Journal of Research in Economics and International Finance (JREIF) (ISSN: 2315-5671) Vol. 1(4) pp. 103-123, October 2012
Available online http://www.interesjournals.org/JREIF

Full Length Research Paper

The relationship of high frequency interactions between Chinese A-shares and Hong Kong H-shares of dual-listed companies

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Abstract

Previous studies showed that Chinese equity markets interact with those other equity markets in Asia and the larger equity markets of developed Western Nations. Established in 1992, the Chinese equity markets grew to become the second largest equity markets after the United States. The Chinese equity changed in an evolutionary manner with the decrease in State owned shares and from CEPA to QDII. However, equity markets still display somewhat immature characteristics. Hence, our purpose is to determine the co integration of Chinese A-shares with that of Hong Kong H-shares, and on how it relates to the functions of finance, including investment strategy and/or arbitrage. Implementing Granger Causality (GE) and the Vector Error Correction Model (VECM), this manuscript pragmatically studies on 44 cross-listed firms. The data examined is high frequency and, in turn, we utilize arbitrage to confirm the co-movement of cross-listed companies under the application of VECM. The results indicate an expected degree of correlation between the two equity markets in the short-term. For the long-term, we find co integration for the firms sampled in the two equity markets. This last result suggests slow movement in the adjustments by the equity markets to each other. We apply time series analysis including unit root and co-integreation tests and vector auto regressions to study the statistical properties of the data series considered.

Keywords: A-shares, H-shares, unit root, co integration, vector error correction model (VECM), Arbitrage.

INTRODUCTION

The Chinese equity markets are no longer among the mysteries of finance and investments due to a large amount of literature in the past several decades. Jarrett, Pan and Chen (2009), studied the relationship of the Chinese equity markets (Shanghai and Shenzhen) to that if the Macroeconomy of China. Thomas (2001) discussed in great detail characteristics of the Shanghai market over its illustrious and ever-changing history offering insights into the characteristics of the market. Others (Eun and Huang, 2007; Ng and Wu, 2007; Shenoy and Ying, 2007; Weilli et al., 2009, Wang et al., 2004; and Wang et al., 2007) investigated the growth in the Chinese equity markets became increasingly important for global investors. Bailey et al., (2006) studied the Shanghai equity market and discovered characteristics concerning order balances of individuals and institutional investors. Jarrett and Kyper (2011) examined anomalies in the Chinese markets that were seen earlier in the m ore developed markets of the Western nations. Finally, Chen and Jarrett (2011) examined the market efficiency of Chinese markets during different periods of decline and growth in the Chinese economy.

The rapid changes in the Chinese economy, equity markets and its integration in the neighboring markets in Asia and the influences of the established western equity markets created the great interest and speculation with regard to Chinese equities. Hence, many Chinese firms

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wish to list in the Hong Kong market as well as the growing Shanghai market. This strategy confirmed their competitive status and enabled investors to purchase equity shares of Chinese firms not heretofore possible in non-Chinese markets. Hence, the equity shares became universally available in a manner similar to the characteristics of the western equity markets. Accordingly, Cross listings (relying heavily on information from the depositary banks to create depository receipt programs) achieved great importance in the international financial markets, and studies correlation with them are going to be a major theme in financial field [See Karolyi (1998)). Studies by Lee (1991), Torabzadeh, Bertin and Zivney (1992), Damodoran, Liu and Van Harlow (1993), Varela and Lee (1993b), and Lau, Diltz and Apilado (1994) which all found the evidence that *share price reactions* to *cross-listing decisions*. Fanto and Karmel (1997) surveyed managers of a number of firms that listed as an American Depositary Receipt(ADR), in the United States and reported that managers cited increased access to new capital as one of the most important motivations for pursuing overseas listings. Karolyi (1998) provides an exhaustive review of the theories and empirical tests of international cross-listing. Foerster and Karolyi (1999) and Miller (1999) found changes in the informational environment of cross-listed firms that influence listing decisions

The Shanghai Stock market, with only about 20 years history, appears somewhat fledgling and irregular with respect to the New York Stock Market. According to China's security statutes, the Chinese corporations may list only in three ways:

(1) Domestically, listed domestic capital stocks, or A shares, which priced and are settled in Chinese currency.

(2) In January, 2002, the Qualified Foreign Institutional Investors (QFII) opened up equity markets in China by supplying access to invest in the "A" share market for foreign institutional investors. In turn, these shares were domestically listed as foreign-investment shares, or "B" shares, which priced in Chinese currency but traded in foreign currency.

(3) Overseas listed foreign equity markets including "H" shares (listed in Hong Kong), "N" shares New York and S shares in Singapore. For example, H shares are priced the par-value (Chinese currency) and transacted in Hong Kong dollars.

Chinese equity markets experienced a rapid increase in volume upon implementing the new strategy. By the end of 2009, the total market capitalization of A shares increased to 24.27 trillion RMB (Chinese currency) (or 3.57 trillion U.S. Dollars) which represented a doubling in size and exceeded the size of the Japanese equity market which had been the second largest equity market for many years.

Following the implementation of the above strategy, cross-listed firms made changes to their capital structure. These changes were related to the opening of global equity markets to otherwise only locally listed firms. A question arises as to the effects of being listed twice on two different markets. In particular, the markets in Shanghai and Hong Kong, although relatively close in global geography, may have differing effects (specifically prices) on the firms that cross-listed. We focus on the differing prices of shares in both of these markets. That is, do these share prices react to each other or are the prices of cross-listed firms on two Asian exchanges entirely independent of each other. With the economic relationship between Hong Kong (HK) and China (MC) increasingly close, more and more mainland enterprises chose the Hong Kong stock market to advance their initial offerings as a first step in the capitalization process. For example, since HK has international status and normative market mechanisms, on July 15, 1993, the first domestic company, TSINGTAO BREW, listed on the Stock Exchange of Hong Kong (SEHK). By March, 2009, sixty-six Chinese incorporated enterprises listed on the SHE by the issuance of H-shares. Recently, many H-shares listed firms, (56 by March, 2009) refinanced on the Shanghai or Shenzhen stock exchanges in China through the issuance of A-shares. This trend not only appears in the capital demand of firms, but also represents the increasing attractiveness of the A-shares market as shown in Table 1 below.

