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The Price Relationships among the Chinese Company's Shares Listing Domestically and Abroad: A Test of the Price Discovery Theory

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Abstract

This thesis investigates the price relationships among 14 Chinese companies' shares traded on domestic and foreign exchanges, i.e. the mainland China stock exchanges [either the Shanghai stock exchange (SHS), or the Shenzhen stock exchange (SHZ)], Hong Kong stock exchange (HKEK) and New York stock exchange (NYSE). The both stock exchanges (SHS, SHZ) in China are taken as one object to analysis. Firstly, the test on whether the stock prices are stationary or not, is performed by testing the unit roots and autocorrelation. The test results show that generally the stock prices are not stationary. Secondly, the tests are performed on the difference series or the return series. The result indicates that the first differences of the stock prices are all stationary. Thirdly, the cointegration tests are performed. The tests show that there are no long-term cointegrations between the prices of the company's shares listed on China (SHS, SHZ) and Hong Kong (HKEX) or China (SHS, SHZ) and New York (NYSE). However, there is a cointegration between the Company's stock prices on HKEX and those on NYSE, which indicates that the efficiency in terms of price discovery existing between the foreign exchanges rather than the domestic and foreign exchange. Finally, the Granger test is employed to perform on the returns series since it cannot be used on the non-stationary series, the share prices. The empirical analysis reveals that price discovery exists only between HKEX and NYSE, which are consistent with the previous cointegration tests. The reasons could be that HKD is pegged USD. The China market shows a high segmentation due to its strict capital control and restrictions on foreign exchange. Although, the common culture, language and other characteristics should give rise to an integrated capital market between the mainland China and Hong Kong, this relationship seems not existing, neither between the China and U.S. markets.

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Introduction

1.1 Background

At present most the classic paradigms in market microstructure concerns a stock that trades in a single centralized market, such situations are becoming increasingly rare in practice. Fragmentation, the dispersal of trading in a firm's stock on multiple sites, has emerged as a dominant institutional trend as a result of the integration of the global financial markets. The reasonable explanations for such trends are that firms can effectively reduce the cost of capitalization if they are listed on different stock exchanges, and enhance liquidity of a firm's stock. Increase in investor recognition can be regarded as another possible explanation. This process is of concern to investors because price information and price discovery (the incorporating new information into the stock price) have critical impact on investing behaviour. It is important to determine where the price information and price discovery come from when the process of fragmentation accelerates.

While greater integration of the short-term financial markets does have important economic consequences, the increased integration of capital markets, including the international equity markets, has serious implications for the efficient international allocation of capital, the levels of capital market volatility, the appropriate degree of multinational regulatory coordination, and the efficiency of economic policies in achieving long-term investment and output goals. In considering such issues, the relationships of stock prices among international capital markets are of quite considerable importance.

1.2 Objective

The objective of this thesis is to investigate price relationships of some Chinese companies' shares traded on different exchanges: the mainland China stock exchanges (Shanghai, Shenzhen), Hong Kong stock exchange (HKEK) and New York stock exchange (NYSE). Today the latter two are the most important capital markets on which Chinese companies capitalize abroad, by testing the existence of price discovery on these exchanges. Granger causality is used to perform this test. Then, the analysis of what kind of impact there is on the investing behaviour of different investor groups is further illustrated.

1.3 Theories and Methodology

This thesis tries to determine what kind of price relationships exist in some Chinese companies that are listed on the mainland China stock markets, Hong Kong market, and New York market by testing the presence of price discovery. The concept of causality comes into discussion. The Granger causality test is chosen to apply in performing such test in this thesis. The sample data collected has to be tested for the order of integration and cointegration before Granger causality can be used. This is performed by employing the unit root test. The causalities of share prices on the stock markets mentioned above is investigated by looking at the 14 Chinese companies that are listed on the different stock exchanges mentioned above.

1.4 Summary

The test results indicate that the price discovery exists neither between the China stock markets and HKEX, nor between the China stock markets and NYSE, but between HKEX and NYSE. The following sections are organized as following: China stock markets, theoretical background, literature study, methodology, data, empirical results and analysis, conclusion.

2 China Stock Markets and Overseas Listed Chinese Companies

The rapidly growing Chinese stock market consists of the Shanghai Stock Exchange (SHS) and the Shenzhen Stock Exchange (SHZ). The former commenced operations in December 1990 while the latter opened in April 1991. The rapid expansion of the China markets reflects China's significant economic growth. According to the China Securities Regulatory Commission (CSRC) China's total stock market cap had reached 4.27 trillion Yuan (about 533 billion U.S. dollars) by the end of 2002. The total number of domestic listed companies topped 1,215 by end of October, up 63 over the same period of last year. By the end of 2002, according to the Securities and Futures Commission of Hong Kong (SFC) 's statistics, the number will be up to US$ 1200 billion including Hong Kong stock exchange, which makes China the sixth largest stock market in terms of market capitalization in the world.

The listed companies in mainland China consist of A shares (restrict to domestic investors) and B shares (restricted to foreign investors) based on share categories. The total number (A shares and B shares) at the end of October 2002 is 1215. Among some of them, 87 companies were listed as A & B shares simultaneously. The shares are identical in terms of voting power and dividend claims. Due to the existing regulations, the amount of outstanding B shares is always smaller. Thus, foreign investors are forced to be minority shareholders, which is a main reason that the trading volumes of B shares are far much thinner than that of the A share, and the B share market value also own a much lower amount of the total Chinese stock market value. Since B shares are listed only on the mainland China stock market, only the international listed companies are focused in this thesis.

From the listing of Qingdao Beer on the Hong Kong Stock Exchange on July 15, 1993 to China telecom IPO on Nov 7, 2002, there are a total of 69 companies listed as H shares that refer to companies incorporated in the People's Republic of China, and approved by the China Securities Regulatory

Commission (CSRC) for a listing in Hong Kong. Shares of these Chinese enterprises are listed on the Hong Kong Stock Exchange, subscribed for and traded in Hong Kong dollars, and referred to as H shares. After finding its way into the Listing Rules, the term H shares has been accepted by, and is widely used in the market. The letter H first stood for Hong Kong, but now H shares are regarded by the market as overseas listing Chinese state-owned companies. Furthermore, among the 69 H-share companies there are 15 companies listed as ADR on NYSE. ADR denotes American Depositary Receipt, A receipt that is issued by a U.S. Depositary Bank, which represents shares of a foreign corporation held by the bank. Because ADR is quoted in U.S. dollars and traded just like any other stock, they make it simple for investors to diversify their holdings internationally. ADR is another kind of substitution for H share: Chinese companies issue H shares that are traded as ADR on NYSE; one unit of ADR is equal to 100 unit of H share. In later analysis, the stock price of NYSE is divided 100 compared with its counterpart on HKEX. Since China Telecom has just been listed on HKEX and NYSE respectively, on November 2002, it will be omitted in the analysis of this study.

The following table is the latest statistic data of the number of listed Chinese companies by categories:

Table 1 Summary of listed companies

	Number	Ratio of other shares to A share
A or B share listed company	1215	
B shares	111	0.1028
H shares	69	0.0639
A shares only	1080	1.0000
B shares only	24	0.0222
H shares only	40	0.0370
A&B shares	87	0.0806
A&H shares	29	0.0269
ADR	15	0.0138

Source: Monthly Statistics of China Security Regulatory Committee

Table 1 shows that the proportion of B shares and H shares are much lower than that of A shares. It can be definitely predicted that more and more Chinese companies including those listed as A shares are looking forward to capitalizing on international stock markets in the future in order to reduce cost of capitalizing, enhance liquidity of their stocks and attract international capital. With the implementation of Qualified Foreign Institutional Investor (QFII) scheme at the end of 2002 that allows the foreign investors approved by CSRC to invest A shares, undoubtedly Chinese company stocks will attract more and more the attention from international investors. It means that it is possible for the three different local investor groups to arbitrage with aid of price discovery to some degree. Thus, the relationships of stock prices for one company listed internationally become interesting issue to Chinese domestic and foreign investors.

3 Theoretical Background

3.1 Price Discovery

Price discovery is the process by which markets attempt to find equilibrium prices (Schreiber and Schwarz, 1986). The concept of price discovery traces back to the mid 80's when both academics and governmental authorities tried to describe the mechanisms of different markets and how the process ends in a correct prices. Fair market prices reflect the demand of all traders and should not be affected by incomplete information, sudden change in the depth and width of the market or the trading system as a whole.

Security markets are more apt to consist of diversely informed traders who collectively possess incomplete information about the assets being traded, rather than being characterized by asymmetric information. With the individual trade, the underlying information is made public through the trade price itself. Trading activity based on less than full information and past prices, markets may collectively error at times or converge to a new price.

Numerous factors, in addition to the underlying information change and liquidity trading, cause the price changes to occur **(**Schreiber and Schwarz, 1986). Even small orders may have huge impacts on the share price for low volumes traded of stocks. Sticky limit order books with outstanding orders can reflect past prices and information situation. And the process of finding the correct price will in itself cause the actual price to fluctuate. The advent of new information will generate a succession of trades and price changes while traders digest the news, including the price movement, and the market searches for a new equilibrium price **(**Schreiber and Schwarz, 1986).

3.2 Efficient Market Hypothesis

Paul Sammuelson developed efficient market hypothesis (EMH) in 1965. Eugene Fama formulated EMH later in 1970. The EMH suggests whether, at any given time, prices fully reflect all available information on a particular stock and/or market. Thus, according to the EMH, no investor has an advantage in predicting a return on a stock price since no one has access to information not already available to everyone else. In other words, the hypothesis says that capital markets are efficient and that security prices fully reflect all available information.

Based on EMH, there are three identified classifications of market efficiency, which are aimed at reflecting the degree to which it can be applied to markets.

Strong efficiency - This is the strongest version, which states that all information in a market, whether public or private, is accounted for in a stock price. Not even insider information could give an investor an advantage.

Semi-strong efficiency -This form of EMH implies that all public information is calculated into a stock's current share price. Neither fundamental nor technical analysis can be used to achieve superior gains.

Weak efficiency - This type of EMH claims that all past prices of a stock are reflected in today's stock price. Therefore, technical analysis cannot be used to predict and beat a market.

The EMH is an appealing description of competitive market equilibrium. An efficient market impounds new information into prices quickly and without bias. Prices fully reflect available information. Market participants adjust the available supply and aggregate demand in response to publicly available information soars to generate market-clearing prices. In major stock markets, where millions of dollars are 'voting', it seems plausible that a rational consensus will be reached as to the share prices which best reflect the prospects for future cash flows given available information.

