Malaysian Journal of Fundamental & Applied Sciences

available online at http://mjfas.ibnusina.utm.my

Stock Networks Analysis in Kuala Lumpur Stock Exchange

Gan Siew Lee*, Maman Abdurachman Djauhari

Department of Mathematical Science, Faculty of Science, UTM, 81310 UTM Skudai, Johor, Malaysia

Received 24 October 2011, Revised 15 December 2011, Accepted 10 February 2012, Available online 15 February 2012

ABSTRACT

This paper deals with an analysis of correlation structure among stocks traded in Kuala Lumpur Stock Exchange (KLSE) by using network analysis approach. The minimum spanning tree (MST) related to that correlation structure will be presented to have a better understanding about stocks topological network. An overall centrality measure will be introduced to filter the economic information contained in the MST. This measure will give additional economic information that cannot be delivered by the conventional centrality measures such as degree centrality, betweenness centrality, closeness centrality and eigenvector centrality.

| Stocks Marke t| Sub-Dominant Ultrametric | Correlation Matrix | Euclidean Distance |

® 2012 Ibnu Sina Institute. All rights reserved.
http://dx.doi.org/10.11113/mjfas.v8n2.124

1. INTRODUCTION

Stock market regards as a complex system of economic transactions for the trading of company stocks and derivatives at an agree price. The stock price of a given company will be affected by its fundamentals, other associated listed companies, and also influenced by the other factors as shown by the previous comprehensive analysis of [1]. The researchers from diverse disciplines including mathematics and theoretical physics are showing a great interest in analyzing stock market system. They are interested in the behaviour of stocks traded in the market, i.e., the way the stocks relate to each other. The relation among stocks is customarily represented by the correlations among the logarithm of their stock returns. The correlation structure, together with the corresponding stocks, constitutes a complex system in the form of a network or, equivalently, an undirected weighted complete graph with finite number of nodes.

Since the work of Mantegna [2], the correlation network has becomes an important model to analyze stocks' behaviour. In that paper, he firstly proposed and introduces the use of minimal spanning tree (MST) to construct and analyze network of stocks from Dow Jones Industrial Average index and S&P500 index respectively. Since then, a number of papers followed his idea in analyzing financial market [1,3-7] and many other areas such as, for example, volatility [5], portfolio [1, 8], risk assessment [8], politics [9] and complex system [10]. In this paper, we analyze the network of 90 most capitalized stocks at Malaysian stock market.

Originally, the dataset consists of 100 stocks that reflect the most capitalized stocks traded in Kuala Lumpur Stock Exchange (KLSE). However, depends on the availability data, there are 90 stocks have completed daily data from the year of 2007 until 2009. Therefore, there are $N = 90$ stocks to be analyzed and listed in Appendix A. The main objective of this paper is to have a better understanding about the stocks topological network and the behaviour of those stocks.

In this paper, the procedure to filter the information contained in the network is (i) to transform the correlation among stocks into distance among them followed by the construction of a minimal spanning tree (MST) to simplify the network, and (ii) to summarize the information contained in MST, the centrality measures of each stock such as degree, betweenness, closeness and eigenvector centralities [11-14]. In order to determine the overall most important stocks, an overall centrality measure will be defined as an optimal linear combination of those measures. The optimality criterion is defined by using principal component analysis (PCA). Furthermore, the visualization of MST together with the stocks' scores in each measure will be made by using Pajek software [15].

The remaining of the paper is organized as follows. In the next section we will briefly discusses the methodology of data analysis. In Section 3 we present and discuss the empirical results. Then, in Section 4 we will summarize this study and highlight some conclusions for further consideration.

*Corresponding author at:
E-mail addresses: kelly_gan0329@hotmail.com (Gan Siew Lee)

2. METHODOLOGY

2.1 Information filtering

Let $p_i(t)$ be the stock price of a company i (i =1, 2,…, N) and $r_i(t)$ be the logarithm of daily stock return at day t in a given period is defined as:

$$r_i(t) = \ln p_i(t+1) - \ln p_i(t). \quad (1)$$

There have a several steps to filter the information contained in a network of stocks,

(i) The construction of correlation matrix $C = (c_{ij})$ of size $N \times N$ where the correlation coefficient between stocks i and j is calculated by using the following formula,

$$c_{ij} = \frac{\langle r_i r_j \rangle - \langle r_i \rangle \langle r_j \rangle}{\sqrt{\left(\langle r_i^2 \rangle - \langle r_i \rangle^2\right)\left(\langle r_j^2 \rangle - \langle r_j \rangle^2\right)}}, \quad (2)$$

Here $\langle r_i \rangle$ is the statistical average of $r_i(t)$ for all t. The value of c_{ij} indicates the strength of the linear relationship between stocks i and j. In particular, stocks i and j is said to be completely correlated (anti – correlated) as the coefficient c_{ij} = 1 (-1) or uncorrelated as c_{ij} = 0.