Fong found a combination of micro and macro factors that accounted for the difference in prices of cross-listed securities in these two markets (Fong et al., , 2007). In turn, the co-movement between both markets was considered important factors by large investment institutions, especially offshore hedge funds in evaluating the performance of cross-listed firms. These evaluations were made by both qualified Foreign Institutional Investors (QFII) and qualified domestic institutional investors (QDII). Sun et al., (2000) indicated that restrictions by similar macroeconomic factors, an inevitable connection exists among the H-shares, the Chinese firms listed in Hong Kong, but based and controlled in MC. Thus, the movements in A-shares and H-shares should be related to each other. Poon et al., (2000) provides evidence that there is a stable inherent relationship among the H-shares, i.e., the "red-chip" markets in Hong Kong, and the A-shares market. Chong and Qian (2006) found that only a small portion of the cross-listed Chinese companies have a co-movement in their A- and H-share prices and that the stock markets of MC and HK are segmented. On the other hand, Han and Dezong (2006) believe that QDII will be one of the important institutions which would remove the segmentation of the A and H shares markets. By implementing a co-integration analysis and test, Chong et al., (2007) speculated that the current Closer Economic Partnership Arrangement (CEPA) between MC and HK resulted in the prices of a substantial number of A

Table 1. increase in Firms using A-shares and H-shares over a twenty-six year period.

	1993-1996	1997-2000	2001-2004	2005-2009
A listed	13	7	12	24
H listed	18	15	7	16
Cross listed	13	5	11	27

shares and H shares to begin to co integrate. Also, they pointed out that the stock market co-movements between dual-listed firms contributed to the increased financial openness of these firms. Zeng and Luo (2009) indicated that the correlation between the A-shares and the H-shares markets is dynamic but not asymmetric. Further, Zhou and Wei (2009) found that movements in Shanghai stock market in part explain movements in the Hong Kong market. Xu (2010) indicated that the share reform in MC caused the increase the interactivity of A and H-shares. By exploring 30 cross-listed firms, Ma et al., (2010) found the prices of these same firms became increasingly co-integrated resulting in an improvement in MC equity market.

From its establishment in 1992, China's equity markets became the second largest of the global equity markets in the world. In part, this is related to the decrease in State-owned shares and from a CEPA to QDII type equity market. Next, we wish to identify and account for the cointegreation of the Shanghai and Hong Kong Equity markets and do this co integration result in greater openness and the evolution of the MC to a fully developed market. Our task is to determine the extent of co integration and would it result on greater internationalization of its a-shares. Using the Granger Causality Test and Vector Error Correction Model, the remainder of this manuscript focuses on a study on 44 cross-listed firms containing adequate data. The data is high frequency. Finally, the data is subjected to an arbitrage test to confirm the co-movement of cross-listed firms under the practical application of the VECM.

Co integration analysis and tests and equity markets

Granger (1981) advanced ***co integration analysis*** for its use studying relationships between different sets of data. Specifically, when studying equity markets, one wants to determine the correlation among equity market data and strategies to diversify one's portfolio to avoid risks associated with investing in capital assets. Grangers methods permit one to determine if one can find what is now called the "Granger cause' on one action with respect to a second action. The analyst employs Granger methods to ascertain whether long-term equilibrium relationship and short-term interaction exists in equity markets of different nations.

This method was used previously by Meric (2001) who applied the relevant examination and factor analysis method to study Argentina, Brazil, Chile and Mexico, i.e., the four biggest Latin American equity markets. He observed that among the four equity markets, there relation rose ceaselessly. Also, investors should pay more attention on individual share prices rather than an index number for price change.

In addition, Pascual (2003) utilized tests for unit root to indicate that the equity markets of Britain, France and Germany do not demonstrate that they have increasing co integration. Darne (2004) expanded the use of the *maximum likelihood co integration method.* He studied both *seasonally adjusted* and *unadjusted time series*, as well as time series with other periodic adjustments. After inspection, the seasonally adjusted time series indicated that strong co integration exists between American manufacturing industry data and that of its stock price.

Utilizing *the time sequence relevant method* for equity market time series data for the United States, Great Britain, Germany and Japan, Morana and Beltrattib (2008) observed that stock prices, the rate of return and the coefficient of fluctuation, have convergent positive correlations, and that the linkage strengthens ceaselessly.

Through the massive theories and the empirical study, the domestic and foreign scholars have proven that under segment market conditions the cross-listing stock appear with price differentials in each equity market. The overseas investor will observe a high price than that of the domestic investor. On the other hand, Bailey (1994), Sun and Tong (2000), Wang and Jiang (2004) and Mei, Scheinkman and Xiong (2005)'s studies indicated that this phenomenon was not true. They indicated that A- share prices possessed a long-term premium in comparison to H-shares. This phenomenon is called, by Bailey, Chung and Kang (1999) and Fernald and Rogers (2002), "the discount puzzle in H- share market." We need to resolve this issue by the methods Granger and verify its results.

Use the Granger causality analysis, Aaltonen and

Östermark (1997) studied the early 1990s Japan equity market's impact on the Finish equity market and found Granger causality. This was an early introduction of Granger causality test into equity market. Pan, Jarrett and Chen (2009) also utilized Granger causality in studying Chinese equity market and macroeconomic. Hence the use of Granger causality is well established in financial time series research and analysis.

Further, Bonfiglioli (2005), studied financial market time series from the United States and Germany. They produced a VECM from their results which indicated that both financial markets do not possess a long-term mutually interdependent relation. Instead they possess short-term interdependence relations, namely the short-term fluctuation of the US stock price overflows to the Germany stock price.