Although the EMH may be an elegant economic concept, even a normatively desirable condition, it may not be true. Prices in securities markets may not fully reflect available information due to all kinds of outside factors. The early literature on market efficiency was widely interpreted as supportive. But, by the late 1970s, the anomalous evidence was growing and began to command attention. There is now a substantial body of empirical research, which casts doubt upon the degree of market efficiency (Faff, 1992).

3.3 Summary and Discussion

In fact Markets cannot be simply regarded to be efficient or inefficient, which means price discovery always exists at different degrees in terms of security market. Market efficiency can be viewed as a continuum running form of the perfect market (i.e., precisely strong form efficient) to the grossly inefficient market where excess earning opportunities abound. We can then think of any market or securities in a market as being characterised by some degree of efficiency. By following this approach, we might think the highly developed NYSE or HKEX is more efficient than the China stock markets because China is an emerging market. Based on the discussion in this section one can go further to investigate whether it is true that the different investor groups (Chinese domestic, Hong Kong and U.S. local) face that the equities of the same company are traded on different exchanges, at different prices resulting from price discovery.

From evaluating the perspective of the investor groups concerning market efficiency, to general degree of efficiency in markets is significantly understated by market participants. There is a large group of market participants who are not particularly interested in economic concepts and flatly reject the idea that shares are efficiently priced. They speculate for profits with the aid of price discovery. At present most the domestic investors are individual investors in China, but main investors in Hong Kong and New York are institutional investors. Compared with individual investors, institutional investors could generally be assumed to be more experienced, have better ways of obtaining information, and have access to more advanced technology to analyse data. Then the presence of foreign institutional investors could be a buy signal for the relatively uniformed domestic investors. In this case, the price of H shares will lead those A shares reflecting that domestic investors get information from Hong Kong market and New York market. However, the domestic investors might have the information advantage; they could get better relevant news from local sources. In this case, the prices of A shares will lead the prices of H shares. Hong Kong investors will lag New York due to one trading day later than New York if information flows from New York market, but in the second case they will lead New York investors due to common culture and language, and geographical cause.

4 Literature Review

Eun (2001) examines the contribution of cross listing to the price discovery for internationally traded securities and discusses policy implications. Specifically using a sample of Canadian stocks listed on the Toronto Stock Exchange, that are also listed in the U.S., to study the contribution of U.S. exchange to the price discovery for the these stocks. His main findings are as follows: first, the prices on both TSE and U.S: exchange are non-stationary with a unit root; second, adjustments maintaining the cointegration equilibrium between the prices on TSE and U.S. exchange occur on both exchanges; third, regression analysis indicates that the TSE share of total adjustment in prices is directly related to the U.S. share of total trading in a stock.

Huang, Yang and Hu (2000) explore the causality and cointegration relationships among the stock markets of the U.S., Japan and the South China Growth Triangle (SCGT) region. They find that the there exists no cointegration among these markets except for that between Shanghai and Shenzhen stock exchange by applying recently developed advanced unit root and cointegration techniques. And they find that stock price changes in the U.S. have more impact on SCGT markets than do those of the Japan and U.S. market leads both the Hong Kong and Taiwan market with one day by using Granger causality test. Furthermore, they find that the stock return of U.S. and Hong Kong markets are contemporaneous and there is a high correlation ship between Shanghai and Shenzhen markets.

Sjöö and Zhang (2000) analyse the information diffusion Chinese A shares (restricted to domestic investors) and B shares (restricted to foreign investors). The results show that there is important long-run information diffusion between A and B shares. The direction of the information diffusion is determined by the choice of stock exchange rather than firm size.

Ding, Harris, Lau and Mclnish (1999) use transactions data for the Kuala Lumpur Stock Exchange and the Stock Exchange of Singapore (SES) for a major Malaysian conglomerate, Sime Darby Berhad, and intraday exchange rate data to investigate whether, and to what extent, each exchange contributes to price discovery. They find that the price series are cointegrated and price discovery takes place in home country (Malaysia). In their study, they have taken into account of whether intraday exchange rate plays as significant role.

Hasbrouck (1995) investigates where price discovery occurs when homogeneous or closely linked securities traded in multiple markets. He suggests an econometric approach based on an implicit unobservable efficient price common to all markets. Applying an error correction approach and one-second sampling intervals over thirty Dow stocks, and six regional exchanges, he suggests the preponderance of price discovery occurs at NYSE.

Harris, Mclnish, Shoesmith, Wood (1995) use synchronous transactions data for IBM from New York, Pacific, and Midwest stock exchange to estimate an error correlation model to investigate whether each of the exchange is contributing to price discovery. They get that IBM prices on NYSE adjust toward IBM prices on the Midwest and Pacific Exchange, just as Midwest and Pacific adjust to the NYSE.

Cochran and Mansur (1991) examine the interrelationships between yields on the U.S. and several foreign market portfolios over the 1980-89 period. The result indicates that international equity market returns are largely contemporaneously determined, and the significance of contemporaneous effects varied over time. Uni-directional and bi-directional causality were found to be relatively weak.

Agmon (1972,1973) investigated the degree of capital market integration, found some evidence of a multinational market, consisting of a central market, the United States, and three peripheral markets, Germany, the United Kingdom, and Japan.

5 Methodology

The simple linear regression model with one independent variable (X) and one dependent variable (Y) looks as follows

$$Y_t = \alpha + \beta X_t + \varepsilon_t \tag{1}$$

where the parameter α is the intercept of the regression line β is its slope ε is error term and t is time. This regression follows the assumption of the classical linear statistical regression model.

It is in fact always necessary to build a model of reality, where all but the most important aspects should be taken away since any possible outside factors could be taken into account. Multiple linear regression analysis is one of such model where all possible explanatory variables considered having an important impact on the result have been incorporated into the regression model. Multiple regression analysis is regression analysis conditional upon the explanatory variables, and what we obtain is the average or mean value of Y means response of Y for the X variables as follows:

$$Y_t = \alpha + \sum_{i=1}^{k} \beta_i X_{t-i} + \varepsilon_t \tag{2}$$

To this model, the random error assumptions employed is continued as earlier simple regression model mentioned earlier, namely that the random errors uncorrelated and $\varepsilon_t \sim (0, \sigma^2)$, also no exact linear relations exist among the explanatory variables. It is also assumed that ε_t is normally distributed.

The factors that end up in the error term are those considered to have little impact on the result, but also the factors that haven't been considered at all. Thus, it is important to consider what might have an important impact on the final result when deciding which factors to include in the model.

Some mathematical methods have been worked out to extract the coefficients in the linear regression model. The methodology chosen should put the best possible values for the coefficients in the regression equation. The principle of ordinary least squares, OLS is one approach most frequently used. Basing on such principle, the coefficients of the model are those that minimize the sum of the squared deviations from the predicted values and the real values of the data set. In order to find the coefficients using the principle of least squares, a mathematical optimising problem has to be solved. Today, many statistical analysis soft packages are available to help find such coefficients, in this thesis; SAS (statistics analysis software) has been employed to service this purpose in this thesis.

5.1Time Series, Distributed Lag Model, Autoregressive Model and Autoregressive Distributed Lag Model

Generally, time series is often defined in the literature as a series or function of a variable over time. This often means that a particular variable takes a particular discrete value at a sequence of points in time. It is usually used to find the causal relationship among variables. To analyse time series, distributed lag models (In regression analysis involving time series data, if the regression model includes not only the current but also the lagged (past) values of the explanatory variables) are used to perform the regression and draw conclusions. Distributed lag models not only consider the effects of events the moment they occur, but also consider the long-time effects that an event has on its environment. Distributed lag models generally looks like so:

$$Y_t = \alpha + \sum_{i=1}^{k} \beta_i X_{t-i} + \varepsilon_t \tag{2}$$

where the subscript is the index of the time series Y. The independent variables in the model are previous values of the dependent variable, also called ‘lagged variables’.

A model which depends only on the values (another time series, i.e. X) to the time series is called a distributed lag model, while A model which depends only on the previous values of the time series is called an distribute lag model or autoregressive model (AR) as following:

$$Y_t = \alpha + \sum_{i=1}^{k} \beta_i Y_{t-i} + \varepsilon_t \tag{3}$$

where the values of Y_t depend on its own past values.

Of course a model based on both Y itself and X time series is an autoregressive-moving-average model (ARDL). The autoregressive distributed lag model (ARDL) model is one of a group of linear prediction formulas that attempt to predict an dependent variable Y_t of a time series based on the previous dependent variables ($Y_{t-1,}$ Y_{t-2}…) and independent variables (X_{t-1}, X_{t-2}...), the autoregressive model looks like so:

$$Y_t = \alpha + \sum_{i=1}^{n} \beta_i Y_{t-1} + \sum_{i}^{n} \delta_i X_{t-1} + \varepsilon_t \tag{4}$$

Note the remarkable similarity between the prediction formula and the difference equation used to describe discrete linear time invariant systems. Computing a set of coefficients that give a good prediction Y_t is tantamount to determining what the system is, within the constraints of the order chosen.

One way to investigate where price discovery occurs is to investigate causality on the prices of a stock listed among different exchanges. In order to econometrically/statistically test this we use the Granger Causality Test, which employs autoregressive-distributed- lag model (ARDL) in this thesis.

5.2 Autocorrelation and the Unit Root Test

Before a Granger causality test can be performed it is necessary to prove that the time series considered are conintegrated, i.e. their residual must be stationary. So we must know that the individual stock price time series have the same order of integration. This requires that we can decide the stationary for each of them.

At present there are two tests, which are relatively popular to perform the stationary. One is autocorrelation function; the other is unit root test. In this paper the autocorrelation check is used only for stationary at price level, the unit root test is employed to perform all the tests of stationary.

Successive values in time series are often correlated with one another. This persistence is known as serial correlation or autocorrelation and leads to increased spectral power at lower frequencies (redness). It needs to be taken into account when testing significance, for example, of the correlation between two time series. Among other things, serial correlation (and trends) can severely reduce the effective number of degrees of freedom in a time series. Serial correlation can be explored by estimating the sample autocorrelation coefficients:

$$r_k = \frac{\frac{1}{n}\sum_{i=k+1}^{n}(x_i - \bar{x})(x_{i-k} - \bar{x})}{\frac{1}{n}\sum_{i=k+1}^{n}(x_i - \bar{x})^2} \tag{5}$$

where k is the time lag. The zero lag coefficient $r_0$is always equal to one by definition, and higher lag coefficients generally damp towards small values with increasing lag. Only autocorrelation coefficients with lags less than n/4 are sufficiently well sampled to be worth investigation.

