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Market impact and structure dynamics of the Chinese stock market based on partial correlation analysis

Xing Li [a], Tian Qiu [a,*], Guang Chen [a], Li-Xin Zhong [b,c], Xiao-Run Wu [a]

[a] School of Information Engineering, Nanchang Hangkong University, Nanchang, 330063, China

[b] School of Finance and Coordinated Innovation Center of Wealth Management and Quantitative Investment, Zhejiang University of Finance and Economics, Hangzhou, 310018, China

[c] China Academy of Financial Research, Zhejiang University of Finance and Economics, Hangzhou, 310018, China

HIGHLIGHTS

- Partial correlation is investigated for the Chinese stock market.
- Native market index has a great impact on the market correlation.
- Stocks are mainly affected by their own or closely related economic sector.
- Structure similarity decays with the time interval.

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ABSTRACT

Partial correlation analysis is employed to study the market impact on the Chinese stock market from both the native and external markets. Whereas the native market index is observed to have a great impact on the market correlations for both the Shanghai and Shenzhen stock markets, some external stock indices of the United States, European and Asian stock markets show a slight influence on the Chinese market. The individual stock can be affected by different economic sectors, but the dominant influence is from the sector the stock itself belongs to or closely related to, and the finance and insurance sector shows a weaker correlation with other economic sectors. Moreover, the market structure similarity exhibits a negative correlation with the price return in most time, and the structure similarity decays with the time interval.

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1. Introduction

Financial market is playing an important role in our daily life, since more and more people invest stocks nowadays. Investigations on financial dynamics have attracted a great interest from the scientists from different disciplines including the physicists. Inspired by an empirical study of the price return feature based on the minutely data of the United States stock market [1], physicists have developed various methods and theoretical approaches to understand the financial dynamics [2–17].

In the past two decades, some stylized facts have been revealed based on the large amount of the historical data, which have been found to be universal for different stock markets [2,3]. For example, the 'fat tail' distributions of the price returns are observed for both the mature and emerging markets [2,3]. And the stock markets of many different countries exhibit

* Correspondence to: 696 South Fenghe Avenue, School of Information Engineering, Nanchang Hangkong University, Nanchang, 330063, China.
E-mail address: tianqiu.edu@gmail.com (T. Qiu).

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the 'volatility clustering' characteristic, revealing the long-range time correlation of the price volatilities [3,4]. Besides the universal behavior in many stock markets, the local behavior that differs in the mature and emerging markets has also been reported, such as the 'leverage effect' of most mature stock markets [18] and the 'anti-leverage effect' of the Chinese stock market [19], and the unique economic sectors of the Chinese stock market [20]. On the other hand, interactive models have been proposed from the microscopic level to understand the underlying mechanism of the market interactions, such as the minority games [21,22], the herding models [23–25], the Ising models [26,27] and the order-driven models [28,29]. More recently, the experimental economic dynamics is also investigated, providing the insights from the experimental perspective [30,31].

A central problem in financial dynamics is the market impact and structure stability [32,33]. The market impact has been studied from the dependence of the price change on the trading volume [34] and the limit order book [35–37], etc. Master curve is obtained and concave characteristic is also revealed. Recently, the partial correlation analysis is applied into the financial dynamics study of some mature stock markets [38], by investigating the third or more factor effect on the stock markets.

In this article, we focus on understanding the market impact on the Chinese stock market, from both the native market and external markets, based on the partial correlation analysis. Our results reveal a great impact of the native market index, but a slight impact of some external stock indices on the Chinese stock market. Moreover, the market structure similarity shows a negative correlation with the price return in most time, and the structure similarity decays with the time interval.

