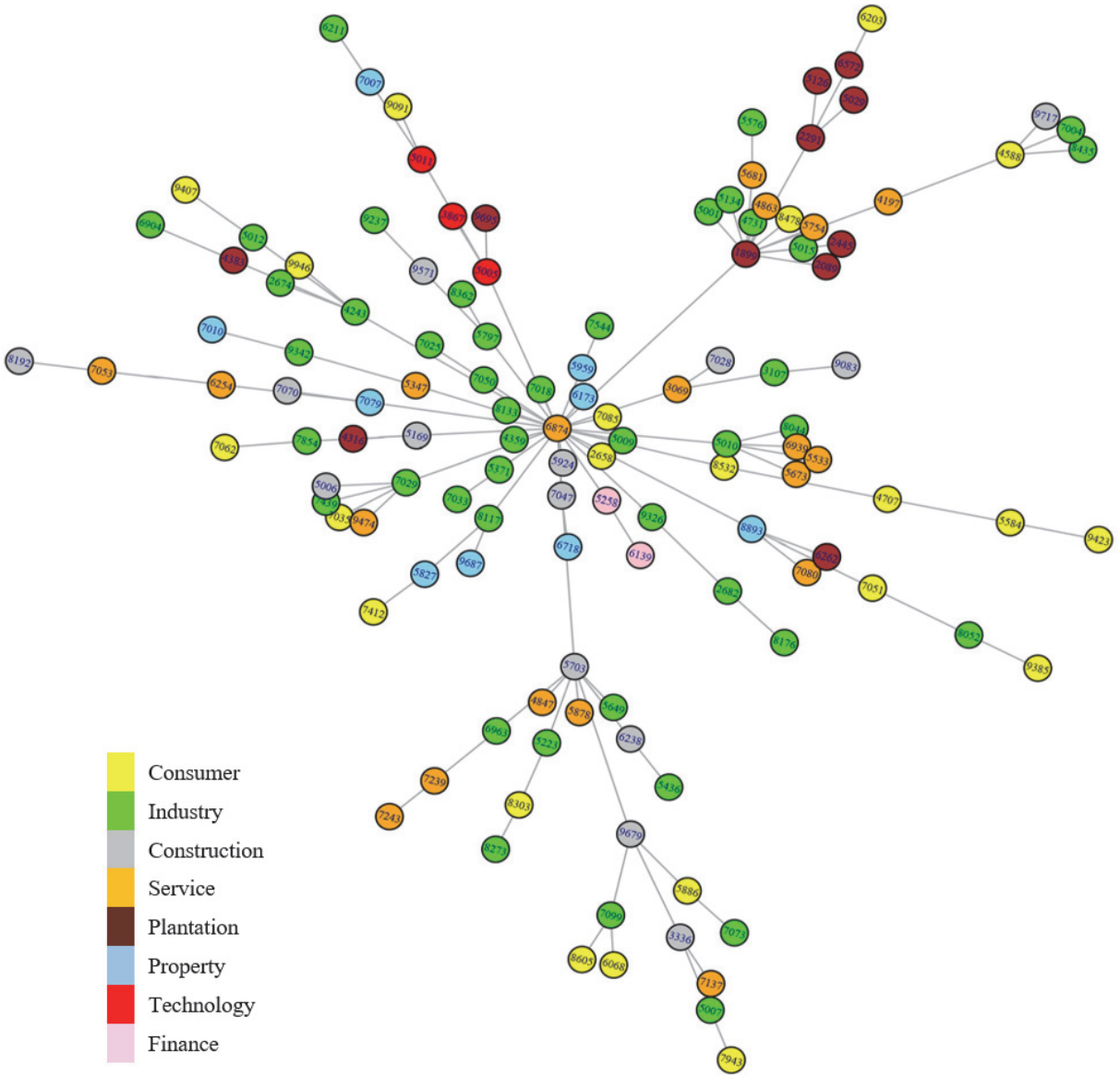

Figure 2. Minimum Spanning Tree (MST) of a crisis period from the year 2007 until 2009

After the turmoil period, Figure 3 portrayed five main clusters in the network with MK Land Holdings (8893) as the most influential stocks with a number of links of 23, tailed by Muhibbah Engineering (5703) with 18 stocks linked to it. The third and fourth clusters were dominated by WTK Holdings (4243) and KUB Malaysia Berhad (6874) respectively, with 12 stocks connected to each of them. Lastly, VS Industry (6963) has 4 number of links.