By applying component analysis and Grange causality, Meric (2008) analyzed the co integration relationship under both ***bull*** and ***bear*** market condition among four developed stock exchanges, i.e., Great Britain, Germany, France and Japan. He found a strong cointegreation in bull markets but a more limited result for bear markets. Another example of this analysis can be found by Vazquez (2008).

THE METHODOLOGY

The phenomenon that a foreign capital stock discount appears in China Stock market data was first researched by Bailey (1994) when he aimed at A- and B- shares. He verified, using Granger causality, the interaction between the two time series. Also, using regression analysis, Bailey explained the factors that influenced the spread in the prices in the two financial markets. Lee (1991) proposed investor sentiment expresses the reasons for the price spread based from a behavioral viewpoint.

Wang Qunyong and Wu Na (2004)'s studies indicated that both A- and H-share prices are a first-order difference variable. The panel cointegreation test indicated that A and H prices are co integrated and maintain the equilibrium during the long-term although other factors exist. Based on the monthly data from June, 2001, to May, 2003, Wang Weian and Bai Na (2004) established other factors for difference in the prices of the A- and H-shares.

Using the multivariable cointegration test, Pan and Wu (2005) empirically studied the relationship among the H-shares, the "red-chip" markets in Hong Kong and A-shares market. They determined that a long-term stability cointegration relation existed in these markets and this balanced relation is strengthened after B-shares open for trading. Wu also used VECM Granger causality. Others utilized the Granger and con integration methods to analyze the relation between A- and H- shares and they include Yang et al., (2006), Chen and Xie (2007), and Liu (2007).

In each case they studied the interaction of data on A- and H-shares and looked at interaction occurring in high frequency. High frequency interaction is the focus of this study because it is with these transactions that we can see the immediate effects on changes in one market as it affects the other without environmental and other factors influencing chare prices. Accordingly, we select 5 minute and 1 minute intervals and will utilize previously used methods to determine the extent and causes of the co integration if it exists.

Time series data and selection

In this paper, all the frequency data, 5 minute (from 2007 to 2009) and 1 minute (from November 2008 to March 2009), come from WSTOCK.NET. The list of cross-listed firms comes from Sina. Finance (http://finance.sina.com.cn/) and Hong Kong Stock Exchange (HKSE:http://www.hkex.com.hk/). Although Hong Kong and China dominate equity transactions in their common time zone, there exist differences between HKSE and the Chinese exchange including the trading days (differing public holidays) and the trading hours. The daily transaction periods in HKSE are from 10:00 to 12:30 and from 14:30 to 15:55; correspondingly, Chinese exchanges operate differently; from 9:30 to 11:30 and from 13:00 to 15:00, each trading day. Table 2.

Stoll and Whaley's (1990) research indicated that the interval from the opening bell to the first transaction is about 5 to 7 minutes for the New York Stock Exchange. This, in turn, eliminated a pair of early transacting in the largest American equity exchanges noted in Darrat et al., (2003). With this knowledge, we take into account the actual conditions both in the China and Hong Kong exchanges. Therefore, we eliminated the first five minutes and paired the Chinese and Hong Kong trading hours, i.e., the hours are now from 10:05 to 11:30 (86 figures) and from 14:35 to 15:00 (26 figures).

Also, the A- shares (and H-shares) price of the last transaction during each minute became the strike price for that minute. For minutes without transactions, we adopted the conventional Fixed Time Intervals method to provide a reasonable estimate the strike price. Fixed Time Intervals method assumed that transaction price changes occur over time in a linear fashion. Based on this assumption, when a one minute, for example T_2 (shown in 1), during which A-shares (H-shares) trading did not occur, the strike price mean cannot be estimated, this text applied the linear interpolation value of price at

Table 2. There are 56 companies both listed in China A stock exchange and Hong Kong H stock exchange.The name, code in A and H market, and listed times are obtained in this table.

Name	A share code	H share code	A listed time	H listed time
ZTE	CH000063	HK763	1997/11/18	2004/12/9
WEICHAI POWER	CH000338	HK2338	2004/3/21	2007/4/30
CHENMING PAPER	CH000488	HK1812	2000/11/20	2008/6/18
NE ELECTRIC	CH000585	HK42	1995/12/13	1995/7/6
JINGWEI TEXTILE	CH000666	HK350	1996/12/10	1996/2/2
SHANDONG XINHUA	CH000756	HK719	1997/8/6	1996/12/31
ANGANG NEWSTEEL	CH000898	HK347	1997/12/25	1997/7/24
GUANGDONG KELON	CH000921	HK921	1999/7/13	1996/7/23
HUANENG POWER	CH600011	HK902	2001/12/6	1998/1/21
ANHUIEXPRESSWAY	CH600012	HK995	2003/1/7	1996/11/13
CHINA SHIP DEV	CH600026	HK1138	2002/5/23	1994/11/11
HUADIAN POWER	CH600027	HK1071	2005/2/3	1999/6/30
SINOPEC CORP	CH600028	HK386	2001/8/8	2000/10/19
CHINA SOUTH AIR	CH600029	HK1055	2003/7/25	1997/7/31
CHINA MERCHANTS BANK	CH600036	HK3968	2002/4/9	2006/9/23
CHINA EAST AIR	CH600115	HK670	1997/11/5	1997/2/5
YANZHOU COAL	CH600188	HK1171	1998/7/1	1998/4/1
GUANGZHOU PHAR	CH600332	HK874	2001/2/6	1997/10/30
JIANGXI COPPER	CH600362	HK358	2002/1/11	1997/6/12
JIANGSU EXPRESS	CH600377	HK177	2001/1/16	1997/6/27
SHENZHEN EXPRESS	CH600548	HK548	2001/12/25	1997/3/12
ANHUI CONCH	CH600585	HK914	2002/2/7	1997/10/21
TSINGTAO BREW	CH600600	HK168	1993/8/27	1993/7/15
GUANGZHOU SHIP	CH600685	HK317	1993/10/28	1993/8/6
SHANGHAI PECHEM	CH600688	HK338	1993/11/8	1993/7/26
NANJING PANDA	CH600775	HK553	1996/11/18	1996/5/2
JIAODA HIGHTECH	CH600806	HK0300	1994/1/3	1993/12/7
MAANSHAN IRON	CH600808	HK323	1994/1/6	1993/11/3
BEIREN PRINTING	CH600860	HK187	1994/5/6	1993/8/6
YIZHENG CHEM	CH600871	HK1033	1995/4/11	1994/3/29
TIANJIN CAPITAL	CH600874	HK1065	1995/6/30	1994/5/17
DONGFANG ELEC	CH600875	HK1072	1995/10/10	1994/6/6
LUOYANG GLASS	CH600876	HK1108	1995/10/31	1994/7/8
CHONGQING IRON	CH601005	HK1053	2007/2/28	1997/10/17