(ii) The construction of distance matrix $D = (d_{ij})$ from C by transforming the correlation coefficient c_{ij} into distance d_{ij} as follows,

$$d_{ij} = \sqrt{2(1 - c_{ij})}\ . \quad (3)$$

(iii) From distance matrix D, a MST is constructed by using Kruskal's algorithm as suggested in [16]. This MST is the principal tool to simplify the complex system of stocks in the form of an optimal tree.

(iv) The information contained in MST is summarized by using centrality measures [11-14].

2.2 Centrality measures

Centrality measures determine the relative importance for each particular stock in the network. There are four measures, namely, degree, betweenness, closeness, and eigenvector centralities [11-14] that usually used in stock network analysis. First, the degree centrality of stock i is defined as

$$C_D(i) = \frac{\sum_{j=1}^{N} A_{ij}}{N-1}, \quad (4)$$

where A_{ij} is the element of the i-th row and j-th column of the adjacency matrix. The larger the value of $C_D(i)$, the more the number of other stocks influenced directly by (or influencing directly) stock i. Second, the betweenness centrality of stock i is

$$C_B(i) = \sum_{\substack{j,k \in V \\ j \neq k \neq i}} \frac{\sigma_{jk}(i)}{\sigma_{jk}}, \quad (5)$$

where,

(i) $\sigma_{jk}(i)$ denotes the total number of pairs (j, k) with $j \neq k \neq i$ and between stock j and stock k there exists a path passing through stock i , and

(ii) σ_{jk} is the total number of paths between stock j and stock k.

The larger the value of $C_B(i)$, the more the role of stock i in coordinating other stocks. In other words, high score in this measure means that there are high numbers of stocks where their behaviours will influence other stocks through stock i. $C_B(i) = 0$ means that stock i have no role in such coordination. The third measure, i.e., closeness centrality of stock i is

$$C_C(i) = \left[\frac{\sum d_G(i,k)}{N-1}\right]^{-1} \quad (6)$$

where $d_G(i,k)$ is the shortest path (geodesic distance) from stock i to stock k. The summation on the numerator is for all other stocks reachable from stock i. Therefore, $C_C(i)$ is the average number of shortest paths between i and all other stocks reachable from it. The last measure is the eigenvector centrality of stock i [14],

$$e_i = \frac{1}{\lambda_{max}} \sum_{j=1}^{N} A_{ij} x_j\ , \quad \text{for } i = 1,2,\dots,N, \quad (7)$$

where $\boldsymbol{x} = (x_1, x_2, \dots, x_N)^t$ is the eigenvector associated with the largest eigenvalue λ_{max} of the adjacency matrix. It is the weighted average of the scores x_j of all stocks linked to stock i. The larger the value of e_i, the more the influence of stock i to other stocks directly or indirectly [17]. High-eigenvector scoring stock is the one that has high connections to other high-scoring stocks.

Those four traditional measures are between 0 and 1 and have different meaning. Therefore, it is necessary to define an overall centrality measure if one needs to indicate the overall role of each stock. In this paper, it will be defined by using PCA on the data matrix of size $N \times 4$ where the first until the fourth columns of row i represent the score of degree, betweenness, closeness and eigenvector centralities, respectively. Let S be the covariance matrix issued from the said data matrix of size $N \times 4$ and $\boldsymbol{v} = (v_1, v_2, v_3, v_4)^t$ be the eigenvector of S associated with the largest eigenvalue θ_{max} . Thus,

$S\boldsymbol{v} = \theta_{max}\, \boldsymbol{v}$

The score of stock i in terms of overall centrality measure is defined by,

$$O_i = v_1 C_D(i) + v_2 C_B(i) + v_3 C_c(i) + v_4 e_i \quad (8)$$

3. RESULTS & DISCUSSION

The network studied in this paper represents the set of stocks traded in Kuala Lumpur Stock Exchange (KLSE). We consider 100 most capitalized stocks and then 90 stocks are selected based on their available data from January 2007 to January 2009. The data used in this paper are the close price of the stocks.