2. Datasets

The datasets we analyzed are the daily data of the native stock markets and the external stock markets from Jan. 1, 2005 to Dec. 31, 2010. Both the Shanghai stock markets (SH) and the Shenzhen stock markets (SZ) are analyzed for the native markets. Two indices of the Shanghai index and Shenzhen component index are studied. For the native market individual stocks, only the stocks whose number of trading days are no less than 150 days are selected to ensure the stock liquidity, including 778 stocks in the SH market, and 474 stocks in the SZ market. For the external markets, some indices of the United States stock markets, European stock markets, and Asian stock markets are analyzed, including the Standard and Poor 500 index(S&P 500), Dow Jones Industrial Average (DJI) and Nasdaq Composite(Nasdaq) indices of the United States stock markets, the German DAX Index(GDAXI), London Financial Times and Stock Exchange 100(FTSE 100), France CAC 40 Index(FCHI), Swiss Market Index(SSMI), Austrian Traded Index(ATX), and Oslo Exchange All Share Index(OSEAX) of the European stock markets, the Nikkei 225(N225), Korea Composite Stock Price Index(KOSPI), Singapore Straits Times Index(STI), Bombay Stock Exchange's benchmark 30-share index(BSE 30), Kuala Lumpur Stock Exchange Composite Index(KLSECI), Jakarta Composite Index(JKSE), and Colombo Stock Exchange All Share Index(CSEALL) of the Asian stock markets.

3. Native and external stock market impact

The world is more and more tightly correlated with the high-speed development of the traffic and internet. The financial markets are also affected by all kinds of factors from the inner and external environments. In our study, we investigate the market impact on the Chinese stock market from both the native market and the external markets, based on the partial correlation analysis.

3.1. Partial correlation analysis

Firstly, let us explain the partial correlation analysis [38–45]. For two series $X(t)$ and $Y(t)$, their correlation can be measured by the Pearson correlation function $\rho(X, Y)$ as [46],

$$\rho(X,Y) = \left\langle \frac{(X(t) - \langle X(t)\rangle)\,(Y(t) - \langle Y(t)\rangle)}{\sigma(X)\sigma(Y)} \right\rangle \tag{1}$$

where $\langle \ldots \rangle$ is the average over time t, and the $\sigma(X)$ and $\sigma(Y)$ are the standard deviations of the series X and Y, respectively. The $\rho(X, Y)$ measures the direct correlation between the two series. To quantify how the third series $M(t)$ affects the correlation between the series X and Y, the partial correlation function $\rho(X, Y : M)$ is proposed as [39–41],

$$\rho(X, Y : M) = \frac{\rho(X,Y) - \rho(X,M)\rho(Y,M)}{\sqrt{\left[1-\rho^2(X,M)\right]\left[1-\rho^2(Y,M)\right]}}. \tag{2}$$

If a fourth series $Z(t)$ is further considered, the partial correlation $\rho(X, Y : M, Z)$ can be extended as,

$$\rho(X, Y : M, Z) \equiv \frac{\rho(X,Y:M) - \rho(X,Z:M)\rho(Y,Z:M)}{\sqrt{\left[1-\rho^2(X,Z:M)\right]\left[1-\rho^2(Y,Z:M)\right]}}. \tag{3}$$

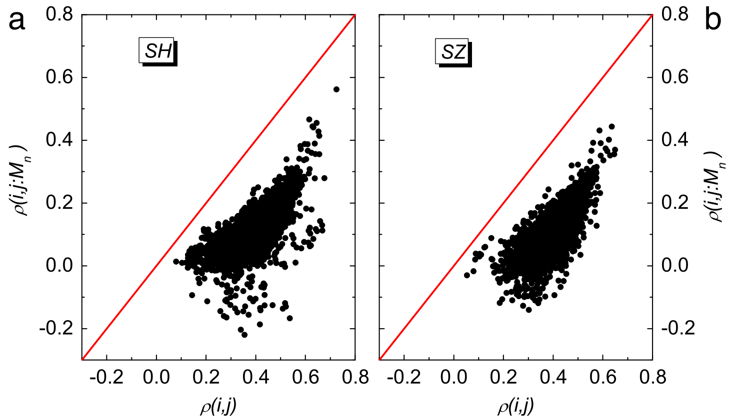

Fig. 1. The partial correlation $\rho(i, j : M_n)$ considering the native market index on the Pearson correlation $\rho(i, j)$ is displayed, with (a) for the SH, and (b) for the SZ market.