Table 2 continued

CHINA SHENHUA ENERGY	CH601088	HK1088	2007/10/9	2005/6/15
AIR CHINA	CH601111	HK0753	2006/8/18	2004/12/15
CHINA RAIL CONS	CH601186	HK1186	2008/3/10	2008/3/14
PING AN	CH601318	HK2318	2007/3/1	2004/6/24
BANKCOMM	CH601328	HK3328	2007/5/15	2005/6/23
GUANGSHEN RAIL	CH601333	HK0525	2006/12/22	1996/5/14
CHINA RAILWAY	CH601390	HK0390	2007/12/3	2007/12/7
ICBC	CH601398	HK1398	2006/10/27	2006/10/27
BEIJING N STAR	CH601588	HK0588	2006/10/16	2006/9/29
CHALCO	CH601600	HK2600	2007/4/30	2001/12/12
CHINA LIFE	CH601628	HK2628	2007/1/9	2007/3/18
CSR	CH601766	HK1766	2008/8/18	2008/8/21
CHINA OILFIELD	CH601808	HK2883	2007/9/28	2002/11/20
PETROCHINA	CH601857	HK0857	2007/11/5	2000/4/7
CSCL	CH601866	HK2866	2007/12/12	2004/6/16
CHINA COAL	CH601898	HK1898	2008/2/1	2006/12/19
ZIJIN MINING	CH601899	HK2899	2008/4/25	2003/12/23
CHINA COSCO	CH601919	HK1919	2007/6/26	2005/6/30
CCB	CH601939	HK0939	2007/9/25	2005/10/27
BANK OF CHINA	CH601988	HK3988	2006/7/5	2006/6/1
DATANG POWER	CH601991	HK0991	2006/12/20	1997/3/21
CITIC BANK	CH601998	HK0998	2007/4/27	2007/4/27

the last deal (occurring at T_1) before time T_2 and the first deal (occurring at T_3) after T_2 as the strike price at T_2.

Namely,

$$P_2 = P_1 + \frac{T_2 - T_1}{T_3 - T_1}(P_3 - P_1), \quad (1)$$

Where P_1, P_2 and P_3 respectively corresponded with the price at T_1, T_2 and T_3; $T_2 - T_1$ denote the time span between T_1 and T_2; $T_3 - T_1$ represent the time span between T_1 and T_3. Figure2.

For the most part, additional models and analyses are based on consecutive data. Since the transaction time limitations exists for both in A- and H-shares, cracks between daily data resulting in differing degree of freedom for each trading day results. This is common in time series data with daily intervals. However, we should account for the continuity of data. To solve this notion as to the cohesion of data, we concluded that the coefficient in each day is the initial step of the analysis. The coefficient found by the VECM, $\hat{\beta}_n$ in each day is the first step in the statistical method to estimate the real coefficient, β for the entire period. That is,

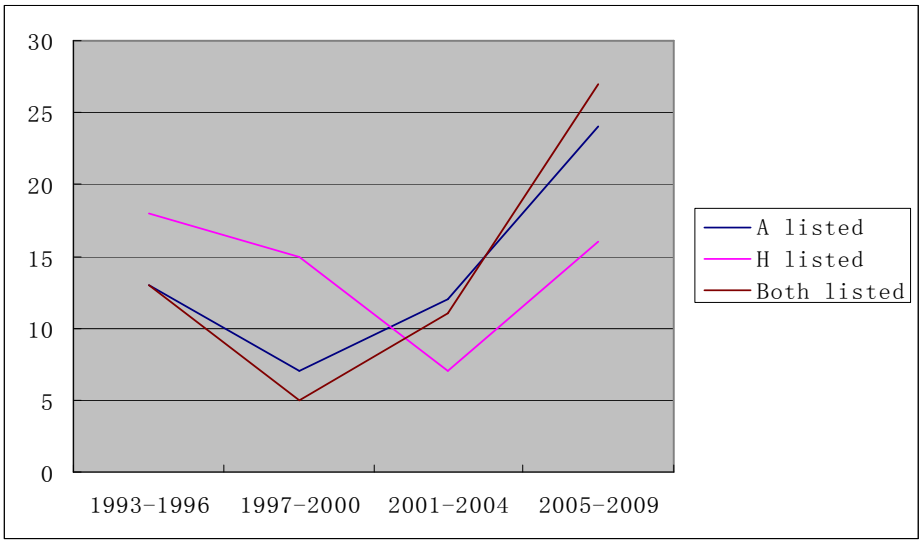

Figure 1. The number of company listed in A and H share market

Figure 2. Sketch of the Fixed Time Intervals method

Market type	A	H	A	A	H	A	A	H	A
Time	10:30	10:35	10:40	11:00	11:05	11:10	14:40	14:45	14:50

Figure 3.Sketch of the Time dimension of the data

$$\hat{\beta}_1 \sim N(\beta, s^2_{\hat{\beta}_1})$$
$$\hat{\beta}_2 \sim N(\beta, s^2_{\hat{\beta}_2})$$
...
$$\hat{\beta}_n \sim N(\beta, s^2_{\hat{\beta}_n})$$
$$\hat{\beta} \sim N\left(\frac{\beta + \beta + \ldots + \beta}{n}, \frac{s^2_{\hat{\beta}_1} + s^2_{\hat{\beta}_2} + \ldots + s^2_{\hat{\beta}_n}}{n}\right) = N(\beta, s^2_{\hat{\beta}})$$

Where $s^2_{\hat{\beta}_n}$ denote standard deviation of daily coefficient, $s^2_{\hat{\beta}}$ denotes standard deviation of real coefficient.

