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The relationship between the cross-correlation of individual stock returns and the return of the Hong Kong stock market

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Abstract

It has been well documented that the cross-correlation of a portfolio of stock returns is generally higher during bear markets than in bull markets. To verify this conclusion using evidence from Hong Kong stock market, around 21 years of daily closing prices of the 22 Hang Seng Index constituent stocks were collected and analysed. The empirical evidence suggests that below-average market returns tend to go hand in hand with a higher average cross-correlation of individual stock returns.

個別股票收益的交叉相關函數與香港股市回報之間的關係

摘要

不少論文載述，在熊市時股票收益組合之間的交叉相關函數，一般較在牛市時為高。為驗證這種結論是否適用於香港股票市場，本文對 22 隻恆生指數成份股在過去約 21 年的每日收市價格進行了收集及分析。數據結果表明，在市場回報低於平均水平時，個別股票收益的平均交叉相關函數往往錄得較高數值。

I. INTRODUCTION

1. Market players have long used correlations as a tool to better understand and predict price movements of financial assets since they can reflect the extent of panic selling in the market. This view is echoed by some researchers, who have suggested that a drastic change in the market's correlation structure can serve as an early warning of financial turmoil as indiscriminate selling of financial assets is often observed before major financial crises.

2. This article seeks to (1) study the relationship between the cross-correlation of individual stock returns and the return of the Hong Kong stock market; and (2) briefly examine the behaviour of this cross-correlation during market crashes. The purpose of this article is to verify previous research findings that market downturns are associated with increases in the cross-correlation among stocks using evidence from Hong Kong's stock market.

II. LITERATURE REVIEW

3. A number of researchers have provided empirical evidence to show that the cross-correlation between a portfolio of stock returns is higher in bear markets than in bull markets. Longin and Solnik (2001)[1] find that international markets are more highly correlated with the US market during market downturns than during upturns. Ang and Chen (2002)[2] and Hong, Tu and Zhou (2007)[3] propose different statistical methods to test the relationship between stock portfolios and the US market and draw the same conclusion. This phenomenon has been commonly referred to as "asymmetric correlation", but the rationale behind it has seldom been explored.

4. As for what rationales have been offered, market participants generally believe that investors tend to be less skeptical and react more strongly and more quickly when hearing about bad news, which in turn causes higher correlations in equity returns during market downturns. Researchers, for their part, have also attempted to explain this phenomenon from a behavioral angle. For instance, Campbell and Hentschel (1992)[4] explain asymmetric correlation by referring to a volatility feedback effect. When bad news prevails in the market, investors generally expect greater risks

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1 Longin, F. and Solnik, B., 2001, "Extreme Correlation of International Equity Markets", *Journal of Finance* 56.2, 649-676.

2 Ang, A. and Chen, J., 2002, "Asymmetric Correlations of Equity Portfolios", *Journal of Financial Economics* 63.3, 443-494.

3 Hong, Y., Tu, J. and Zhou, G., 2007, "Asymmetries in Stock Returns: Statistical Tests and Economic Evaluation", *The Review of Financial Studies* 20.5, 1547-1581.

4 Campbell, J.Y., and Hentschel, L., 1992, "No News is Good News: An Asymmetric Model of Changing Volatility in Stock Returns", *Journal of Financial Economics* 31.3, 281-318.

(volatility) and hence require higher returns to compensate for the risks. Higher required returns cause prices to fall and this co-movement in prices will lead to more highly correlated returns. Barber, Odean and Zhu (2009)[5] document evidence of herding among individual investors which can also account for asymmetric correlation.

III. DATA AND METHODOLOGY

5. To investigate the relationship between the cross-correlation in returns of stocks and the return of Hong Kong's stock market, the historical closing prices of a portfolio of stocks (22 stocks which are currently constituents of the Hang Seng Index (HSI) with over twenty years of trading records and no prolonged period of suspension) and the closing prices of the HSI are collected. The data cover daily closing prices for the period from January 1998 to November 2018. All the data are extracted from Bloomberg.