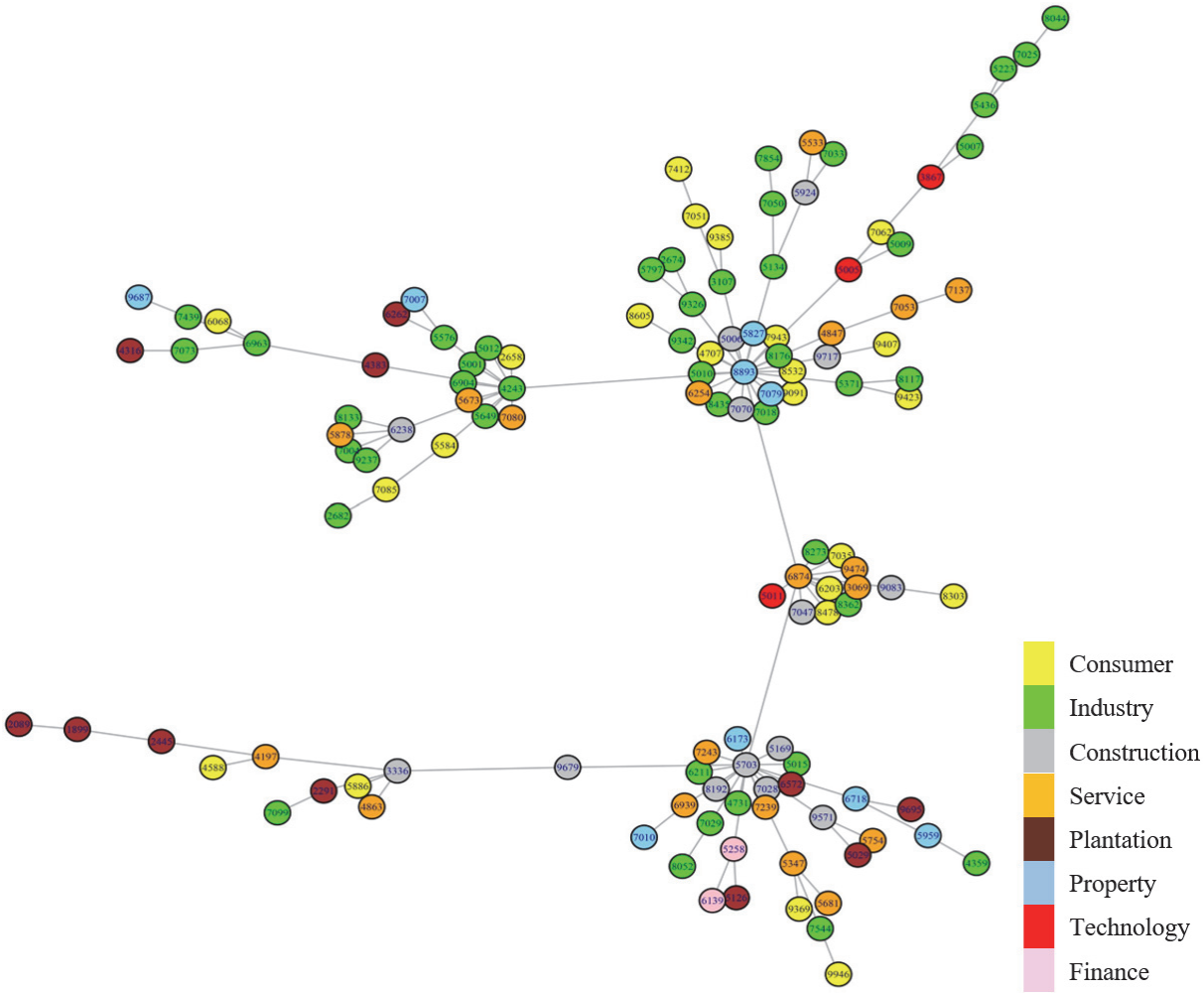

Figure 3. Minimum Spanning Tree (MST) of a post-crisis period from the year 2010 until 2017