By using Kruskal's algorithm provided in Matlab 7.8.0 (R2009a), we obtain a MST of 90 stocks listed in KLSE. The result can be seen in Figure 1. In that figure, the stocks (nodes) are coloured according their economic activities which are: construction (*red*), consumer products (*yellow*), finance (*olive green*), industrial products (*cyan*), IPC (*purple*), plantation (*pink*), properties (*brown*), technology (*black*), and trading and services (*blue*).

From that figure, two clusters are clearly present with MRCB (Malaysian Resources Corporation/

Construction) is the dominant stock in the upper cluster and BURSA (Bursa Malaysia Berhad/ *Finance*) in the lower one. In general, the position of a given stock in a network has its own characteristics and the position it located on will reflects the relationships between it and other stocks. In order to give further interpretation of the structural position of the stocks in Figure1, we report the scores of each stock in the four traditional centrality measures. Then, we combine those measures by using PCA to get an overall centrality score.

3.1 Degree centrality

As a common concept, the score in degree centrality is used to represent the power of each stock to influence directly other stocks in term of the number of influenced stocks. The score of stock *i* is the proportion of other stocks traded in KLSE that are directly influenced by stock *i*. According to this measure as showed in Appendix A, BURSA (Bursa Malaysia Berhad/ *Finance*) and MRCB (Malaysian Resources Corporation/ *Construction*) are the most two influential stocks in KLSE in terms of degree centrality. They have the highest number of connections with other stocks. In this measurement, BURSA score is 0.2584 (23 adjacent links) and 0.2022 (18 adjacent links) for MRCB. They are followed by AMMB scores 0.0787. The three other most important stocks are PPB, YTL and BKAWAN with score 0.0562 each. For SAPCRES, WCT, DIALOG and IJMPLNT scores are 0.0449.

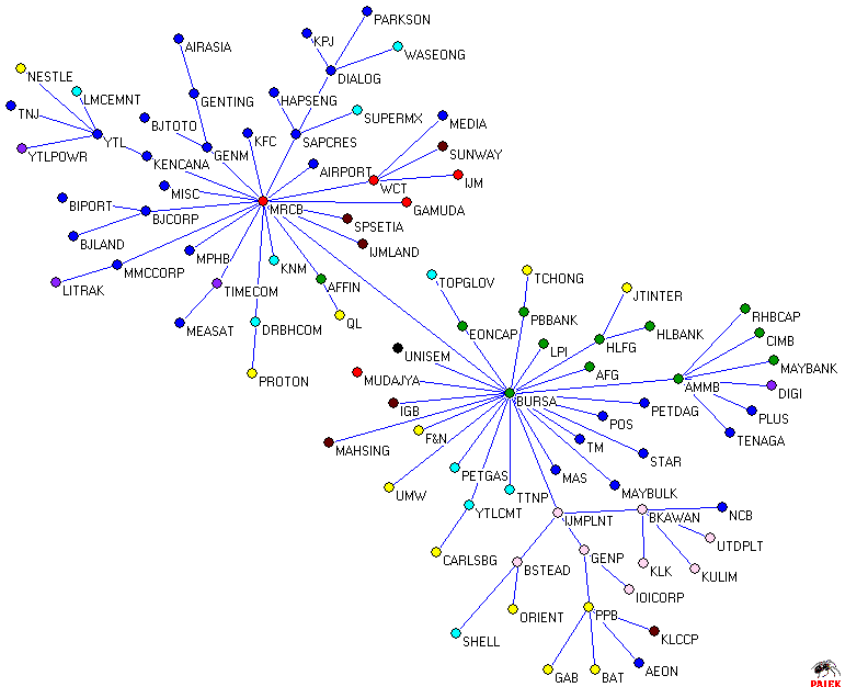

Fig. 1 MST of 90 stocks traded in KLSE.

3.2 Betweenness centrality

According to the betweeness centrality measure, BURSA has the highest score (0.7531). It is then at the best position in KLSE in the following sense. The influences of most stocks to the others are passing through BURSA. In other words, the behaviours of most stocks will influence others after having passed through BURSA. Therefore, it plays an important role in KLSE as a liaison that could flow the information among stocks. The other 9 highest-scoring stocks are MRCB (0.6856), IJMPLNT (0.3016), AMMB (0.1310), SAPCRES (0.1295), GENP (0.1284), KENCANA (0.1073), PPB (0.0884), YTL (0.0884) and BKAWAN (0.884). All those stocks' scores can be referred to Appendix A as attached.