6. To study the dynamic of individual stocks' cross-correlations during different market states, the correlation coefficients for the daily logarithmic returns of all pairs of stocks (N = 22) are computed within each non-overlapping time interval of Δt trading days (10, 15, 30, or 60 days). The daily returns of an individual stock *i* are calculated as

$$R_{i(t,t+1)} = \log(P_{i(t+1)}/P_{i(t)}),$$

where $P_{i(t)}$ denotes the closing price of stock *i* on day *t*.

7. A set of correlations $\overline{Corr}_{i,j(t,t+\Delta t)}$, where each correlation is the Pearson correlation between the daily returns of stock *i* and the daily returns of stock *j* within each discrete time interval, is calculated. In total, for each discrete time interval, there are 231 correlation coefficients that arise from the original portfolio of 22 stocks (one for each unique pair). The mean cross-correlation within each time interval is then measured as

$$\overline{Corr}_{(t,t+\Delta t)} = \frac{2}{N(N-1)} \sum_{i,j,i<j} Corr_{i,j(t,t+\Delta t)} \, .$$

8. To map and relate the mean cross-correlation of individual stock returns to the corresponding prevailing market states during each time interval, the periodic returns of the HSI are computed as the logarithmic changes between its closing prices from trading day *t* to trading day $t + \Delta\, t$:

$$R_{HSI(t,t+\Delta t)} = \log(P_{HSI(t+\Delta t)}/P_{HSI(t)}).$$

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5 Barber, B. M., Odean, T. and Zhu, N., 2009, "Do Retail Trades Move Markets?", *Review of Financial Studies* 22.1, 151-186.

The index return series, $R_{HSI(t,t+\Delta t)}$, is then normalised by subtracting the mean return over the T time intervals and dividing by the standard deviation during these intervals as follows:

$$NR_{HSI(t,t+\Delta t)} = \frac{R_{HSI(t,t+\Delta t)} - \frac{1}{T}\sum_1^T R_{HSI(t+\Delta t)}}{\sigma_{HSI(\Delta t)}}.$$

IV. RESULTS

9. Summary statistics (means, medians and standard deviations) for the average correlations between individual stocks based on different time intervals are reported in ***Table 1***. Panel A depicts the statistics for the whole sample, while Panels B and C illustrate the statistics when the normalised market returns are positive and negative respectively. We examine the relationship between the market returns and the average correlations of individual stock returns by comparing the mean values of the correlations in Panels B and C. It is observed that the average correlations are noticeably higher when below-average market returns are recorded, regardless of the time interval adopted.

Table 1: Summary Statistics for the Within-Interval Average Cross-Correlation of Individual Stock Returns

Times interval Δt	10-day	15-day	30-day	60-day
Panel A: All time intervals				
Mean	0.376	0.376	0.377	0.377
Median	0.359	0.370	0.374	0.369
Standard deviation	0.143	0.127	0.108	0.093
Panel B: Time intervals with positive normalised market returns				
Mean	0.343	0.347	0.351	0.371
Median	0.330	0.343	0.351	0.358
Standard deviation	0.144	0.124	0.098	0.085
Panel C: Time intervals with negative normalised market returns				
Mean	0.408	0.406	0.407	0.384
Median	0.403	0.394	0.397	0.386
Standard deviation	0.135	0.125	0.111	0.101

IV.1 Average cross-correlation and normalised returns

10. To test the statistical significance of this relationship, a regression model

$$\overline{Corr}_{\Delta t} = \beta_0 + \delta_0 \, NR^- + \varepsilon$$

is estimated to explore whether the stock cross-correlations are significantly higher when the normalised market returns are negative. Time subscripts are implicit in this model and the models that follow. The average cross-correlation is regressed on the dummy variable NR^{-}, which is 1 when negative returns are recorded and 0 otherwise.