In this thesis Chi-Square test is applied to perform the autocorrelation check. If a time series is nonstationary, there will be autocorrelation in the time series. The autocorrelation check will be as a supplement support of unit root test for stock prices.

Then consider this model:

$$Y_t = \rho Y_{t-1} + u_t \tag{6}$$

where Y_t is a time series and u_t is a stochastic error term, non-autocorrelated with expected value zero and constant variance. If regression is performed and the coefficient ρ in front of Y_{t-1} equals one, we face what is known as the unit root problem, i.e., the time series is non-stationary situation. Then the time series Y is said to have a unit root.

In order to determine whether a time series is stationary or not, this regression is run on the time series and find out if ρ is statistically equal to one or. Under the null-hypothesis ρ equals one. The calculated t-value is known as the τ-statistics whose critical values have been tabulated by Dickey and Fuller. That is the reason for why the τ-test is also called Dickey-Fuller (DF) test. If the absolute value of the τ-statistics exceeds the critical DF-value, we cannot reject the hypothesis that the time series is stationary. If, on the other hand, the τ-statistics is less than the critical value, the time series is non-stationary.

For the theoretical and practical reasons, the DF-test is carried out on the following three regression models:

$$Y_t = \delta Y_{t-1} + u_t \quad (7)$$

$$Y_t = \alpha + \delta Y_{t-1} + u_t \quad (8)$$

$$Y_t = \alpha + \beta t + \delta Y_{t-1} + u_t \quad (9)$$

where t is the time or a trend variable. The difference between the models is the inclusion of a constant and a trend term.

In this study, the first unit root test is used to perform testing on share prices, and then the second unit root test is on the first difference of share prices, the last one is used on the residual of share prices for cointegration.

5.3 Stationary and Order of Integration

A stochastic process is said to be stationary if its mean and variance are constant over time and the value of covariance between two time periods depends only on the distance or lag between the two time periods, and not on the actual time at which the covariance is computed (Gujarati, 1995). By definition, a time series is stationary if it meets the following criteria:

- Mean: $E(Y_t) = \mu$
- Variance: $Var(Y_{t)=}E(Y_t - \mu) = \sigma^2$
- Covariance: $\gamma^k = E(Y_t - \mu)(Y_{k+1} - \mu)$

where γ^k, the covariance at lag k, is the covariance between the values of Y_t and Y_{k+1} between two Y values k periods apart.

A stationary time series is one whose mean, variance, and autocorrelation function do not change over time. This condition is violated by data that tend to trend upward or downward over time, which is called no stationary time series. If a time series is not stationary it can be differentiated a number of times, thereby eventually by becoming stationary. If x differentiations are required before a stationary time series is reached, the time series are said to be impounding of order x, denoted I (x). A necessary condition for cointegration is that both time series are impounding of the same order (Gujarati, 1995). As mentioned above this is examined by looking at how many times the time series has to be differentiated before it becomes stationary.

5.4 Cointegration

The long run relationship between the price time series has to be tested before any reliable results could be draw from the Granger causality test. If the prices do deviate too much, they cannot have a common trend, which is a necessary condition for price discovery to take place.

Cointegration means that despite being individually nonstationary, its error of a linear combination of two or more time series can be stationary. Cointegration of two (or more) time series suggests that there is a long run or equilibrium, relationship between them (Gujarati, 1995). So the cointegration between X_t and Y_t means that the difference between the time series is stationary, which implies the time series do not deviate too much from each other in the long run. In other words, cointegration implies that X and Y have similar stochastic trends; they exhibit a long-term equilibrium relationship (Hill, 1999). If two-time series X_t and Y_t are I (1) then, in general, the linear combination:

$$Y_t - \beta X_t = u_t \quad (10)$$

where the residual u_t is stationary, that is I (0). However, it is possible that u_t is nonstationary, or not I (0). In order for this to happen the 'trends' in X_t and Y_t must cancel out when $Y_t - \beta X_t = u_t$ is formed. In this case, X_t and Y_t are said to be cointegrated, and β is called the cointegrating parameter.

If two time series fail to be cointegrated, price discovery cannot occur between them. But according to Gujarati, a necessary condition for cointegration between two time series is that these time series are integrated in the same order, stationary and order of integration will be explained shortly.

Before the Granger causality test can be performed, two conditions must be complied with as follows:

- The order of integration of the individual time series must be shown to be the same, and if this is the case then
- The two time series must be checked for cointegration.

In order to find out the order of integration, the stationary of time series must be tested, and if the time series are not differentiating them until stationary occurs. How to test stationary, unit root test is applied to perform it.

5.5 Granger's Causality Test

Price discovery concerns the way in which new information is impounded into the stock prices. As mentioned earlier, if this process is faster at one exchange than at another, one exchange is called the leading exchange and other is called the lagging exchange. The question to be answered in this thesis is whether it is possible to statistically prove a causality relationship between different exchanges. Granger Causality is one of the tests that are used to investigate this relation.

This test decides whether new prices on one exchange can be better explained by extending the autoregressive model with the prices from another exchange. If explaining the prices on the first exchange by information from the second exchange is possible, this is interpreted as evidence that the second exchange, and that price discovery takes place to a greater degree at the second exchange. The second exchange is said to `lead' the first exchange, which 'lags' the second exchange. This relationship is therefore called a 'lead-lag relationship'.

The assumptions of this test are that all relevant information for the prediction of the respective variables, in this cases the stock prices, which is contained in previous variable that is in time series of stock prices.

With the aid of time series for the stock prices X and Y, the corresponding regression is carried out. The idea behind the Granger Causality test is to use an F-Test to compare a univariate time-series model, which is a model where the values of a variable are assumed to be influenced not only by the earlier values of the same variable, with a multivariate model, where the value of variable is assumed to depend on the value of other variables as well. Examples of univariated and multivariate time-series models are shown below:

Univariate model:

$$X = \alpha + \sum_{i=1}^{k} \beta_i X_{t-1} + \varepsilon_t \tag{11}$$

Multivariate model

$$X_t = \alpha + \sum_{i=1}^{k} \beta_{1i} X_{t-i} + \sum_{i}^{K} \delta_{1i} Y_{t-i} + \varepsilon_t \tag{12}$$

$$Y_t = \alpha + \sum_{i=1}^{k} \beta_{2i} Y_{t-i} + \sum_{i}^{k} \delta_{2i} X_{t-i} + \varepsilon_t \tag{13}$$

where k is the number of lags. A critical part of the Granger causality test is the lag length used in the models. Several different methods have been proposed to determine the optimal number of lags used, for example, Schwartz' criteria (Hill, 1999), or starting with a large number of lags, and then reducing them until the gets to small (Gujarati, 1995). A third method is to begin with a small number of lags and then increase this number as long as the extra coefficients are significant and do not switch sign (Gujarati, 1995). Cochran and Mansure choose to use a fixed number of lags, without any a priori statistical research justifying the choice. This is the approach chosen in this study, and the number of lags used is three.

An F-test is used to decide whether the extra information contained in the time series Y helps to better predict the values of the time series X than the time series can do alone.

$$F = \frac{(SSE_R - SSE_{UR})/J}{SSE_{UR}/(n-k)} \tag{14}$$

SSE_R and SSE_{UR} are the sum of squared error for the restricted (univariated) and unrestricted (multivariate) model, respectively J is the number of null hypotheses, k is the number of parameters estimated in the unrestricted regression, and n is number of samples

In the Granger Causality test, the null hypothesis says that β_i=0 and δ_i=0 for every i. The computed F-statistic is compared to the appropriate right-tail critical value for the F-distribution. If the F-test shows that time series Y leads time series X then Y is said to Granger cause X.

Every Granger test examines the causality in bi-direction. It is therefore necessary to perform the test twice for every stock and pair exchanges to completely reveal price discovery process.

Table 2 Conclusions about price discovery drawn from the Granger causality test

	A Granger causes B	A does not Granger cause B
B Granger causes A	Mutual price discovery	Price discovery at B
B does not Granger cause A	Price discovery at A	NO price discovery

.

If the price discovery is present, the leading exchange will set a price that the lagging exchange will adapt to after some time. This means that the prices on the leading and the lagging exchange will go together and that the stock prices do not deviate too much from each other over time (Sjöö& Zhang, 2000).

6 Data

The price relationships of Chinese company stocks listed on the mainland China stock exchanges (either Shanghai, or Shenzhen stock exchanges), Hong Kong stock exchange and New York stock exchange are investigated by looking at the stock prices of 14 Chinese companies during the time period 1993-2002. All the companies studied went to IPO during this period. The tests are performed using weekly stock price data.

Every company studied must comply with a number of common conditions for the results to be comparable. Such conditions are as follow:

- The company must have been continuously listed during the whole time period, on SHS, SHZ, HKEK and NYSE.
- The volume of trade has to be significant during the whole time period.

All companies studied are shown in Table 3.

Table 3

	A-share (China)		H-Share (HKEX)		ADR (NYSE)	
Company	Code	Listing date	Code	Listing date	Code	Listing date
Aluminium Corp.of China Ltd.	No	No	2600	12/12/2001	ACH	12/11/2001
China Eastern Airlines Corp.Ltd.	600115	11/05/1997	0670	02/05/1997	CEA	02/04/1997
China Mobile Ltd.	No	No	0941	10/23/1997	CHL	10/22/1997
China Petroleum&Chemical Corp.	600028	08/08/2001	0386	10/19/2000	SNP	10/18/2000
China Southern Airlines Co. Ltd.	No	No	1055	07/31/1997	ZNH	07/30/1997
China Unicom	No	No	0762	06/22/2000	CHU	06/21/2000
Guangshen Railway Co.Ltd.	No	No	0525	05/14/1996	GSH	05/13/1996
Huangneng Power International Inc	No	No	0902	01/22/1998	HNP	10/06/1994
Jilin Chemical Industrial Company.Ltd.	000618	10/15/1996	0368	05/23/1995	JCC	05/22/1995
PetroChina Company Ltd.	No	No	0857	04/07/2000	PTR	04/06/2000
Beijing Yanhua Petrochemical Co.Ltd.	No	No	0325	06/25/1997	BYH	06/24/1997
Sinopec Shanghai Petrochemical Co.Ltd.	600689	11/08/1993	0338	07/26/1993	SHI	07/26/1993
Yanzhou Coal Mining Co.Ltd	600188	07/01/1998	1171	04/01/1998	YZC	03/31/1998
CNOOC	No	No	0883	02/28/2001	CEO	02/27/2001

In the above table, except YZC, which is listed on SHZ, the other companies are listed on SHS.