3.3 Closeness centrality

Here, BURSA still is the highest-scoring stock in terms of closeness centrality. Its score is 0.4406 followed by MRCB (0.4238), IJMPLNT (0.3423), AMMB (0.3201), HLFG (0.3112), SAPCRES (0.3112), PBBANK (0.3090), EONCAP (0.3090), KENCANA (0.3090) and YTLCMT (0.3090).Those are the 10 most important stocks in KLSE according to the closeness centrality measure. The higher

the closeness centrality score, the quicker the stock receives the influence of other stocks' behaviour.

3.4 Eigenvector centrality

Based on the eigenvector centrality measure, BURSA still has the highest score (0.6186) followed by MRCB with scores 0.3848. The other 6 high-scoring stocks are AMMB (0.1586), IJMPLNT (0.1400), HLFG (0.1320), PBBANK (0.1267), EONCAP (0.1267) and YTLCMT (0.1267).

In summary, according to the four traditional measures, the following high-scoring stocks appeared in all four or three measures. BURSA, MRCB, AMMB and IJMPLNT appeared four times while SAPCRES appeared three times. Therefore, these are the strongest stocks in KLSE in terms of their appearance as part of the high-scoring stocks in all measures. To best our knowledge, BURSA has the highest scores in those four traditional measures and then followed by MRCB.

Table 1 The most overall important sectors.

Sector	Code
Construction	MRCB
	WCT
Finance	BURSA
	AMMB
	HLFG
Plantation	IJMPLNT
	GENP
Trading & Services	SAPCRES
	KENCANA
	GENM

3.5 Overall measure of centrality

The score of each stock based on all centrality measures are presented in Appendix A. Since each measure has different role in stock market compared to the others, we need an overall centrality measure that will guide us to find out the most important stocks in general sense. Here, we define the overall centrality measure as an optimal linear combination of the four measures mentioned previously. For that purpose, we use the optimality criterion based on PCA on data matrix of size 90×4 representing 90 stocks and their scores in the four measures.

The first principal component explains 86.1% of the total variations while the second one only 12.0% which is far less than the first. With that percentage, see [18], the first principal component can be sufficiently adequate to determine the overall centrality measure. Based on the first principal component, the overall centrality score of each stock is presented in the last column of Appendix A. From those scores we present in Table 1.0 the four important sectors out of nine. For this measure, the 10 most important stocks are BURSA (1.0873), MRCB (0.8919), IJMPLNT (0.4085), AMMB (0.2901), SAPCRES (0.2397), KENCANA (0.2133), HLFG (0.1972), GENP (0.1934), WCT (0.1897) and GENM (0.1851).

4. CONCLUSION

In this paper the behaviour of 90 most capitalized stocks traded in KLSE is analyzed using network analysis approach. The stocks together with the correlations among the logarithm of stock returns are considered as a complex system in the form of correlation network. The correlation network is simplified in the form of a MST and the information contained therein is summarized using the four traditional centrality measures, namely, degree, betweenness, closeness, and eigenvector centralities. Since each measure has its own role and purpose, to get overall information about the most important or influential stocks in KLSE, we introduce an overall centrality measure as an optimal linear combination of the traditional centrality measures. The optimality criterion is based on PCA.

According to the traditional measures, there are only five stocks that appeared as the highest-scoring stocks in at least three measures. Those that appeared in the four measures are BURSA, MRCB, AMMB and IJMPLNT while that occur in three measures is SAPCRES. These are the strongest stocks in KLSE in terms of the traditional measures. Similarly, in terms of overall measure, the five highest-scoring stocks are BURSA, MRCB, IJMPLNT, AMMB and SAPCRES.

ACKNOWLEDGEMENT

This research is sponsored by the Ministry of Higher Education of Malaysia under the FRGS vote numbers 4F013 and RUG vote number Q.J130000.7126.02H18. The authors gratefully acknowledge those sponsorships, Government of Malaysia and Universiti Teknologi Malaysia