11. The four estimated regression equations (with *t* statistics in parentheses) are:

10-day interval: $\overline{Corr}_{\Delta t=10} = \underset{(39.51)}{0.343} + \underset{(5.25)}{0.065}\, NR^{-} + \varepsilon$

15-day interval: $\overline{Corr}_{\Delta t=15} = \underset{(37.10)}{0.347} + \underset{(4.37)}{0.059}\, NR^{-} + \varepsilon$

30-day interval: $\overline{Corr}_{\Delta t=30} = \underset{(32.16)}{0.351} + \underset{(3.50)}{0.056}\, NR^{-} + \varepsilon$

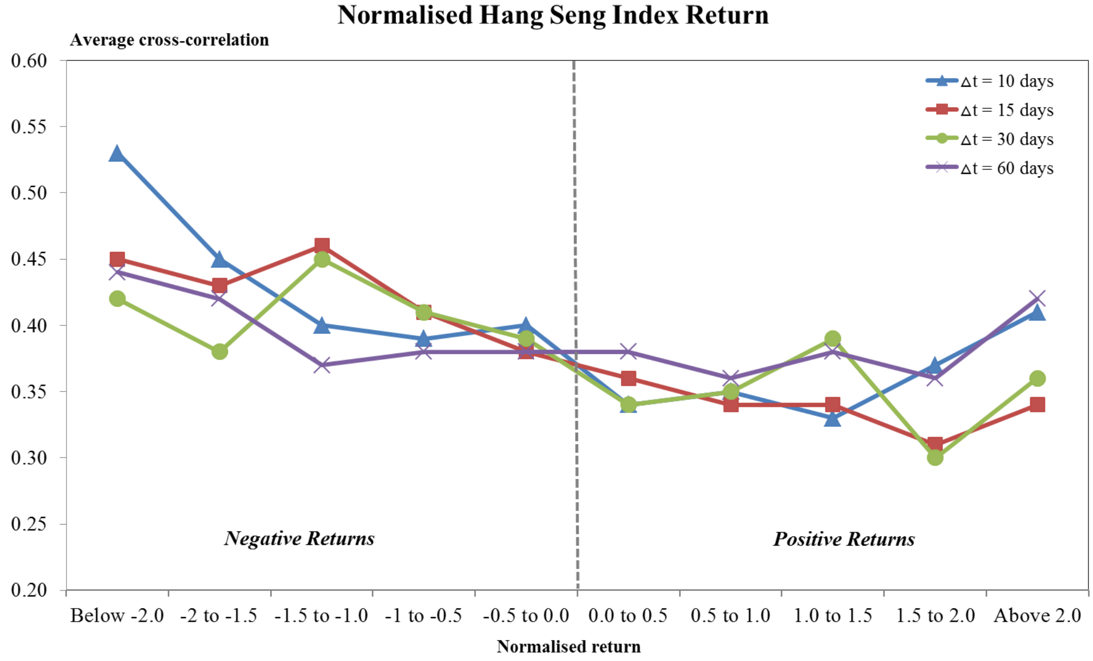
60-day interval: $\overline{Corr}_{\Delta t=60} = \underset{(26.77)}{0.371} + \underset{(0.68)}{0.014}\, NR^{-} + \varepsilon$

The coefficient on the dummy variable is positive and statistically significant for 10-day, 15-day and 30-day time intervals. The cross-correlations of equity returns increase by 0.065 on average within 10-day time intervals when the normalised market returns are negative (0.059 for 15-day and 0.056 for 30-day intervals). Yet the cross-correlation is not statistically higher when adopting a 60-day interval.

12. ***Chart 1*** shows the relationship between the normalised market return and the average cross-correlation of individual stock returns for 10 days $\leq \Delta t \leq 60$ days. Although the cross-correlations of stock returns are generally higher for more negative normalised market returns, the relationship is not strictly linear. Both extreme losses and gains increase the cross-correlation, though the effect is stronger for losses. These results are in line with more recent results in the literature (Reigneron, Allez and Bouchaud, 2011; Preis, Kenett, Stanley, Helbing and Ben-Jacob, 2012)[6].

6 Reigneron, P.A., Allez, R. and Bouchaud, J. P., 2011, "Principal Regression Analysis and the Index Leverage Effect", *Physica A* 390.17, 3026-3035.
Preis, T., Kenett, D.Y., Stanley, H.E., Helbing, D. and Ben-Jacob, E., 2012, "Quantifying the Behavior of Stock Correlations Under Market Stress", *Scientific Reports* 2, article 752.