Then, the resulting hypothesis to be tested is as follow,

$$H_0 : \beta = 0$$
$$H_a : \beta \neq 0$$
$$t = \frac{\hat{\beta}}{s_{\hat{\beta}}} = \frac{\frac{\hat{\beta}_1 + \hat{\beta}_2 + \ldots + \hat{\beta}_n}{n}}{\sqrt{\frac{s^2_{\hat{\beta}_1} + s^2_{\hat{\beta}_2} + \ldots + s^2_{\hat{\beta}_n}}{n}}}$$

Finally, we calculate the ***P-value*** of the conclusion by employing the real degrees of freedom as follows:

$$df = m \times (n - 1)$$

Where, m denotes the amount of sample, n denotes magnitude of sample.

The analysis

Recall that time series regression analysis is based on the assumption that the sequence in the time series is stationary. It may fluctuate and have a trend to close to a mean. Accordingly, if one treats a non-stationary series as if it was stationary, the regression model adopted for estimation will result in spurious estimations. The process to ascertain the stability of time series is to test for its unit root.

There are a variety of methods such as Dickey-Fuller (DF), Augmented Dickey-Fuller (ADF), Phillips-Perron (or PP), ERS-DFGLS, KPSS, ERS point-Optimal and Ng-Perron to test the stability of series. The asymptotic distribution of the test statistics of PP test, which is a nonparametric Unit Root Test denoted by Phillips and Perron (1988), is identical to DF text, denoted by Dickey and Fuller (1979), which is basic test method for unit root. Generally, the familiar static softwares will report the *T-statistics* and *P-values* in the PP test; up0on observation of the *P-value*, we can make a conclusion concerning the existence of the unit root. For this purpose we employed PP. The core of the PP method is to apply a first-order autoregressive model [AR (1)] for one of next three equations of the DF test model:

$$\begin{cases} \Delta y_t = c + \gamma t + \phi y_{t-1} + \varepsilon_t \\ \Delta y_t = c + \phi y_{t-1} + \varepsilon_t \\ \Delta y_t = c + \varepsilon_t \end{cases}$$

The test statistics of PP are expressed as,

$$\tilde{\tau}_\phi = \tau_\phi \left(\frac{\gamma_0}{f_0} \right)^{0.5} - \frac{T(f_0 - \gamma_0)se(\hat{\phi})}{2 f_0^{0.5} s}$$

Where, T is magnitude of swatch, $\hat{\phi}$ denote the estimator of coefficient, ϕ in the model, τ_ϕ represents the test statistics, $se(\hat{\phi})$ denote the estimated standard deviation of coefficient, s is the standard error of the regression equation, and f_0 stands for the residual spectrum estimator of frequency zero. Moreover, γ_0 is the uniform variance estimator. If the number of dependent variables equal to k, the γ_0 could be expressed as,

$$\gamma_0 = \frac{T-k}{T} s^2$$

The sample data set contains 56 cross-listed firms. In turn, we selected the minute data, from Jul. 2007 to Feb. 2009, at the same time each day to create a group of daily data, and made several groups in the same way, to make an approximate evaluation about the unit root of minute data. We show this as follows: Figure 3.

Adopting a *P-value*>0.05 to not reject the null hypothesis, namely the stock price is a non-stationary series, and if P-value<0.05 then we reject the null hypothesis. This means that the stock price series is stationary.

According to the result, almost all the stock price series have a unit root except for CHINA RAIL CONS (CH601186, HK1186), PETRO CHINA (CH601857, HK0857), and DATANG POWER (CH601991, HK0991). The results are in table 3.

Granger (1981) developed the co integration analysis. He stated that there are some linear combinations among time series that could result in stability among them. We can infer a long-run stable relationship may exist in sequences of data. We can describe this relationship in mathematical terms;

we assume that there are two time series variables, x_t and y_t, and both variables obey a first-order integration (I(1)) process, and if one of the linear combinations based on x_t and y_t, for example $z_t = x_t - \beta y_t$, represent a stationary sequence, namely x_t and y_t having a co integration relationship and the co integration vector is (1,- β) .

Moreover, Engle and Granger (1987) provide the method for the co integration test. The main idea of this method is that adopt a methodology to inspect whether a co integration relationship exists among the non-stationary variables (with the integration characteristics); that is, we whether a pre-combination could form a stationary sequence.

PP test was used here and the results show that almost all A and H stock prices have a co integration relation, except BANK OF CHINA (CH601628, HK3328), ZIJIN MINING (CH601899, HK2899), CHINA SHIP DEV (CH600026, HK1138), and BANKCOMM (CH601328, HK3328), shown in Tables 4 and 5.

To avoid the spurious regression results, we adopted a VECM that is a restricted *vector autoregressive model (*VAR) designed for use with non-stationary series that are known to be co integrated. The VECM contains cointegreation relations built into the specification so that it restricts the long-run behavior of the endogenous variables to converge to their cointegrating relationships while allowing for short-run adjustment dynamics. The cointegration term is known as the error correction term since the deviation from long-run equilibrium is corrected gradually through a series of partial short-run

Table 3. P-Values, There are 56 companies both listed in China A stock exchange and Hong Kong H stock exchanges. Some of them have little data because they have only a few transactions. To make an accurate analysis, we selected 44 of them having sufficient data. According to the market conditions, the simultaneous trading hours in A and H share market are from 10:00 to 11:30 and from 14: 30 to 15:00. We extracted the minute data, from Jul. 2007 to Feb. 2009, at same time each day to create a group of daily data, and made several groups in the same way to make an approximate evaluation about the unit root of the time series. ***P-value***s are continued in the table.