As shown in Table 3, based on industrial classification, the companies studied can be generalized as: ACH belongs to metal product sector, CHL and CHU are telecommunication carriers, CEA and ZNH are air transport carriers, SNP, JCC, PTR, BYH, SHI and CEO are manufacturers of petroleum, chemical product, plastics and rubber, GSH belongs to public service sector, HNP is electricity supplier, YZC belongs to mining sector. According to industrial distributions, producing and processing row resource-firms own main proportion of listed companies in the Table 3. Additionally among them, CHL, CHU, CEO are the sample shares of Hang Heng Index on HKEX, further more, CHL is the second biggest market capitalization listed company on HKEX as well.

The data collected comes from different databases. The daily close data of 14 stocks on HKEX and NYSE is collected from finance.yahoo.com. Because the daily close stock prices of five stocks, which are listed on China stock market, are not available from finance.yahoo.com, I received the weekly data (close price of one specific trading day for each week, i.e. fixing on Wednesday data in this thesis) for them from Datastream database. The daily close exchange rate of CNY (Chinese Yuan) to USD (U.S. Dollar), and the daily close exchange rate of HKD (Hong Kong Dollar) to USD come from Ecowin database.

In order to be able to compare such series of stock prices with one another, both stock prices on mainland China stock exchanges and HKEX have been converted into their corresponding U.S. dollar by dividing them from CNY (Chinese Yuan) and HKD (Hong Kong dollar) using daily exchange rates to USD respectively.

Taking data from different databases causes that there exist differences of the time series among the price formats in which dates are included. So the time series have to be matched to include the same dates and be converted to the same format in order to get the comparable data. Since there are different holidays in three locations, it means that the data is not available from four exchanges and from foreign exchange rate for each trading day respectively. Furthermore the daily data has to be matched with the weekly data. In order to deal with such problems, SAS (statistics analysis software) is used to merger such different time series of stock prices and exchange rate with the dates.

Those data with missing price and exchange rate are omitted from the study. At last I received the weekly data (Wednesday close data for each week) for corresponding time series: stock prices, exchange rates including the same dates.

The reason for using weekly Wednesday data and not daily data or monthly data in this study can be explained as follow:

- Daily data always seems significant even after lagged many times, compared with weekly data, it cannot reflect price discovery very well.
- Monthly data, compared with weekly data, misses a lot of price change information due to long interval.
- The data of Wednesday chosen for the weekly data can be effectively avoid so-called ‘weekend effect’ on stock prices.

7 Empirical Results and Analysis

7.1 Basic Statistics

The sample data included in this thesis comprises weekly stock prices at market close as mentioned above, the 14 shares listed on HKEX and NYSE are specifically focused, and five of them are also listed on the mainland China stock exchanges: CEA, SNP, JCC, SHI on SHS, and YZC on SHZ. In this thesis, SHS and SHZ are taken as one object to study.

Table 4 Basic statistics of return of the 14 company share prices

The companies listed on HKEX and NYSE.

	ACH		CHL		ZNH		CHU		GSH	
	HKEX ($)	NYSE	HKEX ($)	NYSE	HKEX ($)	NYSE	HKEX ($)	NYSE	HKEX ($)	NYSE
N	31	31	242	242	214	214	109	109	314	314
Mean	-0.0166	-0.015	0.0018	0.0019	0.0007	0.0008	-0.0112	-0.0108	-0.0026	-0.001
Std Dev	0.0593	0.0583	0.0754	0.0752	0.1022	0.0982	0.0713	0.0751	0.0723	0.0689
Minimum	-0.1419	-0.1271	-0.3259	-0.2972	-0.3733	-0.3605	-0.3013	-0.2257	-0.3022	-0.253
Maximum	0.0906	0.0806	0.2547	0.2302	0.4699	0.3179	0.1984	0.2002	0.3646	0.2869
Kurtosis	-0.5183	-0.7986	1.7632	1.0532	3.5322	1.2166	3.2897	1.2166	3.4612	2.1081

	HNP		PTR		BYH		CEO	
	HKEX ($)	NYSE	HKEX ($)	NYSE	HKEX ($)	NYSE	HKEX ($)	NYSE
N	230	230	94	94	250	250	74	74
Mean	0.0011	0.0023	0.1943	0	-0.0031	-0.0023	0.0054	0.0066
Std Dev	0.0769	0.0798	0.0178	0.0461	0.1153	0.1067	0.0455	0.0474
Minimum	-0.2512	-0.2876	0.1615	-0.1374	-0.3677	-0.33	-0.0974	-0.0889
Maximum	0.2712	0.2181	0.2333	0.0952	0.3302	0.4196	0.1125	0.1154
Kurtosis	1.1555	0.9441	0.3054	0.6828	0.9239	1.4492	-0.2639	-0.2889

The companies listed on the China stock markets (SHS, SHZ), HKEX, NYSE.

	CEA			SNP			JCC		
	China ($)	HKEX ($)	NYSE	China ($)	HKEX ($)	NYSE	China ($)	HKEX ($)	NYSE
N	234	234	234	55	55	55	280	280	280
Mean	-0.0011	-0.0025	-0.0026	0.004	-0.0013	0.0003	-0.0016	-0.0029	0.0021
Std Dev	0.0466	0.097	0.0909	0.0337	0.0472	0.0434	0.0723	0.1207	0.1109
Minimum	-0.1204	-0.4407	-0.3453	-0.0549	-0.096	-0.0941	-0.303	-0.4414	-0.3346
Maximum	0.2082	0.3273	0.2652	0.1609	0.0997	0.0963	0.3493	0.3813	0.4437
Kurtosis	2.8599	2.8196	1.1677	9.451	-0.6602	-0.4415	3.9093	1.3371	1.3474

	SHI			YZC		
	China ($)	HKEX ($)	NYSE	China ($)	HKEX ($)	NYSE
N	437	437	437	155	155	155
Mean	-0.0015	0.0026	-0.0017	0.0016	0.0015	0.0021
Std Dev	0.068	0.0899	0.0788	0.1205	0.1069	0.0969
Minimum	-0.4244	-0.3166	-0.2426	-0.4041	-0.4321	-0.4092
Maximum	0.5123	0.5595	0.3481	0.4891	0.3394	0.2834
Kurtosis	13.8025	4.7904	1.9253	3.5964	2.502	2.1884

The weekly rate of return for the 14 stocks is computed based on the conventional first difference of logarithmic prices:

$$r_t = (\log p_t - \log p_{t-1})$$

Where r_t denotes the rate of return on week t and p_t denoted the corresponding stock price. N= number of observations. Std.Dev. = Standard Deviation, Kurtosis=measures heaviness of tails that is whether some values are very distant from the mean for the population.

The weekly return of share prices for the 14 companies are computed using the conventional first difference of logarithmic prices:

$$r_t = (\log p_t - \log p_{t-1}) \quad (15)$$

where r_t denotes the rate of return on week t and p_t denotes the corresponding stock price. The descriptive statistics reported in Table 4 indicate the mean of the return of the shares on HKEX is lower than that of NYSE, which could result from the continuing economy slowdown of local Hong Kong since 1997's Asian financial crisis. It is surprising to find that the sample shares listed on China markets have relatively lower standard deviation compared with them on Hong Kong and New York markets. The stocks listed on Hong Kong and New York markets have relatively similar standard deviation and they get higher figures of standard deviation than those listed on China market, which means that the risk of China stock market might be lower than that of HKEK and NYSE. One reason for this result can be the currency converting, i.e. from CNY to USD and HKD to USD.

Appendix 1 shows that basic statistics for the stock prices in corresponding currencies. It shows that at price level those company stocks on China stock markets get higher figures of mean and standard deviation than they do on HKEX and NYSE respectively. From this result, it is not difficult to learn that there are more speculations on the China market consisting mainly of individual domestic investors than on HKEX and NYSE consisting mainly of institutional investors. In other words, it can be said that the emerging market is riskier than the developed market

Table 4 indicates that the emerging markets tend to have greater kurtosis with more pronounced fluctuations as well. It is not surprising that the China markets have the greatest Kurtosis. These results are consistent with the conclusion found by Bekaert and Harvey (2000) that returns volatility in emerging markets is greater than that in developed markets. The test results mentioned above at price level follows this conclusion from as well.

Table5 Correlation of return of the company stock prices on different exchanges.

The companies listed on HKEX and NYSE.

	ACH	CHL	ZNH	CHU	GSH	HNP	PTR	BYH	CEO
HK&US	0.9613	0.8630	0.8538	0.9112	0.8447	0.8103	0.4953	0.8444	0.9304

The companies listed on the China stock markets (SHS, SHZ), HKEX, NYSE.

	CEA	SNP	JCC	SHI	YZC
CN&HK	0.3310	0.2345	0.1429	0.1461	0.1435
CN&US	0.2951	0.2500	0.1354	0.1350	0.1611
HK&US	0.8706	0.8683	0.8579	0.8697	0.8987

CN, HK and US denote China stock markets, HKEX, NYSE respectively.

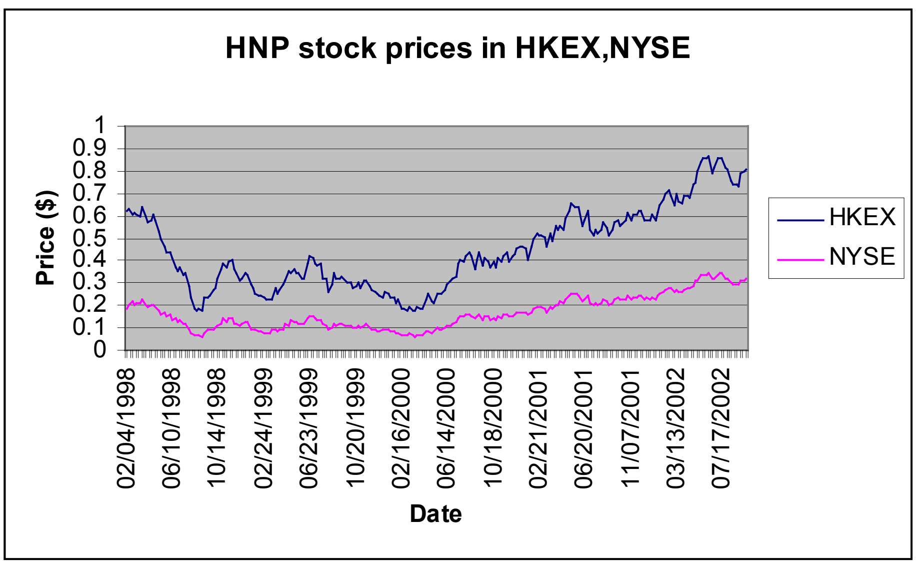
The time series of the share prices between HKEX and NYSE indicates high correlation (Table 5). However, a quite low correlation of the return for the share prices is shown between the China stock markets and the other two markets. This result means the return for the H share prices on HKEX and NYSE can be a good explanation for each other respectively except PTR's, and the return of A share prices and H share prices of the companies can not explain each other well due to their low correlation coefficient. All companies studied get the positive figures of correlation coefficients, which means the return of the sample share prices tend to go up or down together. This correlation test at return can be compared with such test result at price level (Appendix 2). At the price level, the figures of correlation between HKEX and NYSE are similar with those of return on HKEX and NYSE. But there is still some difference between such two test results: some sample A share prices and

H share prices not only get quite small correlation coefficients, but also appear negative values, which means that they do not move together in the same direction. These correlation test results give some interesting implication for the later test results: there might not be causality relationship between the A Share prices and the H share prices.