3.2.1 Degree Centrality

Degree centrality is the number of links connected directly to a node (Freeman, 1978). Normally, node with higher number of links connected to it, is the most important node in terms of degree centrality. Table 1 until Table 3 reveal the top five nodes which have the highest degree centrality for each duration. Table 1 until Table 3 show that KUB Malaysia Berhad (6874) has the highest degree values in pre-crisis and crisis periods which are 0.250 in pre-crisis and decrease during crisis with a degree value of 0.228 as depicted in Table 1 and Table 2. Unfortunately, after the crisis period, KUB Malaysia Berhad decreases to the third rank with 0.097 degree value. While, MK Land Holdings (8893) has the highest rank with a degree value of 0.185 as shown in Table 3. Besides, as observed in Table 1 and Table 2, there are no consistent stocks listed as top five in the degree centrality scores in pre-crisis and crisis periods except for KUB Malaysia Berhad (6874). This signifies that, there was a restructuring of the network in order to acclimatize during a tremendous period.

Table 2 and Table 3 further reveal that, only three stocks are consistently appear as having the uppermost score in crisis and post-crisis periods. The stocks are Muhibbah Engineering (5703), WTK Holdings (4243) and KUB Malaysia Berhad (6874). It explains that, there was a recovery in stocks which is Muhibbah Engineering (5703), which has increase in its degree value from 0.065 in the crisis period to 0.145 in post-crisis period. In addition, WTK Holdings (4243) shows an arising value from 0.041 during crisis period to 0.097 in post-crisis period. Nevertheless, the value for KUB Malaysia Berhad (6874), has sharply decrease from 0.228 to 0.097. Moreover, Table 3 tells that, there were stocks in the post-crisis period that entered the top five list after the crisis period. Example of the stocks are MK Land Holdings (8893), Hock Seng Lee (6238), IJM Corporation (3336) and VS Industry (6963). In other words, these stocks increase in the number of incident links after the crisis period.

Further, in Table 1 and Table 2 expose that the service sector was the strongest sector before crisis and during crisis

periods. Then, it was replaced by the property sector in the post-crisis period as illustrated in Table 3. Table 2 also displays that the industry sector played an important role since there are three out of five stocks belongs to the industry sector. Similar to the construction sector, it was also an influential sector during the post-crisis period as it appears three times in Table 3. Thus, this shows that, these sectors have many stocks linked to them which make them the most crucial stocks across all periods.

Table 1. The highest degree centrality values for the pre-crisis period (2000-2006)

No	Name	Code	Sector	Degree
1	KUB Malaysia Berhad	6874	Service	0.250
2	Paragon Union	9407	Consumer	0.113
3	Utusan Melayu Malaysia	5754	Service	0.056
4	Genting Plantations	2291	Plantation	0.056
5	Rex Industry	9946	Consumer	0.048
6	Mieco Chipboard	5001	Industry	0.048
7	Chin Well Holdings	5007	Industry	0.040

Table 2. The highest degree centrality values for the crisis period (2007-2009)

No	Name	Code	Sector	Degree
1	KUB Malaysia Berhad	6874	Service	0.228
2	Batu Kawan	1899	Plantation	0.106
3	Muhibbah Engineering	5703	Construction	0.065
4	Master-Pack Group	7029	Industry	0.041
5	Tong Herr Resources	5010	Industry	0.041
6	WTK Holdings	4243	Industry	0.041
7	UMW Holdings	4588	Consumer	0.033

Table 3. The highest degree centrality values for the post-crisis period (2010-2017)

No	Name	Code	Sector	Degree
1	MK Land Holdings	8893	Property	0.185
2	Muhibbah Engineering	5703	Construction	0.145
3	WTK Holdings	4243	Industry	0.097
4	KUB Malaysia Berhad	6874	Service	0.097
5	Hock Seng Lee	6238	Construction	0.040
6	IJM Corporation	3336	Construction	0.040
7	VS Industry	6963	Industry	0.032

3.2.2 Betweenness Centrality

Freeman (1978) stated that, betweenness centrality is a method to determine the importance of a node as an intermediary. The node that has the highest betweenness centrality value is interpreted as having the ability to control the information flow within a network. Thus, the node is considered as the most influential node in terms of betweenness centrality measure. The findings expose that the top five of betweenness centrality measure for three periods are presented in Table 4 until Table 5.