Name	A code	H code	A 10:30	H 10:35	A 10:40	A 11:00	H 11:05	A 11:10	A 14:40	H 14:45	A 14:50
ZTE	CH000063	HK763	0.5819	0.4884	0.5852	0.5962	0.4819	0.587	0.5934	0.4981	0.5931
WEICHAI POWER	CH000338	HK2338	0.8056	0.8528	0.8027	0.7844	0.8357	0.7886	0.7819	0.8081	0.7799
ANGANG NEWSTEEL	CH000898	HK347	0.8523	0.7798	0.851	0.8465	0.7841	0.844	0.8561	0.788	0.8549
HUANENG POWER	CH600011	HK902	0.6868	0.3484	0.6882	0.677	0.3685	0.6736	0.6754	0.3281	0.6657
ANHUIEXPRESSWAY	CH600012	HK995	0.8512	0.8458	0.8482	0.8502	0.8571	0.8461	0.853	0.8199	0.8522
HUADIAN POWER	CH600027	HK1071	0.7103	0.6722	0.7045	0.6682	0.6452	0.6687	0.6966	0.634	0.6962
SINOPEC CORP	CH600028	HK386	0.7744	0.7744	0.7933	0.8035	0.7625	0.7879	0.7827	0.7755	0.7756
CHINA SOUTH AIR	CH600029	HK1055	0.7654	0.8857	0.7739	0.7633	0.8784	0.7661	0.7527	0.8864	0.7748
CHINA MERCHANTS BANK	CH600036	HK3968	0.8685	0.8367	0.8652	0.8593	0.8401	0.852	0.8662	0.8363	0.8681
CHINA EAST AIR	CH600115	HK670	0.8662	0.6491	0.77	0.7655	0.5954	0.7602	0.7668	0.6115	0.7606
JIANGXI COPPER	CH600362	HK358	0.6861	0.724	0.6897	0.6733	0.7303	0.6759	0.6886	0.7245	0.6764
JIANGSU EXPRESS	CH600377	HK177	0.7469	0.3968	0.743	0.7381	0.4371	0.737	0.7277	0.4216	0.7289
SHENZHEN EXPRESS	CH600548	HK548	0.7657	0.8998	0.7641	0.7909	0.9006	0.7879	0.7448	0.8986	0.7423
ANHUI CONCH	CH600585	HK914	0.7477	0.4883	0.748	0.7447	0.4984	0.7424	0.7587	0.4485	0.7674
TSINGTAO BREW	CH600600	HK168	0.6948	0.518	0.6998	0.6475	0.5903	0.651	0.664	0.513	0.659
GUANGZHOU SHIP	CH600685	HK317	0.8505	0.8133	0.8527	0.8578	0.8043	0.8603	0.8721	0.8015	0.871
SHANGHAI PECHEM	CH600688	HK338	0.8306	0.6844	0.8347	0.8516	0.6775	0.8579	0.8455	0.6628	0.8503
MAANSHAN IRON	CH600808	HK323	0.7312	0.6914	0.7346	0.7434	0.6872	0.7443	0.7647	0.6752	0.7583
YIZHENG CHEM	CH600871	HK1033	0.8575	0.7445	0.8542	0.8611	0.7042	0.8626	0.8593	0.7248	0.8633
TIANJIN CAPITAL	CH600874	HK1065	0.5863	0.5399	0.5919	0.5349	0.5334	0.5754	0.5968	0.6472	0.5941
DONGFANG ELEC	CH600875	HK1072	0.7475	0.7409	0.7428	0.7563	0.7515	0.7554	0.715	0.7299	0.7127
CHONGQING IRON	CH601005	HK1053	0.6907	0.6879	0.6943	0.6976	0.7026	0.7054	0.7197	0.7218	0.7214
CHINA SHENHUA ENERGY	CH601088	HK1088	0.7239	0.8389	0.7289	0.7327	0.8464	0.734	0.7287	0.8433	0.7242
AIR CHINA	CH601111	HK0753	0.7977	0.8099	0.8093	0.8034	0.818	0.8335	0.8434	0.8067	0.8137