7.2 Unit Root Test

7.2.1 Unit Root Test for the Stock Prices

The results of the unit root test for the 14 stock prices in China, Hong Kong, New York from 1993-2002 are shown in Appendix 3. It is easy to find out that in general the stock prices should not be stationary during some period. They always have some trend to go up or down in this term, for instance, as the following graphs:



Huaneng international Inc. stock prices in Hong Kong and New York

Sinopec Shanghai Petrochemical Co.Ltd stock prices in China, Hong Kong, and New York

It means the time series of share prices could not be expected to have a constant mean and variance over time, in other words they have unit root and are nonstationary. The exception: JCC, SHI, YZC on China market, ZNH on HKEX, ACH and CEA on HKEX and NYSE are stationary at 5% significance level during the tested period, but all 14 stocks are nonstationary at 1% significance level during the tested period. One reasonable explanation for their stationary is their thinly trading volumes and low stock prices.

This test result of unit root for stationary of stock prices can be supported by the autocorrelation check for the stationary of stock prices (Appendix 4). If the time series is nonstationary, there exists autocorrelation in the time series. The autocorrelation check obviously illustrates that there exists strong autocorrelation at both 1% and 5% significance level among the each stock price time series, which means all the time series of stock prices cannot be stationary.

7.2.2 Unit Root Test for the First Difference of the Stock Price

Compared with Appendix 4, the vast majority of test shows that stock prices themselves are nonstationary, but their first difference is stationary. It means that share price time series in general are integrated of order one supported by the test results (Appendix 5). According to Gujarati (1995), a necessary condition for cointegration between two time series is that these time series are integrated of the same order, the test results for the first difference of stock prices makes sense to go ahead with cointegration test.

The equation 15 represents that the equation itself is one kind of first differences. From the above discussion it implies that the returns of share prices are stationary and integrated at order one as well, which are supported by the results of unit root test for the return of the share prices (Appendix 6).

7.2.3 Cointegration

The prices of sample stocks on three stock markets have been analysed to show that they are nonstationary and integrated order one. The sample stocks are cross-listed both in Hong Kong and New York, and five of them also listed in China, they are expected an equilibrium relationship among the different prices of a stock on three locations, and two of them cannot move independently. The bivariate cointegration tests employed by Huang (2000) are performed between the share price time series, which are to be tested using the unit root test, for instance, the share prices for a specific stock on two different exchanges: (1) the stocks on China and Hong Kong markets, (2) the stocks on China and New York markets, (3) the stocks on Hong Kong and New York markets.

Table 6 Cointegration test for the return of the 14 stocks

The companies listed on HKEX and NYSE.

	HK->US		US->HK	
	Tau	Pr < Tau	Tau	Pr < Tau
ACH	-3.65*	0.0428	-3.62*	0.0452
CHL	-9.57*	<. 0001	-9.58*	<. 0001
ZNH	-8.9*	<. 0001	-8.9*	<. 0001
CHU	-7.17*	<. 0001	-7.14*	<. 0001
GSH	-2.23	0.4732	-3.1	0.1083
HNP	-4.85*	0.0005	-4.61*	0.0013
PTR	-3.01	0.1353	-2.92	0.162
BYH	-6.49*	<.0001	-7.35*	<.0001
CEO	-3.53*	0.0434	-3.44*	0.0537

The companies listed on the China stock markets (SHS, SHZ), HKEX, NYSE.

	CN->HK		HK->CN		CN->US		US->CN		HK->US		US->HK	
	Tau	Pr < Tau	Tau	Pr < Tau	Tau	Pr < Tau	Tau	Pr < Tau	Tau	Pr < Tau	Tau	Pr < Tau
CEA	-0.425	0.0045	-3.64	0.0286	-4.4*	0.0027	-3.68*	0.0259	-8.73*	<. 0001	-8.59*	<. 0001
SNP	-2.72	0.2329	-2.68	0.2501	-3.27	0.0816	-2.54	0.3069	-2.31	0.4232	-1.89	0.6466
JCC	-2.76	0.2153	-4.47*	0.002	-3.04	0.1238	-4.47*	0.002	-8.44*	<. 0001	-8.92*	<. 0001
SHI	-3.14	0.0984	-3.5*	0.0406	-3.21	0.0838	-3.53*	0.0371	-4.9*	0.0004	-5.21*	0.0001
YZC	-2.51	0.3221	-3.31	0.0688	-2.77	0.2123	-3.46*	0.0473	-5.02*	0.0003	-4.67*	0.0011

Statistics summary

Ratio	Cointegration	Noncointegration
CN<->HK	0	100%
CN<->US	20%	80%
HK<->US	78.57%	21.43%

Where *denote Tau value < critical value at different degree of freedom at 5% significance.
Critical t-value at the 5% level is –3,50 at 50 degree of freedom.
Critical t-value at the 5% level is –3,45 at 100 degree of freedom.
Critical t-value at the 5% level is –3,43 at 250 degree of freedom.
Critical t-value at the 5% level is –3,42 at 500 degree of freedom
CN, HK, US denote China, Hong Kong, New York markets respectively; <-> denotes direction.

In Table 6, the regression model

$$Y_t - \beta X_t = u_t \tag{16}$$

is used for such test. If u_t has not unit root at I (0), a cointegration is ascertained. As shown in Table 6, the test statistics indicate that we reject the null hypothesis at 5% significance level, that is, there only exists a statistically significance cointegration on the stocks between HKEX and NYSE and no statistically significance on most stocks between China market and HKEX, or between China market and NYSE. A moment's inspection indicates that the test statistics are smaller between China market and New York market than those between China market and Hong Kong market. However, they most are not statistically significance according to the critical values provided by Gujarati (1995). This implies that there exists no long-term cointegration relation on the stock markets between China and Hong Kong market or between China and New York market.

Despite the similarities in culture and language and close geographical proximity, it seems to exist no stable cointegration between mainland China and Hong Kong. To some degree, it is not difficult to find out one of the reasons is segmented capital markets, because there are strict restrictions on capital movements. The Shanghai and Shenzhen markets, facing severe restrictions on foreign exchange, have the stiffest controls. From this perspective, the capital controls may play a key role in economic integration or segmentation more than any other factors. Therefore, Chinese domestic investors have no other choice than investing in A shares. The same to the foreign investors, they cannot access Chinese A share market through normal channels, but if they exchange their foreign currency to CNY for investing A shares, they have to face huge foreign exchange risk, since CNY is the currency not exchanged freely. The consequence of cointegration test on the stocks shown above does not support the notion of cointegrating relations between China and Hong Kong market, although the interregional trades have intensified.

Although there are some stocks prices that do not reflect long-term cointegration ship existing between HKEX and NYSE, the result of testing still support the existence of long-term cointegration relationship between HKEX and NYSE as individual sample data. This result is consistent with the conclusion found by Huang (2000) that there exists long-term cointegrating relation in the stock markets between Hong Kong market and New York market. It is easy to find out that the investors in Hong Kong, New York can invest both sides relatively freely, and there is no restriction on foreign exchange.

This test result can be used to support another hypothesis as mentioned earlier that HKEX and NYSE are more efficient than the China stock markets as an emerging market according to Maddala (1992) that the both markets or more are efficient if they were cointegrated. It means that stock prices on HKEX and NYSE are able to embody relevant information more efficiently, which will efficiently reflect on the change of stock prices compared with those on China stock market.

7.3 Granger Causality Test

The cointegration between stock prices on HKEX and NYSE implies that their time series are influenced by the extent of any deviation from equilibrium. If the time series is to return equilibrium, the movements of one or both the prices must respond to the magnitude of the disequilibria. Hence, I expect that both prices can cause each other to adjust. But, in the absence of long-term equilibrium (cointegration) relationships for all stocks among China market, Hong Kong market, and New York market based on the cointegration test for the prices of a stock, a study on short-term interactions is in order. The return of the share prices is employed to perform Granger causality test for price discovery using a lag length of three, based on the following bivariate multivariate time series model:

$$\Delta X_t = \alpha + \beta_1 \Delta X_{t-1} + \beta_2 \Delta X_{t-2} + \beta_3 \Delta X_{t-3} + \delta_1 \Delta Y_{t-1} + \delta_2 \Delta Y_{t-2} + \delta_3 \Delta Y_{t-3} + \varepsilon_1 \quad (17)$$

$$\Delta Y_t = \alpha + \delta_1 \Delta Y_{t-1} + \delta_2 \Delta Y_{t-2} + \delta_3 \Delta Y_{t-3} + \beta_1 \Delta X_{t-1} + \beta_2 \Delta X_{t-2} + \beta_3 \Delta X_{t-3} + \varepsilon_2 \quad (18)$$

ΔX_t and ΔY_t denote the returns of share prices of one stock of two different markets, and ε_1, ε_2 are assumed to be serially uncorrelated with zero mean and finite covariance matrix. When the null hypothesis H_0: $\delta_1 = \delta_2 = \delta_3 = 0$ (17) is retained, it suggests that Y_t does not Granger cause X_t. Conversely, if the null hypothesis H_0: $\beta_1 = \beta_2 = \beta_3 = 0$ (18) is not rejected, it implies that X_t does not Granger-cause Y_t.

The main problem with using daily close returns is that it is difficult to determine the lag length: no mater how many lags are added, they are still significant. Another problem may be explained in that daily returns across countries are the non-synchronous trading periods for different markets around the world. Such feature of markets has been the focus of large literature research international returns volatility spillovers. The trading hours of the NYSE take place one calendar day before those of other markets. This is to say that the China market and HKEX lag the NYSE stock prices by one day in performing the Granger causality tests between NYSE and other markets if using daily data. Use of weekly close data can avoid such problem relatively effectively. But there is a potential limitation of this study, which results from the use of weekly data in the empirical analysis. As noted in Granger (1969), observation intervals exceeding one day may introduce spurious statistical significance in the tests for contemporaneous adjustment. Another limitation is the exchange rate, because there was a big volatility for the exchange rate of CNY to USD during the period 1993-1994 due to the behaviour of the Chinese government. However, this problem has an impact only on SHI, which had been listed before the end of 1993 on the three markets.