REFERENCES

[1] J. –P. Onnela, A. Chakraborti, K. Kaski, J. Kert'esz, and A. Kanto, Physical Review E, 68 (2003), 056110(1)-056110(12).
[2] R. N. Mantegna, The European Physical Journal B, 11 (1999), 193-197.
[3] G.Bonanno, N. Vandewalle, and R. N. Mantegna, Physical Review E, 62 (2000), R7615-R7618.
[4] G. Bonanno, F. Lillo, and R. N. Mantegna, Physica A, 299 (2001). 16-27.
[5] G. Bonanno, G. Caldarelli, F. Lillo, and R. N. Mantegna, Physical Review E, 68 (2003), 046130-046133.
[6] S. Micciche, G. Bonanno, F. Lillo, and R. N. Mantegna, Physica A, 324 (2003), 66-73.
[7] B. M. Tabak, T. R. Serra, and D. O. Cajueiro, Physica A, 389 (2010), 3240-3249.
[8] V. Tola, F. Lillo, M. Gallegati and R. N. Mantegna, Journal of Economic Dynamic and Control, 32 (2008), 235-258.
[9] H. Situngkir, and Y. Surya. Working Paper WPM 2004 Bandung Fe Institute, (2004), Pre-print: arxiv:nlin.PS/0405005.
[10] M. Tumminello, T. Aste, T. D. Matteo and R. N. Mantegna, Proceedings of the National Academy of Sciences USA, 102 (2005), 10421-10426.
[11] L. C. Freeman, Sociometry, 40 (1977), 35-41.
[12] L. C. Freeman, Social Networks, 1 (1979), 251-239.
[13] P. Bonacich, American Journal of Sociology, 92 (1987), 1170-1182.
[14] S. P. Borgatti, Social Networks, 27 (2005), 55-71.
[15] A. Mrvar and V. Batagelj, http://pajek.imfm.si/doku.php?id=download (accessed on 13 February 2011).
[16] J. B. Kruskal, American Mathematical Society, 7(1) (1956), 48-50.
[17] P. Bonacich, Social Networks, 29 (2007), 555-564.
[18] I. T. Jolliffe, Principal Component Analysis, Springer, New York, 2002.

APPENDIX A

		Degree	Between	Close	Eigen	Overall
1	MAYBANK	0.0112	0.0000	0.2432	0.0312	0.0851
2	CIMB	0.0112	0.0000	0.2432	0.0312	0.0851
3	PBBANK	0.0225	0.0225	0.3090	0.1267	0.1742
4	MISC	0.0112	0.0000	0.2987	0.0757	0.1241
5	TENAGA	0.0112	0.0000	0.2432	0.0312	0.0851
6	IOICORP	0.0112	0.0000	0.2099	0.0059	0.0624
7	GENTING	0.0225	0.0225	0.2354	0.0168	0.0949
8	PPB	0.0562	0.0884	0.2139	0.0070	0.1418
9	PETGAS	0.0112	0.0000	0.3069	0.1218	0.1512
10	DIGI	0.0112	0.0000	0.2432	0.0312	0.0851
11	PLUS	0.0112	0.0000	0.2432	0.0312	0.0851
12	KLK	0.0112	0.0000	0.2079	0.0064	0.0621
13	GENM	0.0337	0.0664	0.3048	0.0822	0.1851
14	YTLPOWR	0.0112	0.0000	0.1952	0.0036	0.0572
15	AMMB	0.0787	0.1310	0.3201	0.1586	0.2901
16	YTL	0.0562	0.0884	0.2418	0.0185	0.1555
17	HLBANK	0.0112	0.0000	0.2380	0.0260	0.0808
18	RHBCAP	0.0112	0.0000	0.2432	0.0312	0.0851
19	BAT	0.0112	0.0000	0.1766	0.0014	0.0509
20	TM	0.0112	0.0000	0.3069	0.1218	0.1512
21	PETDAG	0.0112	0.0000	0.3069	0.1218	0.1512
22	NESTLE	0.0112	0.0000	0.1952	0.0036	0.0572
23	HLFG	0.0337	0.0447	0.3112	0.1320	0.1972
24	TNJ	0.0112	0.0000	0.1952	0.0036	0.0572
25	MMCCORP	0.0225	0.0225	0.3007	0.0788	0.1461
26	UMW	0.0112	0.0000	0.3069	0.1218	0.1512
27	MAS	0.0112	0.0000	0.3069	0.1218	0.1512
28	IJM	0.0112	0.0000	0.2342	0.0169	0.0749
29	GAMUDA	0.0112	0.0000	0.2987	0.0757	0.1241
30	LMCEMNT	0.0112	0.0000	0.1952	0.0036	0.0572
31	AIRPORT	0.0112	0.0000	0.2987	0.0757	0.1241