Table 3 Continue

CHINA RAIL CONS	CH601186	HK1186	0.0402	0.0198	0.0356	0.0468	0.0309	0.0469	0.0257	0.0267	0.0275
PING AN	CH601318	HK2318	0.8471	0.7235	0.8462	0.8507	0.7208	0.8489	0.8572	0.7559	0.8542
BANKCOMM	CH601328	HK3328	0.9097	0.8096	0.9094	0.9089	0.8155	0.9043	0.8949	0.8177	0.891
GUANGSHEN RAIL	CH601333	HK0525	0.8851	0.8392	0.8859	0.8765	0.8428	0.8737	0.8666	0.7716	0.8622
CHINA RAILWAY	CH601390	HK0390	0.6357	0.6748	0.6303	0.6217	0.6492	0.6138	0.6337	0.6485	0.6234
ICBC	CH601398	HK1398	0.8209	0.6616	0.8199	0.8219	0.6365	0.8174	0.8089	0.6784	0.7929
BEIJING N STAR	CH601588	HK0588	0.8613	0.8353	0.8584	0.851	0.8536	0.8553	0.8419	0.814	0.8377
CHALCO	CH601600	HK2600	0.8211	0.7755	0.8279	0.8206	0.7599	0.8221	0.8229	0.7687	0.8195
CHINA LIFE	CH601628	HK2628	0.8565	0.7096	0.8564	0.8376	0.6784	0.8419	0.8498	0.6865	0.8481
CSR	CH601766	HK1766	0.6776	0.3713	0.622	0.6283	0.3357	0.6327	0.5487	0.2327	0.559
CHINA OILFIELD	CH601808	HK2883	0.4865	0.8	0.4973	0.5005	0.7761	0.4728	0.5233	0.7856	0.5279
PETROCHINA	CH601857	HK0857	0	0.0481	0	0	0.0821	0	0	0.0751	0
CSCL	CH601866	HK2866	0.4543	0.6871	0.4742	0.4525	0.5882	0.468	0.4116	0.5075	0.4085
CHINA COAL	CH601898	HK1898	0.5905	0.7565	0.6477	0.5743	0.763	0.5729	0.5867	0.7787	0.5848
ZIJIN MINING	CH601899	HK2899	0.3022	0.5251	0.3093	0.3527	0.5359	0.3574	0.3611	0.554	0.3575
CHINA COSCO	CH601919	HK1919	0.8154	0.8165	0.8191	0.8071	0.8213	0.8051	0.8133	0.7843	0.8095
CCB	CH601939	HK0939	0.8372	0.6642	0.8269	0.838	0.6562	0.8353	0.8135	0.6728	0.8047
BANK OF CHINA	CH601988	HK3988	0.892	0.8342	0.8878	0.8652	0.8097	0.8523	0.841	0.7852	0.8266
DATANG POWER	CH601991	HK0991	0.8283	0.0031	0.8164	0.806	0.0025	0.8096	0.7906	0.002	0.7947
CITIC BANK	CH601998	HK0998	0.8835	0.7426	0.8791	0.881	0.7467	0.8823	0.9045	0.7347	0.9017

Table 4. PP test used here and the result that almost all 27 listed companies', with sufficient data, A and H stock price have a co-integration relation, P-value shown as P-value

Name	A(10:30) to H(10:35)	H(10:35) to A(10:40)	A(11:00) to H(11:05)	H(11:05) to A(11:10)	A(14:40) to H(14:45)	H(14:45) to A(14:50)
CHINA LIFE	0.002	0.005	0.003	0.002	0.004	0.008
CHINA COSCO	0.024	0.037	0.021	0.032	0.027	0.033
SINOPEC CORP	0	0.001	0.003	0.003	0.004	0.004
ANGANG NEWSTEEL	0.002	0.003	0.002	0.003	0.003	0.003
ZTE	0.013	0.017	0.015	0.024	0.019	0.026
HUANENG POWER	0.001	0.004	0.002	0.004	0.001	0.004
CHINA SOUTH AIR	0.031	0.015	0.028	0.019	0.03	0.021
CHINA MERCHANTS BANK	0.015	0.02	0.016	0.017	0.013	0.017
CCB	0.043	0.09	0.044	0.096	0.043	0.089
BANK OF CHINA	0.05	0.063	0.056	0.072	0.048	0.067
ZIJIN MINING	0.129	0.084	0.108	0.086	0.16	0.149
CHINA COAL	0.018	0.017	0.017	0.012	0.01	0.007
CSR	0.014	0.038	0.011	0.039	0.004	0.014
GUANGZHOU SHIP	0.001	0.002	0.001	0	0.001	0.002
TSINGTAO BREW	0	0	0	0	0	0.001
CHINA SHIP DEV	0.061	0.059	0.059	0.051	0.037	0.038
CHINA EAST AIR	0	0	0	0	0	0
ICBC	0.0399	0.0889	0.0456	0.0879	0.051	0.0777
BEIJING N STAR	0.0043	0.0071	0.0113	0.0127	0.0107	0.0114
CHALCO	0.003	0.0033	0.0025	0.0036	0.0027	0.0037
CHINA RAILWAY	0.0037	0.004	0.0029	0.0023	0.005	0.0066
CHONGQING IRON	0.0041	0.0047	0.0043	0.0033	0.0056	0.0056
AIR CHINA	0.0004	0.0007	0.0006	0.0006	0.0004	0.0004
BANKCOMM	0.0902	0.1227	0.0812	0.1268	0.0932	0.1285
GUANGSHEN RAIL	0.0003	0.0005	0.0004	0.0005	0.0007	0.0009
PING AN	0.003	0.0047	0.0022	0.0035	0.0019	0.0056
CHINA SHENHUA ENERGY	0.0011	0.0016	0.0011	0.0009	0.0016	0.0014

adjustments.

Although a long-run equilibrium relation exited between x_{1t} and x_{2t}, hence the expect value of e_t will equal to 0 in a long term, a disequilibrium occur in the short term condition. Then, x_{1t} and x_{2t} should experience the dynamic adjustment, correcting the disequilibrium into an equilibrium state.

The corresponding VECM is:

$$\begin{cases} \Delta x_{1,t} = \gamma_1 (x_{2,t-1} - \beta x_{1,t-1}) + \varepsilon_{1,t} \\ \Delta x_{2,t} = \gamma_2 (x_{2,t-1} - \beta x_{1,t-1}) + \varepsilon_{2,t} \end{cases}$$