Across pre-crisis and crisis periods, KUB Malaysia Berhad (6874) remained as the highest rank with betweenness centrality values of 0.908 in pre-crisis period and 0.921 in crisis period as described in Table 4 and Table 5. Therefore, the information must pass through KUB Malaysia Berhad before it reached other stocks. In other words, KUB Malaysia Berhad controlled the information flow in the networks. Thus, KUB Malaysia Berhad was the most influential stock in both pre-crisis and crisis periods networks. Additionally, the highest value of betweenness centrality of KUB Malaysia Berhad indicates that the service sector was the most important sector in Malaysian Islamic market during those periods. However, the betweenness value of KUB Malaysia Berhad (6874) decreased slightly after crisis period with a score of 0.557 as portrayed in Table 6. In the recovery phase, Table 5 painted MK Land Holdings (8893) as having the highest score in betweenness centrality value of 0.767. The post-crisis period displays an increased intermediary influence of Muhibbah Engineering (5703) and WTK Holding (4243).

Muhibbah's betweenness value has increased in value from 0.306 during crisis period to 0.532 in post-crisis period, while WTK's value has sharply increased from 0.095 to 0.359 as shown in Table 6.

The findings in Table 4 and Table 5 show that there are no consistent stocks listed as the top five in pre-crisis and crisis periods except for KUB Malaysia Berhad (6874). In contrast, there are four stocks consistently appear in the top five list in the crisis and post-crisis periods which are KUB Malaysia Berhad (6874), Muhibbah Engineering Berhad (5703), WTK Holdings (4243) and WCT Holdings (9679). Above all, only KUB Malaysia Berhad (6874) appears across all periods of study. Thus, it concludes that, KUB Malaysia Berhad (6874) was a good mediator in all periods. Likewise, it makes the service sector as an important sector. Besides, property sector also played an influential sector in the post-crisis period.

Table 4. The highest betweenness centrality values for the pre-crisis period (2000-2006)

No	Name	Code	Sector	Betweenness
1	KUB Malaysia Berhad	6874	Service	0.908
2	Paragon Union	9407	Consumer	0.334
3	Unisem	5005	Technology	0.298
4	Mesiniaga	5011	Technology	0.192
5	Utusan Melayu Malaysia	5754	Service	0.183

Table 5. The highest betweenness centrality values for the crisis period (2007-2009)

No	Name	Code	Sector	Betweenness
1	KUB Malaysia Berhad	6874	Service	0.921
2	Batu Kawan	1899	Plantation	0.310
3	Muhibbah Engineering	5703	Construction	0.306
4	WCT Holdings	9679	Construction	0.140
5	WTK Holdings	4243	Industry	0.095

Table 6. The highest betweenness centrality values for the post-crisis period (2010-2017)

No	Name	Code	Sector	Betweenness
1	MK Land Holdings	8893	Property	0.767
2	KUB Malaysia Berhad	6874	Service	0.557
3	Muhibbah Engineering	5703	Construction	0.532
4	WTK Holdings	4243	Industry	0.359
5	WCT Holdings	9679	Construction	0.149

3.2.3 Closeness Centrality

Closeness centrality is defined as a measure of the average shortest distance from one stock to all the other stocks (Freeman, 1978). Besides, closeness centrality quantifies how quick the information is distributed to all other stocks in the network. The top five of closeness centrality measures is depicted in Table 7 until Table 9.

Analysis reveals that KUB Malaysia Berhad (6874) continues to be the top scorer in closeness centrality for both periods, pre-crisis and crisis with a score of 0.357 in pre-crisis and increase a little bit during the turmoil period with a score of 0.381 as displayed in Table 7 and Table 8. In the next period, in Table 9, KUB Malaysia Berhad (6874) was replaced by MK Land Holdings (8893) with a score of 0.292. Remarkably, MK Land Holdings (8893) jumped from the fourth place in the crisis period to first place during post-crisis period. Besides, KUB Malaysia Berhad (6874) and Unisem (5005) remained in the top five list for all periods. This result discloses that all other stocks were closely connected to KUB Malaysia Berhad (6874) and Unisem (5005) across all periods.

This investigation also reveals that the property sector was the most influential sector in the post-crisis period, while, the service sector was the most influential sector in both before and during crises. In general, KUB Malaysia Berhad (6874) and MK Land Holdings (8893) were near to other stocks in the networks. Also, it can be said that, the crisis spread through these key stocks.