Chart 1 : Average Cross-Correlation of Individual Stock Returns and Normalised Hang Seng Index Return



IV.2 Lagged rate of change in average cross-correlation and normalised returns

13. Further to the above analysis, another regression model

$$NR_{HSI(\Delta t)} = \beta_1 + \delta_1 \, \Delta C^{+} + \varepsilon$$

is estimated to determine whether the rate of change in average cross-correlation of stock returns has any impact or forecasting power on the normalised market return in the following time interval. The normalised market return is regressed on the dummy variable ΔC^{+}, which is 1 when the rate of change $\log(\overline{\mathrm{Corr}}_{(t-\Delta t,t)} / \overline{\mathrm{Corr}}_{(t-2\Delta t,t-\Delta t)})$ is positive in the prior time interval and 0 otherwise.

14. The four estimated regression equations (with *t* statistics in parentheses) are:

10-day interval: $NR_{HSI(\Delta t=10)} = \underset{(1.90)}{0.113} - \underset{(-2.67)}{0.226} \, \Delta C^{+} + \varepsilon$

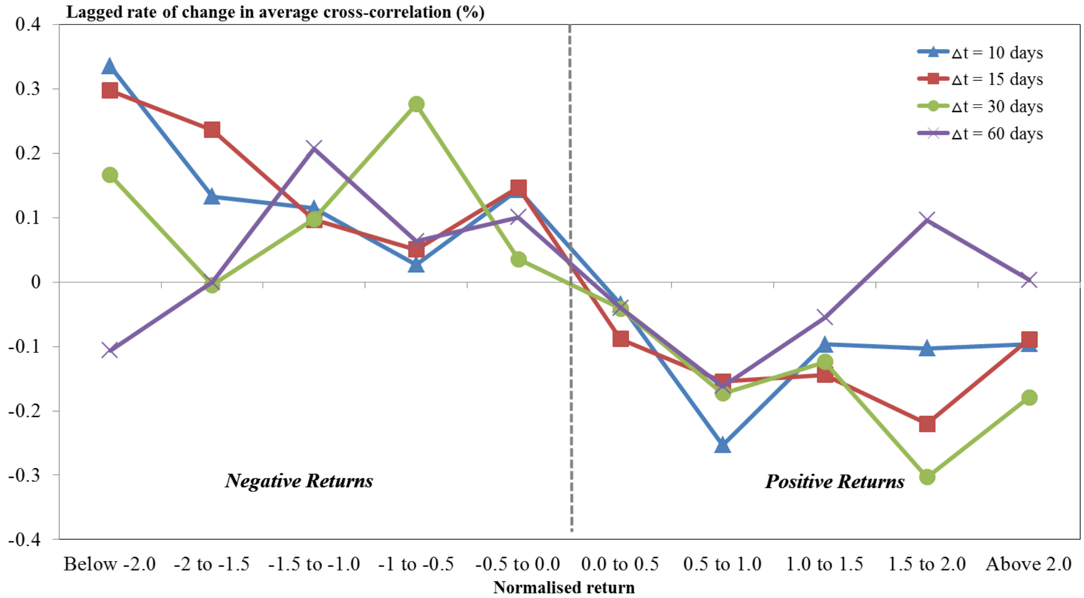
15-day interval: $NR_{HSI(\Delta t=15)} = \underset{(3.28)}{0.237} - \underset{(-4.78)}{0.489} \, \Delta C^{+} + \varepsilon$

30-day interval: $NR_{HSI(\Delta t=30)} = \underset{(3.02)}{0.311} - \underset{(-4.32)}{0.631} \, \Delta C^{+} + \varepsilon$

60-day interval: $NR_{HSI(\Delta t=60)} = \underset{(1.09)}{0.157} - \underset{(-1.28)}{0.271} \Delta C^{+} + \varepsilon$

The coefficient on the dummy variable is negative and statistically significant for 10-, 15- and 30-day time intervals, but not for 60-day intervals. Adopting 10-day time intervals, the normalised returns in the following time intervals decrease by 0.226 on average when the rates of change in the cross-correlation are positive (0.489 for 15-day and 0.631 for 30-day intervals). ***Chart 2*** shows the relationship between the normalised market return and the lagged rate of change in the average cross-correlation of individual stock returns for 10 days $\leq \Delta t \leq$ 60 days.