Table 7 Granger causality test results

	CN->HK	HK->CN	CN->US	US->CN	HK->US	US->HK
ACH					0.8993	1.0131
CHL					0.2857	12.6243*
ZNH					3.0120*	1.991
CHU					0.1764	2.9327*
GSH					1.9692	1.8452
HNP					3.5792*	3.7384*
PTR					3.6076*	0.7377
BYH					3.9219*	3.7917*
CEO					2.0196	1.0372
CEA	1.9194	1.598	2.1363	2.7150*	1.4744	3.4090*
SNP	3.5240*	1.0593	1.5019	0.9754	2.5731	0.7658
JCC	1.4628	0.6235	1.4004	0.1648	1.5625	5.9004*
SHI	0.2746	0.8355	0.1291	0.8629	1.8027	9.8098*
YZC	0.2596	1.1154	0.016	1.7507	1.3824	1.7371
Summary statistics%	20%	0	0	20%	28.57%	50%

Critical F-value at the 5% level is 2,92 at 30 degree of freedom for denominator.
Critical F-value at the 5% level is 2,76 at 60 degree of freedom for denominator.
Critical F-value at the 5% level is 2,60 at ∞ degree of freedom for denominator.
CN, HK, US denotes China market, HKEX, NYSE respectively,
-> denotes the direction of causality.
* denotes that price discovery occurs.

Table 7 indicates that there exists no price discovery happening between the China markets and the Hong Kong Market, except SNP whose price discovery occurs on China market. There is no price discovery between the China market and the New York market either, the only exception is that the share prices of CEA on the China market seems to impact on its own prices on the New York market. To Hong Kong market and New York market, price discovery on NYSE is found to lead that on HKEX in terms of CHL, CHU, HNP, BYH, CEA, JCC, and SHI. Conversely, ZNH, HNP, PTR and BYH have found that their prices on HKEX lead theirs on NYSE. The ACH and CEO have found that no price discovery exists on HKEX and NYSE due to the relatively less observed numbers. From this test, it seems that NYSE has bigger impact on HKEX according to the bigger significance and summary statistics, which supports NYSE as the most important leading financial market more efficient than others, in other words, NYSE contributes more to price discovery.

Table 7 reveals that there exists no price discovery between the China market and the other two markets. In contrast, the New York market is found to lead Hong Kong market, which corresponds with the test of correlation on the return of share prices. The result that the previous week's price movement on the New York market has a positive impact on the following week's price movement on the Hong Kong market is logical, which is consistent with the result from Huang (2000) and Wei etal (1995): NYSE as the most important global stock market has significant impact on other stock markets, which has been ascertained by large literatures. Furthermore, the Hong Kong dollar has been pegged to the U.S. dollar since 1983. As a result, if the U.S. market movement is to reflect the expected change in the interest rate in the U.S., the movement of the U.S. will have an immediate spillover effect to Hong Kong. On the other hand, stock prices in Hong Kong could have an impact on the U.S. market since it serves as the financial centre in Asia. It is little wonder that the globalisation of financial markets has intensified the repercussive effect, with news announcements now simultaneously transmitted across continents, for instance, during the Asian financial crisis starting October of 1997, the plummeting of the Hang Seng Index (1438 points) transmits its impact to the Dow Jones Index (554,26-point fall).

As discussed above, the China market exhibits that there is no relationship with Hong Kong and New York respectively in long run and short-run. In short, it can be concluded that the China market is segmented with the other two markets.

(The detailed estimated coefficients for granger test are shown in Appendix 7)

8 Conclusion

This thesis investigates the price relationships among 14 Chinese companies' shares traded on domestic and foreign exchanges, i.e. the mainland China stock exchanges (either the Shanghai stock exchange, or the Shenzhen stock exchange), Hong Kong stock exchange (HKEK) and New York stock exchange (NYSE).

Firstly, the test on whether the stock prices are stationary or not, is performed by testing the unit roots and autocorrelation. The test results show that generally the stock prices are not stationary. Secondly, the tests are performed on the difference series or the return series. The result indicates that the first differences of the stock prices are all stationary. Thirdly, the cointegration tests are performed. The tests show that there is no long-term conintegration between the prices of the company's shares listed on the China stock markets (SHS, SHZ) and Hong Kong stock exchange (HKEX) and the China markets (SHS, SHZ) and New York stock exchange (NYSE). However, there is a cointegration between the Company's stock prices on HKEX and those on NYSE, which indicates that the efficiency in terms of price discovery existing between the foreign exchanges rather than the domestic and foreign exchange.

Finally, the Granger test is employed to perform on the returns series since it cannot be used on the non-stationary series, the share prices. The empirical analysis reveals that price discovery exists only between HKEX and NYSE, which are consistent with the previous cointegration tests. The reasons could be that HKD is pegged USD. The China Market shows a high segmentation due to its strict capital control and restrictions on foreign exchange. Although, the common culture, language and other characteristics should give rise to an integrated capital market between mainland China and Hong Kong, this relationship seems not existing, neither between the China and U.S. markets.

If the different investor groups have the same information, the international financial markets are integrated and efficient, one price of the company's different classes of shares would be expected. But if the markets are highly segmented, there will be less or no price discovery among them. The test result demonstrates that due to the market segmentation, no price discovery occurs between China market and the other two markets. The Chinese domestic investors cannot arbitrage between the A shares and H shares or the ADRs using the information from overseas. The domestic investors are not able to diversify their portfolio by investing H shares and ADRs due to strict capital control either. Although foreign investors could invest in the A shares, they will definitely expose to the high risks, i.e., foreign exchange risk, politic risk. Since the results in the study shows the China's equity market is not correlated or cointegrated with the foreign markets, investing in the A shares could have the diversification benefit for the foreign investors.

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Appendix

Appendix 1 Basic Statistics of the Stock Prices in the Respective Currencies

	ACH			CHL			ZNH		
	HKEX	HKEX ($)	NYSE	HKEX	HKEX ($)	NYSE	HKEX	HKEX ($)	NYSE
N	31	31	31	242	242	242	214	214	214
Mean	1.4531	0.1853	0.1800	0.1705	0.0018	0.1936	1.8128	0.2327	0.1143
Std Dev	0.2471	0.0317	0.0306	17.3104	0.0754	0.1108	0.6951	0.0890	0.0431
Minimum	1.0100	0.1294	0.1310	8.9000	-0.3259	0.0592	0.5500	0.0709	0.0366
Maximum	1.8700	0.2397	0.2384	75.7800	0.2547	0.4969	3.4000	0.4359	0.2111
Kurtosis	-1.0093	-1.0093	-1.0573	-0.2367	-0.2290	-0.1400	-0.8519	-0.8465	-0.8483

	CHU			GSH			HNP		
	HKEX	HKEX ($)	NYSE	HKEX	HKEX ($)	NYSE	HKEX	HKEX ($)	NYSE
N	109	109	109	314	314	314	230	230	230
Mean	10.7859	1.3898	0.1373	1.6215	0.2083	0.0770	3.4748	0.4457	0.1670
Std Dev	4.0823	0.5210	0.0515	0.9134	0.1179	0.0350	1.4270	0.1827	0.0752
Minimum	5.0000	0.6794	0.0637	0.6800	0.0877	0.0302	1.3400	0.1729	0.0603
Maximum	19.9500	2.5588	0.2519	3.8500	0.4973	0.1569	6.7500	0.8654	0.3425
Kurtosis	-0.5069	-0.5060	-0.4834	-0.1103	-0.1134	-0.5390	-0.7113	-0.7132	-0.6261

	PTR			BYH			CEO		
	HKEX	HKEX ($)	NYSE	HKEX	HKEX ($)	NYSE	HKEX	HKEX ($)	NYSE
N	94	94	94	250	250	250	74	74	74
Mean	1.5168	0.1943	0.1517	1.0943	0.1405	0.0632	8.5206	1.0951	0.2129
Std Dev	0.1386	0.0178	0.0171	0.4790	0.0618	0.0249	1.3891	0.1778	0.0373
Minimum	1.2600	0.1615	0.1195	0.0250	0.0568	0.0250	6.2000	0.7949	0.1535
Maximum	1.8200	0.2333	0.1932	0.4400	0.4519	0.1691	11.1000	1.4231	0.2888
Kurtosis	-0.9627	-0.9625	-0.3943	5.9147	5.9345	4.5578	-1.1438	-1.1438	-1.0793

The price in HKEX column is represented in HKD, the others in USD.

(Continued)

	CEA					SNP				
	China	China ($)	HKEX	HKEX ($)	NYSE	China	China ($)	HKEX	HKEX ($)	NYSE
N	234	234	234	234	234	55	55	55	55	55
Mean	4.8085	0.5795	0.9537	0.1221	0.1186	3.5450	0.1549	1.2085	0.4265	0.1457
Std Dev	0.9070	0.1079	0.2884	0.0364	0.0356	0.3060	0.0138	0.1069	0.0347	0.0127
Minimum	2.9800	0.3599	0.3700	0.0477	0.0479	3.0100	0.1307	1.0200	0.3636	0.1195
Maximum	7.3300	0.7897	1.7500	0.2079	0.2288	4.3600	0.1820	1.4200	0.5158	0.1707
Kurtosis	-0.7644	-0.7646	-0.6554	-0.6373	-0.8694	-0.4800	-0.4806	-0.9290	-0.9294	-1.0186

	JCC					SHI				
	China	China ($)	HKEX	HKEX ($)	NYSE	China	China ($)	HKEX	HKEX ($)	NYSE
N	280	280	280	280	280	436	436	436	436	436
Mean	5.6360	0.6789	0.7458	0.0959	0.0918	3.8673	0.4687	1.6229	0.2091	0.1820
Std Dev	1.4906	0.1778	0.3726	0.0482	0.0447	1.2757	0.1611	0.7097	0.0919	0.0675
Minimum	3.2300	0.3902	0.2800	0.0361	0.0400	1.3400	0.1553	0.4400	0.0567	0.0612
Maximum	13.1500	1.5843	2.7200	0.3512	0.3132	8.1600	0.9831	3.7500	0.4854	0.3788
Kurtosis	5.5825	5.5386	6.5532	6.5290	7.1195	0.0954	0.0342	-0.9077	-0.9123	-0.8694

	YZC				
	China	China ($)	HKEX	HKEX ($)	NYSE
N	155	155	155	155	155
Mean	9.0969	1.1000	2.2556	0.2898	0.9379
Std Dev	1.9573	0.2369	0.7302	0.0937	0.0474
Minimum	5.3600	0.6474	0.8400	0.1084	0.0473
Maximum	12.6600	1.5293	3.5300	0.4546	0.2185
Kurtosis	-1.0800	-1.0802	-1.1529	-1.1515	-1.1679

The prices in China and HKEX columns are represented in CNY and HKD respectively, others in USD.