Table 7. The highest closeness centrality scores for the pre-crisis period (2000-2006)

No	Name	Code	Sector	Closeness
1	KUB Malaysia Berhad	6874	Service	0.357
2	Paragon Union	9407	Consumer	0.284
3	Unisem	5005	Technology	0.283
4	Utusan Melayu	5754	Service	0.272
5	Chin Well Holdings	5007	Industry	0.264

Table 8. The highest closeness centrality scores for the crisis period (2007-2009)

No	Name	Code	Sector	Closeness
1	KUB Malaysia Berhad	6874	Service	0.381
2	Muhibbah Engineering	5703	Construction	0.306
3	Batu Kawan	1899	Plantation	0.300
4	MK Land Holdings	8893	Property	0.290
5	Unisem	5005	Technology	0.279

Table 9. The highest closeness centrality scores for the post-crisis period (2010-2017)

No	Name	Code	Sector	Closeness
1	MK Land Holdings	8893	Property	0.292
2	KUB Malaysia Berhad	6874	Service	0.278
3	Muhibbah Engineering	5703	Construction	0.250
4	WTK Holdings	4243	Industry	0.242
5	Unisem	5005	Technology	0.223

3.2.4 Eigenvector Centrality

According to Newman (2010) eigenvector centrality is a natural extension of the simple degree centrality. This measure shows the neighbour of a particular node, and also plays crucial roles in determining the importance of a node. It also can be said that, the stock (node) with the highest eigenvector centrality measure indicates that it is connected to the stock with a high degree scoring. Table 10 until Table 12 illustrate the top five highest eigenvector centrality measures in all periods.

Table 10 and Table 11 portray that KUB Malaysia Berhad (6874) has the highest scoring in both pre-crisis and crisis periods with scores of 0.679 and 0.674, respectively. Unfortunately, with a value of 0.23, it made KUB Malaysia Berhad (6874) as the second important stock during post-crisis as revealed by Table 12. MK Land Holdings (8893) replaced KUB Malaysia Berhad (6874) as the uppermost score during post-crisis period with a score of 0.654. Thus, MK Land Holdings dominated the network in terms of eigenvector centrality during post-crisis period. Interestingly, the results show that there are no consistent stocks listed in the top five except for KUB Malaysia Berhad across all durations of the study.

Generally, the service sector with KUB Malaysia Berhad took over the network in both before crisis and during crisis periods. While, property sector was the strongest sector in post-crisis period with MK Land Holdings as the important stock. In other words, these stocks had many important stocks connected to them.

Table 10. The highest eigenvector centrality scores for the pre-crisis period (2000-2006)

No	Name	Code	Sector	Eigenvector
1	KUB Malaysia Berhad	6874	Service	0.679
2	Paragon Union	9407	Consumer	0.202
3	Rex Industry	9946	Consumer	0.136
4	Utusan Melayu Malaysia	5754	Service	0.136
5	Mieco Chipboard	5001	Industry	0.134

Table 11. The highest eigenvector centrality scores for the crisis period (2007-2009)

No	Name	Code	Sector	Eigenvector
1	KUB Malaysia Berhad	6874	Service	0.674
2	Batu Kawan	1899	Plantation	0.191
3	Master-Pack Group	7029	Industry	0.160
4	Tong Herr Resources	5010	Industry	0.146
5	Ho Hup Construction	5169	Construction	0.141

Table 12. The highest eigenvector centrality scores for the post-crisis period (2010-2017)

No	Name	Code	Sector	Eigenvector
1	MK Land Holdings	8893	Property	0.654
2	KUB Malaysia Berhad	6874	Service	0.233
3	WTK Holdings	4243	Industry	0.211
4	Southern Acids (M)	5134	Industry	0.145
5	Fima Corporation	3107	Industry	0.141

3.3 Overall Centrality Measure

From the above centrality measures, each of the measures has a unique definition. It defines that each of the centrality measures has distinctive characteristics. So, to determine the most prominent stocks with overall characteristics, an overall centrality measure is computed by using Principal Component Analysis (PCA), similar to the seminal work of Lee and Djauhari (2012), Pasini (2017) and Yee and Salleh, (2018). Tables 13 until Table 15 show the proportion of variance for the first principal component pre-crisis period which is 83.19%, 85.78% is in the crisis period and 83.49% in the post-crisis period. It is effectively acceptable to identify the overall centrality measure as mentioned by Jolliffe (2002). Consequently, the overall centrality measure is computed and the five most influential stocks are exhibited in Table 13 until Table 15.