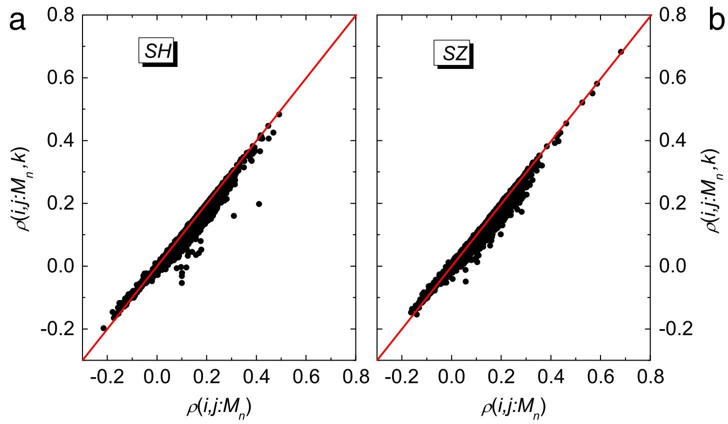

Fig. 2. The extended partial correlation $\rho(i, j : M_n, k)$ considering both another individual stock and the native market index on the partial correlation $\rho(i, j : M_n)$ merely considering the native market index is displayed, with (a) for the SH, and (b) for the SZ market.

3.2. Native market index and individual stock impact

Generally, the market index can reflect the market dynamics on average, and thus serves as a benchmark for individual stock dynamics. By employing the partial correlation analysis, we investigate the native market impact for both the SH and SZ markets. For the SH market, the Shanghai index is used, and for the SZ market, the Shenzhen component index is used as the native market index.

The price return of stock i is defined as,

$$r_i(t) = \ln[P_i(t)/P_i(t-1)] \tag{4}$$

where $P_i(t)$ is the price of stock i at day t. The correlation between the stock i and j can be quantified by the Pearson correlation $\rho(i, j) = \left\langle \frac{(r_i(t)-\langle r_i(t)\rangle)(r_j(t)-\langle r_j(t)\rangle)}{\sigma(r_i)\sigma(r_j)} \right\rangle$. By considering the native market index M_n, the partial correlation function $\rho(i, j : M_n)$ is computed. As shown in Fig. 1, the partial correlation $\rho(i, j : M_n)$ on the Pearson correlation $\rho(i, j)$ is displayed for the SH and SZ markets. It is observed that nearly all the partial correlations are smaller than the corresponding Pearson correlations for both the SH and SZ markets, i.e., the correlations between individual stocks are weakened after considering the market index. It suggests that the market index has a strong influence on the individual stock dynamics.

Further, we investigate the extended partial correlation $\rho(i, j : M_n, k)$ by considering another individual stock k after excluding the market index impact. The extended partial correlation $\rho(i, j : M_n, k)$ on the partial correlation $\rho(i, j : M_n)$ is displayed in Fig. 2 for the SH and SZ markets. For both markets, some extended partial correlations $\rho(i, j : M_n, k)$ are also found to be smaller than the partial correlations $\rho(i, j : M_n)$. That is to say, if excluding the market index influence, the third individual stock still has an impact on the stock correlation, but the influence becomes weak.

3.3. Economic sector impact

As is well known, the stocks can be classified into different economic sectors in the stock market, and each sector has its own dynamical rhythm. How the economic sector affects the stock dynamics?

To answer this question, an impact coefficient $d(i, j : k)$ is introduced [38], by quantifying the difference between the partial correlation and the extended partial correlation,

$$d(i, j : k) = \rho(i, j : M_n) - \rho(i, j : M_n, k). \tag{5}$$

By taking an average over all the stocks j in the market, the impact of the stock k on i is denoted as $d(i : k) = \langle d(i, j : k)\rangle_{j\neq i,k}$. Then, the economic sector impact $d(i : K)$ on stock i can be defined as the average impact of all the stocks in the economic sector K on the stock,

$$d(i : K) = \frac{1}{N_K}\sum_{k\in K} d(i : k) \tag{6}$$

where stock k belongs to the economic sector K, and N_K is the number of stocks in the sector K. The normalized sector impact coefficient β_i^K is defined as the proportion of the economic impact coefficient of the sector K to the impact coefficients of all the sectors, which is formulated as,