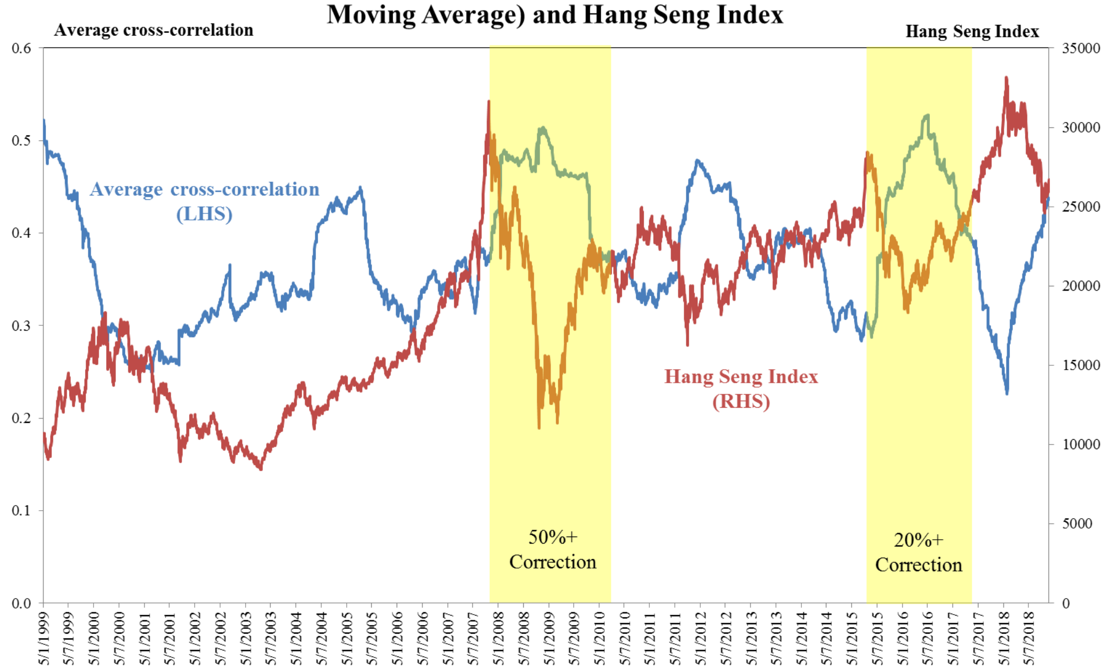
Chart 2 : Lagged Rate of Change in Average Cross-Correlation of Individual Stock Returns and Normalised Hang Seng Index Return



V. DISCUSSION

15. Based on the above findings, I examine further the movement of the cross-correlation of individual stock returns during periods of market turmoil, and specifically if a drastic increase in the average cross-correlation can be found and serve as an early warning signal. ***Chart 3*** shows the movements of the cross-correlation of daily stock returns (250-day moving average) against the HSI.

Chart 3 : Average Cross-Correlation of Individual Stock Returns (250-Day Moving Average) and Hang Seng Index



16. There were two major market corrections in the sample period during which the HSI fell by more than 20% from its peak levels. The HSI plummeted by more than 50% from its peak in 2007-2008 and by more than 20% in 2015-2016. We can see that the average cross-correlation rose sharply to a high level of 0.5 after the HSI reached its peaks. Yet no prior jump in the cross-correlation before the crashes can be detected.

17. Although a simple moving average of the cross-correlations of individual stock returns does not seem to serve as an early warning indicator for future market crashes, it may provide hints on when the market has started to stabilise. We can observe that after the HSI reached its troughs, the average cross-correlation dropped noticeably and persistently.

VI. CONCLUDING REMARKS

18. In summary, the evidence from the Hong Kong stock market shows that below-average market returns tend to go hand in hand with a higher average cross-correlation of individual stock returns. In addition, an increase in the rate of change of the average cross-correlation provides certain indications on possible future price movements. The results are largely consistent with international evidence.