KUB Malaysia Berhad (6874) played a very crucial role in the networks of pre-crisis and crisis periods as displayed in Table 13 and Table 14 with scores of 1.112 and 1.115, respectively. While, in Table 12, the post-crisis period, MK Land Holdings (8893) with a score of 0.968 has replaced KUB Malaysia Berhad (6874) as the highest scoring in the overall centrality measure. This analysis tells us that, KUB Malaysia Berhad (6874) and MK Land Holdings (8893) have repeatedly appeared as the highest scoring in all centrality measures and all durations of study. As can be observed from Table 13 until Table 15, even though Unisem (5005) was not having the highest score in the overall centrality measure, but it consistently was in the list in all periods of study. This makes Unisem (5005) also one of the influential stocks.

Hence, the results from the overall centrality measure expose that the service sector, property sector and technology sector were crucial sectors in the networks across all periods.

Table 13. The highest overall centrality scores for the pre-crisis period (2000-2006)

No	Name	Code	Sector	Overall Score
1	KUB Malaysia Berhad	6874	Service	1.112
2	Paragon Union	9407	Consumer	0.360
3	Unisem	5005	Technology	0.272
4	Utusan Melayu Malaysia	5754	Service	0.193
5	Chin Well Holdings	5007	Industry	0.152

Table 14. The highest overall centrality scores for the crisis period (2007-2009)

No	Name	Code	Sector	Overall Score
1	KUB Malaysia Berhad	6874	Service	1.115
2	Batu Kawan	1899	Plantation	0.334
3	Muhibbah Engineering	5703	Construction	0.292
4	WTK Holdings	4243	Industry	0.124
5	Unisem	5005	Technology	0.117

Table 15. The highest overall centrality scores for the post-crisis period (2010-2017)

No	Name	Code	Sector	Overall Score
1	MK Land Holdings	8893	Property	0.968
2	KUB Malaysia Berhad	6874	Service	0.556
3	Muhibbah Engineering	5703	Construction	0.487
4	WTK Holdings	4243	Industry	0.378
5	Unisem	5005	Technology	0.135

4. Conclusions

This paper applies MST as a filtering tool to construct a financial network of 125 Malaysian shariah-compliant stocks which are consistently listed in SAC's list. The data collected is divided into three periods namely pre-crisis (2000-2006), crisis (2007-2009) and post-crisis (2010-2017). This study aims to determine the topological structure of the Malaysian shariah-compliant stocks and identify the most influential stocks in each duration by using four centrality measures which are degree centrality, betweenness centrality, closeness centrality and eigenvector. The overall characteristic of each stock was presented by computing an overall centrality measure using PCA.

Generally, there were seven main clusters during pre-crisis period and three main clusters during crisis period. KUB Malaysia Berhad (6874) was the most important stock during both periods. Next, post-crisis network portrays five main clusters with MK Land Holdings (8893) was the most influential stocks among the five stocks. The service sector was a prominent sector during pre-crisis and during crisis periods, while during the post-crisis period, property sector was the strongest sector.

In terms of overall centrality measures which concluded all the four centrality measures, KUB Malaysia Berhad (6874) played a very crucial role in the networks during pre-crisis and crisis periods. It has the highest scores in all centrality measures in both pre-crisis and post-crisis periods. However, in the post-crisis period, MK Land Holdings (8893) replaced KUB Malaysia Berhad (6874) as the highest scoring stock in the overall centrality measure. Not only that, Unisem (5005) also contributed as an important stock although it does not have the highest score, but it appears in all three periods. Hence, service sector was an important sector before and during the financial crisis, whereas property sector was an important sector after financial crisis. Lastly, technology sector was considered as crucial sector since it emerges in the top five list of overall centrality measure across the periods of study. Above all, these findings may benefit investors who are interested in shariah-compliant stocks and consequently to determine which sectors and stocks they should invest in.