$$\beta_i^K = \frac{d(i : K)}{\sum_K d(i : K)}. \tag{7}$$

The normalized sector impact coefficient β_i^K quantifies how much influence the stock i receives from different sectors. Here we use the economic sector classification of the China Securities Regulatory Commission (CSRC) industry classification standard. As a representative, four individual stocks belonging to four different economic sectors are analyzed. The Zte corporation is classified into the information technology (IT) sector, the Suning appliance is classified into the wholesale and retail trade (WRT) sector, the Cofco property is classified into the real estate (RE) sector, and the Hongyuan securities is classified into the finance and insurance (FI) sector. By computing the normalized sector impact coefficient β_i^K, the impacts of different sectors on the stock are displayed in Fig. 3. It is observed that the stock is affected by different economic sectors, but the largest impact on the stock is from the sector that the stock belongs to or the closely related sector, for all the four stocks. The Zte corporation is significantly influenced by the IT sector, and the Hongyuan securities is significantly influenced by the FI sector. For the Suning appliance, the largest influence sector is the social service sector, which is closely related to the Suning appliance business. For the Cofco property, the largest influence is from the construction sector, also relevant to the Cofco property business, and then followed by the RE sector. The results suggest that the individual stock dynamics is mainly affected by the economic sector the stock belongs to or the closely related sector.

Further, considering the economic sector impact $d^K = \{d(i, K)\}$ on all the stocks of the market, the sector impact on the market can be studied. The Pearson correlation $\rho(d^{K_x}, d^{K_y})$ of the sector impacts between different economic sectors are shown in Fig. 4. For most sectors in both the SH and SZ markets, they present a high correlation between each other. But the finance and insurance sector exhibits a relatively weaker correlation with other sectors for the SH market, and the finance and insurance, the construction and the real estate sectors show a relatively weaker correlation with other sectors for the SZ markets, indicating a more independence of these sectors.

3.4. External stock market impact

The globalization of the world economy makes the financial markets of many countries highly correlated [47]. As an emerging market, it has been reported that the Chinese stock market on the one hand shows the similar behavior as other mature stock markets in some aspects such as the 'fat tail' distribution of the price returns, on the other hand has its own unique characteristic such as the anti-leverage effect. One may ask how the external stock markets affect the Chinese stock market?

In our study, the S&P 500, DJI and Nasdaq indices of the United States stock markets, GDAXI, FTSE 100, FCHI, SSMI, ATX and OSEAX indices of the European stock markets, N225, KOSPI, STI, BSE 30, KLSECI, JKSE and CSEALL indices of the Asian stock markets are considered, to understand the external market impact on the Chinese stock market. In Fig. 5, the extended partial correlation $\rho(i, j : M_n, M_e)$ on the partial correlation $\rho(i, j : M_n)$ is displayed, where nearly all the correlation points are found to be around the diagonal straight line. It suggests that the external indices including those of the United States stock markets [48], European stock markets and Asian stock markets have a very slight impact on the Chinese stock market.

4. Market structure similarity and persistence

Financial market is a highly unstable system, usually along with large fluctuations. The market structure also changes with time. To depict the market structure evolution, a Kendall rank correlation coefficient τ [49] is introduced, which