Appendix 2 Correlation Tests for the Stock Prices

The companies listed on HKEX and NYSE

	ACH	CHL	ZNH	CHU	GSH	HNP	PTR	BYH	CEO
HK&US	0.9966	0.9986	0.9974	0.9979	0.9605	0.9936	0.6843	0.9821	0.9962

The companies listed on the China stock markets, HKEX and NYSE

	CEA	SNP	JCC	SHI	YZC
CN&HK	0.8351	-0.1885	0.2711	-0.0939	0.5835
CN&US	0.8341	-0.1564	0.2374	-0.0404	0.6496
HK&US	0.9939	0.9443	0.9890	0.9884	0.9900

CN, HK and US denote China stock markets, HKEX, NYSE respectively.

Appendix 3 Unit Root Test for the Stock Prices

	CHINA			HKEX			NYSE		
	Tau	Pr < Tau	Stationary I (0)	Tau	Pr < Tau	Stationary I (0)	Tau	Pr < Tau	Stationary I (0)
ACH				-4.18*	0.0137	No	-4.43*	0.0076	No
CHL				-0.9	0.9532	No	-0.95	0.9477	No
ZNH				-3.58*	0.0336	No	-3.43	0.0504	No
CHU				-2.49	0.3321	No	-2.73	0.2252	No
GSH				-1.16	0.9153	No	-1.11	0.9241	No
HNP				-2.71	0.2355	No	-2.75	0.216	No
PTR				-2.55	0.3051	No	-2.74	0.2215	No
BYH				-2.33	0.4138	No	-2.62	0.2708	No
CEO				-1.74	0.7217	No	-1.83	0.6792	No
CEA	-2.99	0.1373	No	-3.76*	0.0202	Yes	-4.05*	0.0085	Yes
SNP	-2.29	0.4327	No	-2.3	0.4258	No	-3	0.1408	No
JCC	-4.33*	0.0032	Yes	-2.42	0.3701	No	-2.73	0.2245	No
SHI	-3.55*	0.0353	Yes	-3.17	0.0916	No	-3.24	0.0787	No
YZC	-3.62*	0.031	Yes	-2.19	0.4894	No	-2.2	0.4852	No

Where *denote Tau value < critical value at different degree of freedom at 5% significance.

Critical t-value at the 5% level is –3,50 at 50 degree of freedom.

Critical t-value at the 5% level is –3,45 at 100 degree of freedom.

Critical t-value at the 5% level is –3,43 at 250 degree of freedom.

Critical t-value at the 5% level is –3,42 at 500 degree of freedom

If the critical value based on 1% significance level, all stock prices are nonstationary.

Critical t-value at the 1% level is –4.15 at 50 degree of freedom.

Critical t-value at the 1% level is –4.04 at 100 degree of freedom.

Critical t-value at the 1% level is –3.99 at 250 degree of freedom.

Critical t-value at the 1% level is –3.98 at 500 degree of freedom.

Appendix 4 Autocorrelation Check for the Stock Prices

	CHINA			HKEX			NYSE		
	Chi-sq	Pr >chi-sq	Autocorrelation	Chi-sq	Pr >chi-sq	Autocorrelation	Chi-sq	Pr >chi-sq	Autocorrelation
ACH				96.63	<0.0001	Yes	96.88	<0.0001	Yes
CHL				1334.31	<0.0001	Yes	1326.77	<0.0001	Yes
ZNH				1061.60	<0.0001	Yes	1066.47	<0.0001	Yes
CHU				505.05	<0.0001	Yes	503.07	<0.0001	Yes
GSH				1771.06	<0.0001	Yes	1763.68	<0.0001	Yes
HNP				1205.21	<0.0001	Yes	1236.04	<0.0001	Yes
PTR				268.76	<0.0001	Yes	230.57	<0.0001	Yes
BYH				1021.24	<0.0001	Yes	1016.55	<0.0001	Yes
CEO				321.32	<0.0001	Yes	324.31	<0.0001	Yes
CEA	1047.66	<0.0001	Yes	941.04	<0.0001	Yes	959.32	<0.0001	Yes
SNP	131.08	<0.0001	Yes	140.01	<0.0001	Yes	165.51	<0.0001	Yes
JCC	975.17	<0.0001	Yes	1197.00	<0.0001	Yes	1198.65	<0.0001	Yes
SHI	2089.61	<0.0001	Yes	2294.77	<0.0001	Yes	2200.78	<0.0001	Yes
YZC	626.08	<0.0001	Yes	674.38	<0.0001	Yes	713.33	<0.0001	Yes

At 1% level and 5% significance level, there exists autocorrelation in all the companies.

Appendix 5 Unit Root Test for the First Difference for the Stock Prices

	CHINA			HKEX			NYSE		
	Tau	Pr < Tau	Stationary I (1)	Tau	Pr < Tau	Stationary I (1)	Tau	Pr < Tau	Stationary I (1)
ΔACH				-5.18	0.0013	Yes	-5.56	0.0005	Yes
ΔCHL				-11.47	<0.0001	Yes	-11.66	<0.0001	Yes
ΔZNH				-11.18	<0.0001	Yes	-11.10	<0.0001	Yes
ΔCHU				-7.89	<0.0001	Yes	-8.77	<0.0001	Yes
ΔGSH				-12.83	<0.0001	Yes	-12.74	<0.0001	Yes
ΔHNP				-10.11	<0.0001	Yes	-9.92	<0.0001	Yes
ΔPTR				-8.56	<0.0001	Yes	-7.63	<0.0001	Yes
ΔBYH				-10.35	<0.0001	Yes	-9.89	<0.0001	Yes
ΔCEO				-8.38	<0.0001	Yes	-8.91	<0.0001	Yes
ΔCEA	-9.71	<0.0001	Yes	-11.46	<0.0001	Yes	-10.93	<0.0001	Yes
ΔSNP	-4.86	<0.0001	Yes	-5.87	<0.0001	Yes	-5.80	<0.0001	Yes
ΔJCC	-13.17	<0.0001	Yes	-11.10	<0.0001	Yes	-10.77	<0.0001	Yes
ΔSHI	-13.68	<0.0001	Yes	14.39	<0.0001	Yes	-14.03	<0.0001	Yes
ΔYZC	-14.39	<0.0001	Yes	-8.61	<0.0001	Yes	-7.85	<0.0001	Yes

At 5% significance level,

CN, HK, US denotes China stock markets, HKEX, NYSE.

Regression model $\Delta Y=\alpha+\beta\Delta X+\varepsilon$ is used to perform the unit root test for ε.

-> denotes direction.

Appendix 6 Unit Root Test for The Return of the Stock Prices

	CHINA			HKEX			NYSE		
	Tau	Pr < Tau	Stationary I (1)	Tau	Pr < Tau	Stationary I (1)	Tau	Pr < Tau	Stationary I (1)
ΔACH				-5.18	0.0013	Yes	-5.56	0.0005	Yes
ΔCHL				-11.47	<0.0001	Yes	-11.66	<0.0001	Yes
ΔZNH				-11.18	<0.0001	Yes	-11.10	<0.0001	Yes
ΔCHU				-7.89	<0.0001	Yes	-8.77	<0.0001	Yes
ΔGSH				-12.83	<0.0001	Yes	-12.74	<0.0001	Yes
ΔHNP				-10.11	<0.0001	Yes	-9.92	<0.0001	Yes
ΔPTR				-8.56	<0.0001	Yes	-7.63	<0.0001	Yes
ΔBYH				-10.35	<0.0001	Yes	-9.89	<0.0001	Yes
ΔCEO				-8.38	<0.0001	Yes	-8.91	<0.0001	Yes
ΔCEA	-9.71	<0.0001	Yes	-11.46	<0.0001	Yes	-10.93	<0.0001	Yes
ΔSNP	-4.86	<0.0001	Yes	-5.87	<0.0001	Yes	-5.80	<0.0001	Yes
ΔJCC	-13.17	<0.0001	Yes	-11.10	<0.0001	Yes	-10.77	<0.0001	Yes
ΔSHI	-13.68	<0.0001	Yes	14.39	<0.0001	Yes	-14.03	<0.0001	Yes
ΔYZC	-14.39	<0.0001	Yes	-8.61	<0.0001	Yes	-7.85	<0.0001	Yes

At 5% significance level,

CN, HK, US denote China stock markets, HKEX, NYSE respectively.

Regression model $\Delta Y=\alpha+\beta\Delta X+\varepsilon$ is used to perform the unit root test for ε.

-> denotes direction of causality.