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Appendix

Table 16. The list of stocks from the year 2000 to the year 2017

No	Name	Code	No	Name	Code
1	Ajinomoto	2658	13	Emico Holdings	9091
2	Amtek Holdings	7051	14	Federal International Holdings	8605
3	Cck Consolidated Hdg.	7035	15	Hwa Tai Industries	8478
4	Cwg Holdings	9423	16	Khee San	6203
5	Khind Holdings	7062	17	Computer Forms (Mal.)	8044
6	Kuantan Flour Mills	8303	18	Concrete Engr.Prds.	8435
7	Lay Hong	9385	19	Ata Ims	8176
8	Ltkm	7085	20	Fima Corporation	3107
9	Mintye	5886	21	Golden Pharos	5649
10	Nestle (Malaysia)	4707	22	Kia Lim	6211
11	Paragon Union	9407	23	Kim Hin Industry	5371
12	Pccs Group	6068	24	Kumpulan H&L High-Tech	7033
25	Rex Industry	9946	68	Kym Holdings	8362
26	Sand Nisko Capital	7943	69	Lb Aluminium	9326
27	Shh Resources Holdings	7412	70	Master-Pack Group	7029
28	Sinotop Holdings	8532	71	Mce Holdings	7004
29	Teo Guan Lee Corporation	9369	72	Mentiga Corporation	5223
30	Umw Holdings	4588	73	Mieco Chipboard	5001
31	Yee Lee Corporation	5584	74	Minho (M)	5576
32	Alcom Group	2674	75	Perstima.Mal.(Perstima)	5436
33	Amalgamated Indl.Steel	2682	76	Poly Glass Fibre (M)	8117
34	Anzo Holdings	9342	77	Public Packages Hdg.	8273
35	Apm Automotive Hdg.	5015	78	Quality Concrete Hdg.	7544
36	Atta Global Group	7099	79	Sarawak Cons.Inds.	9237
37	Boustead Heavy Industries	8133	80	Scientex	4731
38	Central Industrial Corporation	8052	81	Seacera Group	7073
39	Chin Well Holdings	5007	82	Turiya	4359
40	Choo Bee Metal Inds.	5797	83	Southern Acids (M)	5134
41	Cme Group	7018	84	Subur Tiasa Holdings	6904
42	Ta Ann Holdings	5012	85	Ipmuda	5673
43	Teck Guan Perdana	7439	86	Konsortium Transnasional	4847
44	Timberwell	7854	87	Kpj Healthcare	5878
45	Tong Herr Resources	5010	88	Kub Malaysia Berhad	6874
46	Vs Industry	6963	89	Mega First Corporation	3069
47	White Horse	5009	90	Mesb	7243
48	Wong Engineering Corporation	7050	91	Ocb	5533
49	Woodlandor Holdings	7025	92	Pdz Holdings	6254

50	Wtk Holdings	4243	93	Permaju Industries	7080
51	Mtd Acpi Engineering	5924	94	Petronas Dagangan	5681
52	Fajarbaru Builder Group	7047	95	See Hup Consolidated	7053
53	Ho Hup Construction	5169	96	Sime Darby	4197
54	Hock Seng Lee	6238	97	Telekom Malaysia	4863
55	Ijm Corporation	3336	98	Tenaga Nasional	5347
56	Kumpulan Jetson	9083	99	Ums Holdings	7137
57	Mercury Industries	8192	100	Utusan Melayu (Malaysia)	5754
58	Merge Energy	5006	101	Yinson Holdings	7239
59	Mitrajaya Holdings	9571	102	Genting Plantations	2291
60	Muhibbah Engineering (M)	5703	103	Batu Kawan	1899
61	Sycal Ventures	9717	104	Far East Holdings	5029
62	Vizione Holdings	5029	105	Jaya Tiasa Holdings	4383
63	Wct Holdings	9679	106	Kuala Lumpur Kepong	2445
64	Zecon	7028	107	Kwantas Corporation	6572
65	Brahim's Holdings	9474	108	Pls Plantations	9695
66	Fiamma Holdings	6939	109	Sarawak Oil Palms	5126
67	Sin Heng Chan (Malaya)	5126	110	Mk Land Holdings	8893
111	Innoprise Plantations	4316	119	Oriental Interest	5827
112	United Plantations	6262	120	Tiger Synergy	7079
113	Ideal United Bintang International	2089	121	Malaysian Pacific Inds.	3867
114	Amverton	9687	122	Mesiniaga	5011
115	Ark Resources Holdings	5959	123	Unisem (M)	5005
116	Bina Darulaman	7007	124	Bimb Holdings	5258
117	Crescendo Corporation	6173	125	Syarikat Takaful Malaysia	6139
118	Grand Hoover	7010			