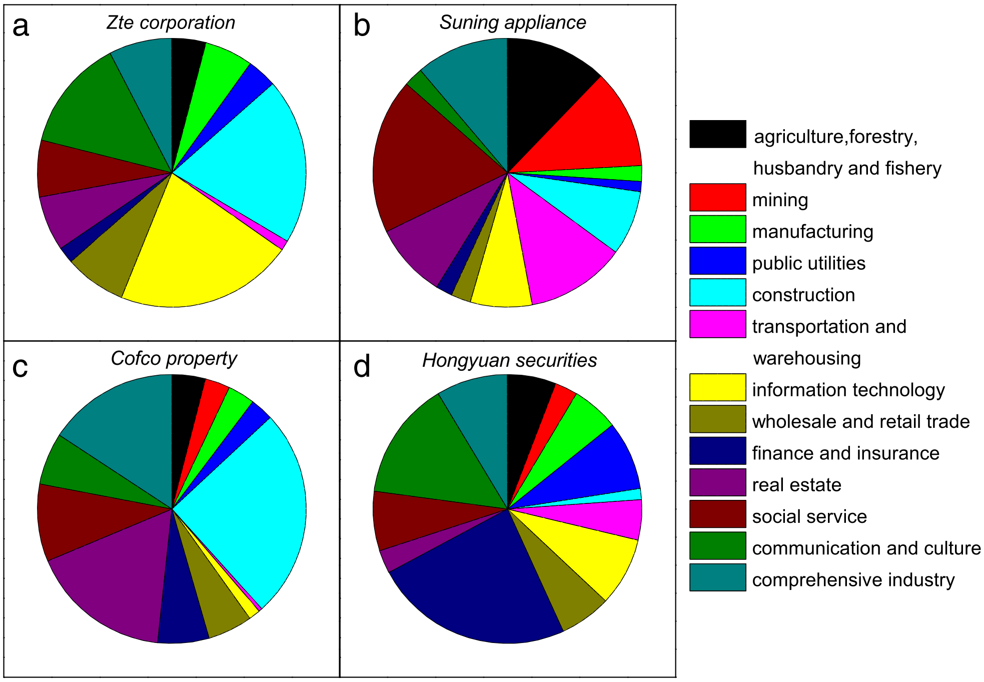

Fig. 3. The normalized economic sector impact coefficient β_i^K is displayed for the Zte corporation, Suning appliance, Cofco property and Hongyuan securities in the panel (a), (b), (c) and (d), respectively.

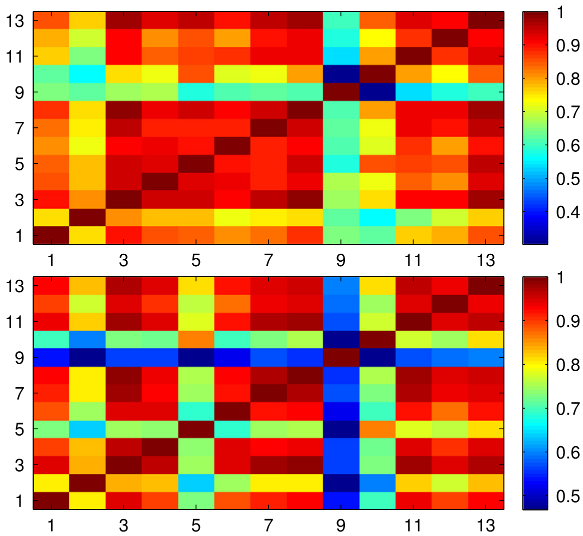

Fig. 4. The correlation of sector impact between different economic sectors $\rho(d^{K_x}, d^{K_y})$ is investigated for 13 sectors, with the label on the axes 1–13 to be the agriculture, extractive industry, manufacturing, public utilities, construction, transportation and warehousing, information technology, wholesale and retail trade, finance and insurance, real estate, social services, communication and cultural industry and integrated industry sector, respectively. The upper panel is for the SH market, and the lower panel is for the SZ market.

measures the similarity of time series in different periods, and is employed to quantify the market structure dynamics in our study.

Let $X(t) = \{x_1(t), \ldots, x_i(t), \ldots, x_j(t), \ldots, x_n(t)\}$ be a set of time series of the variables X. If at time t, $x_i(t) \geq x_j(t)$ (or $x_i(t) < x_j(t)$), and at time t', $x_i(t') \geq x_j(t')$ (or $x_i(t') < x_j(t')$) also holds, then the pair $(x_i(t), x_i(t'))$ and the pair $(x_j(t), x_j(t'))$ are taken as concordant, i.e., Concordant Pair (CP), otherwise, they are taken as discordant, i.e., Discordant Pair (DCP). The Kendall rank correlation coefficient τ is defined as:

$$\tau = \frac{2}{n(n-1)}(n_{CP} - n_{DCP}) \tag{8}$$

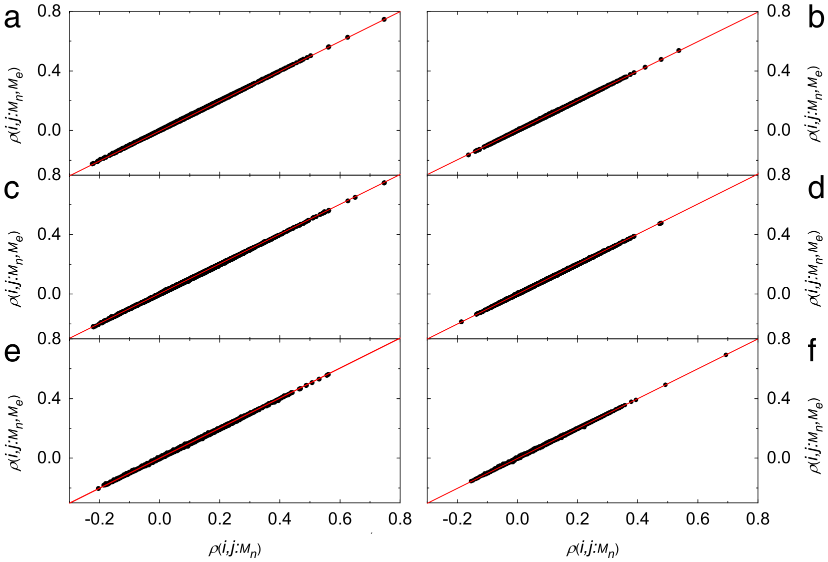

Fig. 5. The extended partial correlation $\rho(i, j : M_n, M_e)$ on the partial correlation $\rho(i, j : M_n)$ is displayed, where M_n and M_e are the native stock market index and external stock market index, respectively. (a) is for the United States stock markets on the SH market, (b) is for the United States stock markets on the SZ market, (c) is for the European stock markets on the SH market, (d) is for the European stock markets on the SZ market, (e) is for the Asian stock markets on the SH market, and (f) is for the Asian stock markets on the SZ market.

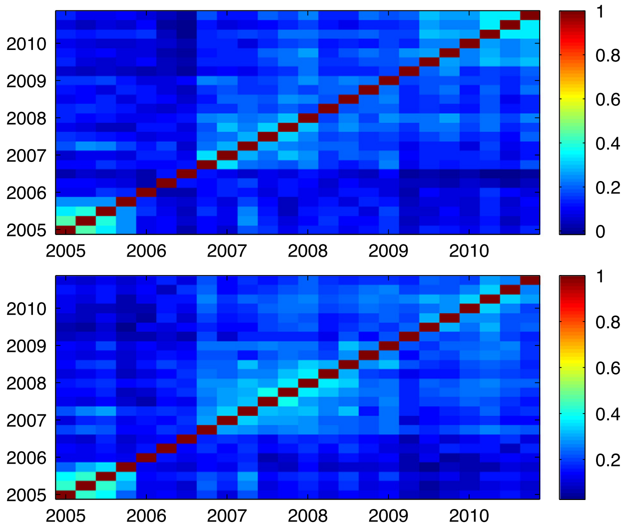

Fig. 6. The Kendall rank correlation coefficient τ is shown, with the upper panel for the SH market, and the lower panel for the SZ market.

where n is the stock number of the market, n_{CP} and n_{DCP} are the number of the concordant pairs and the discordant pairs in the market at the time t and t', respectively. Introducing the Kendall rank correlation coefficient τ to analyze the stock market structure similarity, the τ is investigated for the stock influence $d(i)$ on the market denoted as $d(i) = \langle d(i : k) \rangle$, with $\langle \dots \rangle$ being the average over all other stocks k.

By dividing the time periods of the data into 24 quarter time intervals Δt, the Kendall rank correlation coefficient τ of the market is shown in Fig. 6. It is observed that the τ around the diagonal line usually shows a greater value than the τ away from the diagonal line, suggesting that the market structures are generally more similar in a short time interval between two stages, and the similarity would become weaker as the time interval becomes large. Moreover, a relatively stronger structure similarity is observed for some time periods corresponding to the price dropping trend, such as the year 2005. Taking the SZ market index as an example, the average index is 3210, 2995, 2916 and 2739 point from the first to the fourth quarter of the year 2005. It motivates us to detect the relation between the market structure similarity and the price return of the index, with the price being the average of a quarter. As shown in Fig. 7(a) and (b) for the SH and SZ markets, the Pearson correlation coefficient shows a negative correlation between the Kendall rank correlation coefficient τ and the price return r. If dividing the data into 72 month time intervals, similar negative correlations can be observed for most time intervals Δt,