32	PARKSON	0.0112	0.0000	0.1952	0.0038	0.0573
33	BJTOTO	0.0112	0.0000	0.2342	0.0162	0.0745
34	GENP	0.0337	0.1284	0.2649	0.0301	0.1934
35	BJLAND	0.0112	0.0000	0.2330	0.0162	0.0742
36	BKAWAN	0.0562	0.0884	0.2618	0.0326	0.1686
37	F&N	0.0112	0.0000	0.3069	0.1218	0.1512
38	EONCAP	0.0225	0.0225	0.3090	0.1267	0.1742
39	AFFIN	0.0225	0.0225	0.3007	0.0788	0.1461
40	AFG	0.0112	0.0000	0.3069	0.1218	0.1512
41	AIRASIA	0.0112	0.0000	0.1910	0.0033	0.0559
42	BJCORP	0.0337	0.0447	0.3027	0.0821	0.1679
43	SPSETIA	0.0112	0.0000	0.2987	0.0757	0.1241
44	TOPGLOV	0.0112	0.0000	0.2367	0.0249	0.0799
45	TTNP	0.0112	0.0000	0.3069	0.1218	0.1512
46	BSTEAD	0.0337	0.0447	0.2587	0.0299	0.1278
47	BURSA	0.2584	0.7531	0.4406	0.6186	1.0873
48	TCHONG	0.0112	0.0000	0.2367	0.0249	0.0799
49	ORIENT	0.0112	0.0000	0.2060	0.0059	0.0613
50	SHELL	0.0112	0.0000	0.2060	0.0059	0.0613
51	KLCCP	0.0112	0.0000	0.1766	0.0014	0.0509
52	UTDPLT	0.0112	0.0000	0.2079	0.0064	0.0621
53	SAPCRES	0.0449	0.1295	0.3112	0.0862	0.2397
54	MAYBULK	0.0112	0.0000	0.3069	0.1218	0.1512
55	IGB	0.0112	0.0000	0.3069	0.1218	0.1512
56	BIPORT	0.0112	0.0000	0.2330	0.0162	0.0742
57	STAR	0.0112	0.0000	0.3069	0.1218	0.1512
58	KULIM	0.0112	0.0000	0.2079	0.0064	0.0621
59	PROTON	0.0112	0.0000	0.2318	0.0155	0.0735
60	KENCANA	0.0225	0.1073	0.3090	0.0794	0.2133
61	IJMLAND	0.0112	0.0000	0.2987	0.0757	0.1241
62	GAB	0.0112	0.0000	0.1766	0.0014	0.0509
63	LPI	0.0112	0.0000	0.3069	0.1218	0.1512
64	MRCB	0.2022	0.6856	0.4238	0.3848	0.8919
65	MPHB	0.0112	0.0000	0.2987	0.0757	0.1241
66	WCT	0.0449	0.0666	0.3048	0.0857	0.1897
67	DRBHCOM	0.0225	0.0225	0.3007	0.0788	0.1461
68	KFC	0.0112	0.0000	0.2987	0.0757	0.1241
69	MEDIA	0.0112	0.0000	0.2342	0.0169	0.0749
70	DIALOG	0.0449	0.0666	0.2418	0.0192	0.1367
71	KNM	0.0112	0.0000	0.2987	0.0757	0.1241
72	SUPERMX	0.0112	0.0000	0.2380	0.0170	0.0759
73	YTLCMT	0.0225	0.0225	0.3090	0.1267	0.1742
74	IJMPLNT	0.0449	0.3016	0.3423	0.1400	0.4085
75	MUDAJYA	0.0112	0.0000	0.3069	0.1218	0.1512
76	KPJ	0.0112	0.0000	0.1952	0.0038	0.0573
77	AEON	0.0112	0.0000	0.1766	0.0014	0.0509
78	SUNWAY	0.0112	0.0000	0.2342	0.0169	0.0749

79	NCB	0.0112	0.0000	0.2079	0.0064	0.0621
80	TIMECOM	0.0225	0.0225	0.3007	0.0788	0.1461
81	QL	0.0112	0.0000	0.2318	0.0155	0.0735
82	HAPSENG	0.0112	0.0000	0.2380	0.0170	0.0759
83	WASEONG	0.0112	0.0000	0.1952	0.0038	0.0573
84	POS	0.0112	0.0000	0.3069	0.1218	0.1512
85	LITRAK	0.0112	0.0000	0.2318	0.0155	0.0735
86	MEASAT	0.0112	0.0000	0.2318	0.0155	0.0735
87	CARLSBG	0.0112	0.0000	0.2367	0.0249	0.0799
88	MAHSING	0.0112	0.0000	0.3069	0.1218	0.1512
89	UNISEM	0.0112	0.0000	0.3069	0.1218	0.1512
90	JTINTER	0.0112	0.0000	0.2380	0.0260	0.0808