Appendix 7 Estimated Coefficients for Granger Causality Test

The companies listed on HKEX and NYSE

ACH	H	U->H	U	H->U	CHL	H	U->H	U	H->U
Coefficient	Restricted	Unrestricted	Restricted	Unrestricted	Coefficient	Restricted	Unrestricted	Restricted	Unrestricted
α	-0.0295	-0.0286	-0.0268	-0.0255	α	0.0013	0.0008	0.001	0.001
β1	-0.2526	-0.3551	-0.2265	-0.312	β1	-0.0831	-0.9332	-0.0249	0.0884
β2	-0.2472	0.6807	-0.2894	-1.327	β2	0.0137	-0.6339	-0.027	0.1276
β3	-0.0906	-0.399	-0.0069	0.0344	β3	0.1327	-0.2928	0.1965	0.2485
δ1		0.1732		0.1124	δ1		0.914		-0.1266
δ2		-0.9773		1.0653	δ2		0.6429		-0.1594
δ3		0.324		-0.0589	δ3		0.5012		-0.0376
SSE	0.00283	0.0025	0.00277	0.00241	SSE	1.3198	1.1366	1.219	1.2146
N		31		31	N		242		242
F-statistic		1.056		1.195	F-statistic		12.6243*		0.2857

ZNH	H	U->H	U	H->U	CHU	H	U->H	U	H->U
Coefficient	Restricted	Unrestricted	Restricted	Unrestricted	Coefficient	Restricted	Unrestricted	Restricted	Unrestricted
α	0.0021	0.0019	0.0018	0.0021	α	-0.0138	-0.013	-0.0143	-0.0143
β1	-0.042	-0.3562	-0.0393	-0.448	β1	-0.0892	-0.859	-0.0613	0.1143
β2	-0.0677	-0.1633	-0.0527	-0.44	β2	-0.0506	-0.4916	-0.1599	-0.0586
β3	0.1381	0.1427	0.09	-0.2417	β3	0.0818	-0.1725	0.1123	0.1138
δ1		0.3714		0.4297	δ1		0.7734		-0.1993
δ2		0.0909		0.3662	δ2		0.4371		-0.0985
δ3		-0.0152		0.3474	δ3		0.3472		0.027
SSE	2.129	2.0693	1.9966	1.9131	SSE	0.5264	0.4846	0.5619	0.559
N		214		214	N		109		109
F-statistic		1.9131		3.0120*	F-statistic		2.9327*		0.1764

GSH	H	U->H	U	H->U	HNP	H	U->H	U	H->U
Coefficient	Restricted	Unrestricted	Restricted	Unrestricted	Coefficient	Restricted	Unrestricted	Restricted	Unrestricted
α	-0.0027	-0.003	-0.0011	0.0002	α	0.001	0.0004	0.0017	0.0021
β1	-0.0671	-0.2765	0.0535	-0.3359	β1	0.0221	-0.374	-0.0038	-0.2774
β2	0.0051	-0.0011	0.0064	-0.3382	β2	0.0445	-0.234	0.0974	-0.1009
β3	0.011	0.0157	-0.02	-0.2758	β3	0.1202	-0.0269	0.0229	-0.1142
δ1		0.2587		0.2883	δ1		0.434		0.329
δ2		-0.0085		0.3516	δ2		0.4804		0.179
δ3		-0.0161		0.274	δ3		0.1416		0.1607
SSE	1.6288	1.6	1.4817	1.427	SSE	1.3294	1.2658	1.4247	1.388
N		314		314	N		230		230
F-statistic		1.8452		3.9219*	F-statistic		3.7384*		1.9692

(Continued)

PTR Coefficient	H Restricted	U->H Unrestricted	U Restricted	H->U Unrestricted	BYH Coefficient	H Restricted	U->H Unrestricted	U Restricted	H->U Unrestricted
α	-0.0003	0	-0.0027	-0.0029	α	-0.003	-0.0034	-0.0021	-0.002
1β	-0.1464	-0.2475	0.0323	0.0296	1β	0.0033	-0.3535	0.0402	-0.3016
2β	0.1258	-0.0973	-0.0868	-0.0642	2β	0.0679	-0.3001	0.0917	0.0156
3β	0.2291	0.23	0.0591	-0.1074	3β	-0.0315	-0.361	-0.0362	0.1107
1δ		0.1601		-0.0674	1δ		0.4329		0.3614
2δ		-0.0489		-0.0445	2δ		0.3707		0.0787
3δ		0.016		0.3967	3δ		0.3602		-0.1472
SSE	0.1721	0.1679	0.2323	0.2068	SSE	3.2651	3.1191	2.7688	2.6508
N		94		94	N		250		250
F-statistic		0.7377		3.5792*	F-statistic		3.7917*		3.6076*

CEO Coefficient	H Restricted	U->H Unrestricted	U Restricted	H->U Unrestricted
α	0.0099	0.0101	0.0121	0.0123
1β	-0.3563	-0.0452	-0.4131	-1.1623
2β	-0.1351	0.4044	-0.2228	-1.1107
3β	0.1113	0.0226	0.0715	-0.1305
1δ		-0.306		0.7965
2δ		-0.5315		0.9609
3δ		0.0913		0.1872
SSE	0.119	0.1137	0.1305	0.1196
N		74		74
F-statistic		1.0372		2.0196

The companies listed on the China stock markets, HKEX, NYSE.

CEA Coefficient	C Restricted	H->C Unrestricted	U->C Unrestricted	H Restricted	C->H Unrestricted	U->H Unrestricted	U Restricted	C->U Unrestricted	H->U Unrestricted
α	0.0000	0.0001	0.0001	-0.0018	-0.0018	-0.0016	-0.0017	-0.0017	-0.0017
β1	-0.0119	-0.0383	-0.0045	-0.0226	-0.0631	-0.5062	0.0147	-0.0271	-0.2652
β2	0.0884	0.0917	0.0837	-0.0559	-0.1162	-0.3487	-0.0309	-0.0866	-0.1684
β3	0.1058	0.0744	0.0769	0.0131	-0.0244	-0.1138	-0.0261	-0.0716	-0.1441
δ1		0.0552	0.0859		0.1563	0.5674		0.1573	0.2944
δ2		-0.0251	-0.0317		0.3025	0.2866		0.2674	0.1186
δ3		0.0372	0.0335		0.1231	0.1299		0.1646	0.1341
SSE	0.4744	0.4645	0.4579	2.1720	2.1182	2.0783	1.8768	1.8252	1.8409
N		234	234		234	234		234	234
F-statistic		1.5980	2.7150*		1.9194	3.4090*		2.1363	1.4744

(Continued)

SNP	C	H->C	U->C	H	C->H	U->H	U	C->U	H->U
Coefficient	Restricted	Unrestricted	Unrestricted	Restricted	Unrestricted	Unrestricted	Restricted	Unrestricted	Unrestricted
α	-0.0025	-0.0028	-0.0030	0.0002	-0.0006	0.0008	0.0017	0.0015	0.0040
β1	0.0764	0.0700	0.0861	-0.0527	-0.0962	-0.0752	-0.0536	-0.0836	-0.5290
β2	-0.0051	-0.0578	-0.0212	-0.1005	-0.0329	0.2496	-0.1063	-0.0620	-0.7844
β3	-0.0803	-0.1124	-0.1332	0.1923	0.2866	0.3547	0.0805	0.1206	-0.4956
δ1		0.1010	0.0242		0.3184	0.0547		0.2973	0.4448
δ2		0.0013	0.0049		-0.1654	-0.4242		-0.1939	0.6848
δ3		0.1739	0.1947		-0.4301	-0.1863		-0.1168	0.6052
SSE	0.0583	0.0547	0.0550	0.0955	0.0782	0.0911	0.0876	0.0801	0.0755
N		55	55		55	55		55	55
F-statistic		1.0593	0.9754		3.5240*	0.7658		1.5019	2.5731

JCC	C	H->C	U->C	H	C->H	U->H	U	C->U	H->U
Coefficient	Restricted	Unrestricted	Unrestricted	Restricted	Unrestricted	Unrestricted	Restricted	Unrestricted	Unrestricted
α	-0.0021	-0.0088	-0.0021	-0.0022	-0.0017	-0.0024	-0.0016	-0.0012	-0.0014
β1	-0.0037	0.0096	0.0009	-0.0705	0.0813	-0.5542	0.0175	0.0131	-0.1550
β2	-0.0687	-0.0699	-0.0733	0.0863	0.0833	-0.1267	0.0733	0.0689	-0.2072
β3	0.0953	0.0997	0.0982	0.0352	0.0208	-0.1177	-0.0191	0.0337	-0.0503
δ1		-0.0421	-0.0154		0.1171	0.5922		0.0188	0.1805
δ2		0.0091	0.0195		0.0331	0.1800		0.0630	0.2903
δ3		-0.0136	-0.0087		0.1895	0.1435		0.1835	0.0254
SSE	1.2887	1.2799	1.2864	4.0050	3.9416	3.7611	3.4074	3.3557	3.3499
N		280	280		280	280		280	280
F-statistic		0.6235	0.1648		1.4628	5.9004*		1.4004	1.5625

SHI	C	H->C	U->C	H	C->H	U->H	U	C->U	H->U
Coefficient	Restricted	Unrestricted	Unrestricted	Restricted	Unrestricted	Unrestricted	Restricted	Unrestricted	Unrestricted
α	-0.0014	-0.0013	-0.0013	-0.0023	-0.0023	-0.0027	-0.0018	-0.0018	-0.0017
β1	0.1457	0.1361	0.1348	-0.0569	-0.0632	-0.6656	0.0217	0.0174	-0.1867
β2	-0.0085	-0.0172	-0.0164	0.0663	0.0638	-0.4060	0.0691	0.0664	-0.1636
β3	0.0255	0.0260	0.0237	0.0071	0.0066	-0.2593	-0.0062	-0.0081	-0.0373
δ1		0.0401	0.0499		0.0555	0.7410		0.0334	0.2025
δ2		0.0439	0.0457		-0.0024	0.4992		0.0050	0.2258
δ3		-0.0104	0.0001		-0.0163	0.2658		0.0003	0.0238
SSE	1.9574	1.9460	1.9456	3.3652	3.3587	3.1491	2.5728	2.5705	2.5407
N		437	437		437	437		437	437
F-statistic		0.8355	0.8629		0.2746	9.8098*		0.1291	1.8027

YZC	C	H->C	U->C	H	C->H	U->H	U	C->U	H->U
Coefficient	Restricted	Unrestricted	Unrestricted	Restricted	Unrestricted	Unrestricted	Restricted	Unrestricted	Unrestricted
α	0.0050	0.0049	0.0049	0.0040	0.0042	0.0035	0.0045	0.0045	0.0049
β1	-0.6322	-0.6239	-0.6224	-0.0549	-0.0556	-0.4371	0.0489	0.0509	-0.1734
β2	-0.3636	-0.3495	-0.3480	0.1083	0.1183	-0.0350	0.0721	0.0706	-0.3003
β3	-0.1008	-0.1147	-0.1160	0.1219	0.1180	-0.0303	0.1346	0.1336	-0.1586
δ1		-0.0465	0.0975		0.0157	0.4691		-0.0123	0.2116
δ2		0.0070	0.0260		-0.0578	0.0986		-0.0029	0.3804
δ3		0.1379	0.1766		-0.0272	0.1499		0.0061	0.3051
SSE	1.5219	1.4882	1.4697	1.5093	1.5014	1.4580	1.2326	1.2322	1.1990
N		155	155		155	155		155	155
F-statistic		1.1154	1.7507		0.2596	1.7371		0.0160	1.3824

Critical F-value at the 5% level is 2,92 at 30 degree of freedom for denominator.

Critical F-value at the 5% level is 2,76 at 60 degree of freedom for denominator.

Critical F-value at the 5% level is 2,60 at ∞ degree of freedom for denominator.

C, H, U denote China market, HKEX, NYSE respectively.

->Denotes that price discovery occur direction.