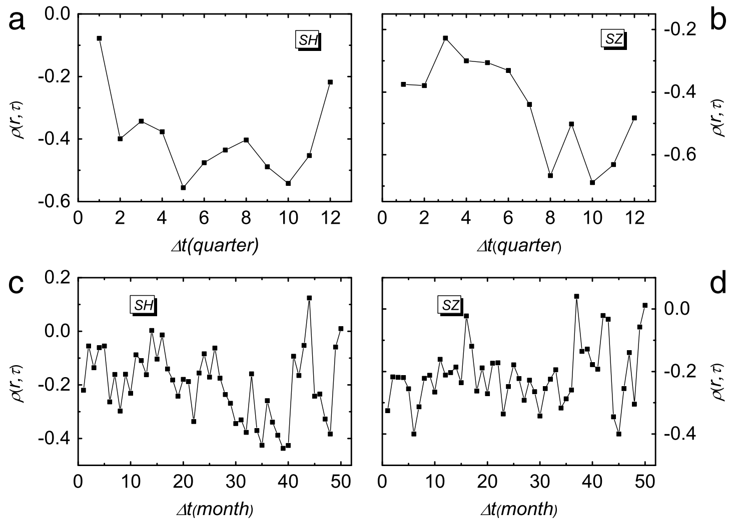

Fig. 7. The Pearson correlation coefficient $\rho(r,\tau)$ between the Kendall rank correlation coefficient τ and the price return r is displayed for different time intervals. (a) for the SH market under the quarter time scale, (b) for the SZ market under the quarter time scale, (c) for the SH market under the month time scale, and (d) for the SZ market under the month time scale.

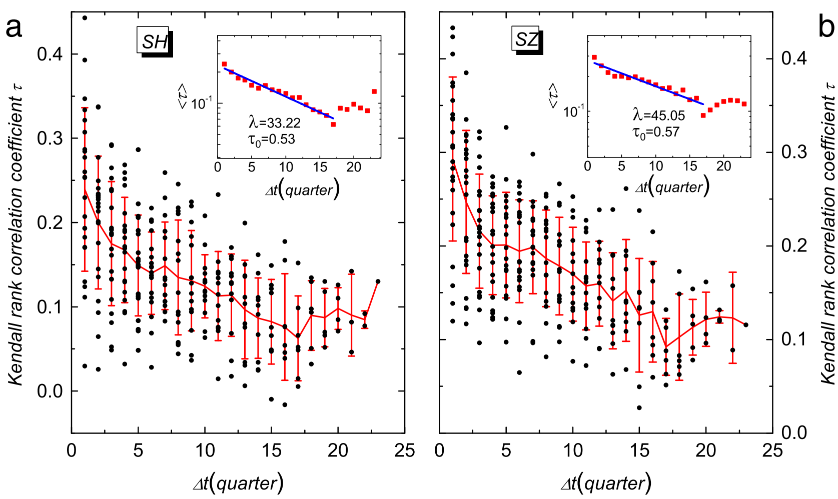

Fig. 8. The Kendall rank correlation coefficient τ on the time intervals is displayed, with (a) for the SH market, and (b) for the SZ market. The error bar is shown by the red vertical line. The inner panel shows the exponential fit for the average of τ. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

as shown in Fig. 7(c) and (d). That is to say, the market structure similarity is negatively correlated with the price return in most time.

How the market structure persists? Intuitively, the time intervals are longer, the market structure could be more different. We then study the Kendall rank correlation coefficient τ on different time intervals Δt. As shown in Fig. 8, the τ is observed to rapidly decay with the time interval. The average $\langle\tau\rangle$ can be fitted by an exponential function $\tau = \tau_0 e^{(-t/\lambda)}$, with $(\tau_0, \lambda) = (33.22, 0.53)$ for the SH, and $(\tau_0, \lambda) = (45.05, 0.57)$ for the SZ market. It indicates that, in a short time period, the market may keep a stronger structure similarity, while for a long time period, the market structure similarity would become weaker.

5. Conclusion

The market impact is investigated for the Chinese stock market, based on the partial correlation analysis. For both the Shanghai and Shenzhen stock markets, the market index presents a great impact on the market correlations. However, the external markets such as some stock indices of the United States stock markets, the European stock markets and the Asian stock markets are found to have a slight impact on the Chinese stock market. Economic sector influence is also studied, and the individual stocks are observed to be affected by different economic sectors, but the main influence is from their own or closely related sectors. Moreover, the finance and insurance sector shows a weaker correlation with other economic sectors for both the Shanghai and Shenzhen stock markets.

Market structure dynamics is further investigated, by quantifying the structure similarity between different time periods, based on the Kendall rank correlation coefficient analysis. A negative correlation is observed between the market structure similarity and the price return in most time, and the structure similarity decays with the increasing time interval.

Acknowledgments

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