To build a VECM, the lag length must be confirmed firstly

Table 5. Co integration

Name	A(10:30) to H(10:35)	H(10:35) to A(10:40)	A(11:00) to H(11:05)	H(11:05) to A(11:10)	A(14:40) to H(14:45)	H(14:45) to A(14:50)
CHINA LIFE	YES	YES	YES	YES	YES	YES
CHINA COSCO	YES	YES	YES	YES	YES	YES
SINOPEC CORP	YES	YES	YES	YES	YES	YES
ANGANG NEWSTEEL	YES	YES	YES	YES	YES	YES
ZTE	YES	YES	YES	YES	YES	YES
HUANENG POWER	YES	YES	YES	YES	YES	YES
CHINA SOUTH AIR	YES	YES	YES	YES	YES	YES
CHINA MERCHANTS BANK	YES	YES	YES	YES	YES	YES
CCB	YES	NO	YES	NO	YES	NO
BANK OF CHINA	YES	NO	NO	NO	YES	NO
ZIJIN MINING	NO	NO	NO	NO	NO	NO
CHINA COAL	YES	YES	YES	YES	YES	YES
CSR	YES	YES	YES	YES	YES	YES
GUANGZHOU SHIP	YES	YES	YES	YES	YES	YES
TSINGTAO BREW	YES	YES	YES	YES	YES	YES
CHINA SHIP DEV	NO	NO	NO	NO	YES	YES
CHINA EAST AIR	YES	YES	YES	YES	YES	YES
ICBC	YES	NO	YES	NO	NO	NO
BEIJING N STAR	YES	YES	YES	YES	YES	YES
CHALCO	YES	YES	YES	YES	YES	YES
CHINA RAILWAY	YES	YES	YES	YES	YES	YES
CHONGQING IRON	YES	YES	YES	YES	YES	YES
AIR CHINA	YES	YES	YES	YES	YES	YES
BANKCOMM	NO	NO	NO	NO	NO	NO
GUANGSHEN RAIL	YES	YES	YES	YES	YES	YES
PING AN	YES	YES	YES	YES	YES	YES
CHINA SHENHUA ENERGY	YES	YES	YES	YES	YES	YES

and both sufficient lags and degree of freedom are required. We utilized the Akaike Information Criterion (AIC), shown as,

$$AIC = -1l / T + 2k / T$$

Where, *T* is magnitude of swatch and *k* is the number of dependent variables.

The optimal lag length present equals 1. Finally, a more general A-H stock price VECM is built:

$$\begin{cases} \Delta A_t = \gamma_A (A_{t-1} + \beta H_{t-1} + C) + \alpha_A \Delta A_{t-1} + \beta_A \Delta H_{t-1} + c_A \\ \Delta H_t = \gamma_H (A_{t-1} + \beta H_{t-1} + C) + \alpha_H \Delta A_{t-1} + \beta_H \Delta H_{t-1} + c_H \end{cases}$$

Where, A_t (or H_t) is A (or H) share the stock price at time t, ΔA_t (or ΔH_t) is the difference between A_t and A_{t-1} (or H_t and H_{t-1}), α and β represent regression coefficients, C and c are the constant before and after correction, moreover γ_A and γ_H work as correction factors.

Table 6. VECM estimation under 1 minute data

Name	A code	H code				ΔA				ΔH			
				β	C	γ_A	α_A	β_A	c_A	γ_H	α_H	β_H	c_H
CHINA LIFE	CH601628	HK2628	value	-0.876	-0.332	-0.077	0.073	0.015	0.000	0.063	-0.009	-0.062	0.000
			P-value	0.000		0.000	0.000	0.219	0.807	0.000	0.780	0.000	0.669
			TRUE	YES		YES	YES	NO	NO	YES	NO	YES	NO
CHINA COSCO	CH601919	HK1919	value	-0.207	-8.777	-0.083	0.212	0.028	0.000	0.026	0.016	0.034	0.000
			P-value	0.283		0.000	0.000	0.130	0.585	0.001	0.465	0.046	0.550
			TRUE	NO		YES	YES	NO	NO	YES	NO	YES	NO
SINOPEC CORP	CH600028	HK386	value	0.725	-12.268	-0.110	0.012	0.013	0.000	0.035	0.008	-0.082	0.000
			P-value	0.467		0.000	0.475	0.512	0.769	0.000	0.640	0.000	0.239
			TRUE	NO		YES	NO	NO	NO	YES	NO	YES	NO
ANGANG NEWSTEEL	CH000898	HK347	value	-5.049	42.884	-0.080	-0.035	0.027	0.000	0.035	0.045	0.047	0.000
			P-value	0.003		0.000	0.037	0.062	0.607	0.002	0.098	0.001	0.317
			TRUE	YES		YES	YES	NO	NO	YES	NO	YES	NO
CHINA MERCHANTS BANK	CH600036	HK3968	value	-1.513	6.139	-0.079	0.089	0.029	0.000	0.016	0.061	0.013	0.000
			P-value	0.000		0.000	0.000	0.044	0.599	0.096	0.019	0.348	0.720
			TRUE	YES		YES	YES	YES	NO	NO	YES	NO	NO
CHINA SOUTH AIR	CH600029	HK1055	value	-1.437	-1.811	-0.103	-0.073	-0.032	-0.001	0.012	0.013	-0.152	0.000
			P-value	0.000		0.000	0.034	0.614	0.135	0.400	0.684	0.018	0.329
			TRUE	YES		YES	YES	NO	NO	NO	NO	YES	NO
CHINA SHENHUA ENERGY	CH601088	HK1088	value	0.066	-16.873	-0.073	0.017	0.050	0.000	0.024	-0.007	0.082	0.000
			P-value	0.818		0.000	0.325	0.001	0.933	0.009	0.768	0.000	0.893
			TRUE	NO		YES	NO	YES	NO	YES	NO	YES	NO
HUANENG POWER	CH600011	HK902	value	0.837	-11.485	-0.153	-0.121	0.050	0.000	0.003	0.009	-0.017	0.000
			P-value	0.000		0.000	0.000	0.006	0.506	0.778	0.662	0.342	0.607
			TRUE	YES		YES	YES	YES	NO	NO	NO	NO	NO

Table 6. Continue.

ZTE	CH000063	HK763	value	0.835	-40.813	-0.069	0.081	0.014	0.001	0.015	0.092	0.002	-0.001
			P-value	0.020		0.000	0.000	0.406	0.485	0.082	0.000	0.900	0.550
			TRUE	YES		YES	YES	NO	NO	NO	YES	NO	NO
CHINA EAST AIR	CH600115	HK670	value	19.178	-24.079	-0.064	0.002	0.027	-0.001	0.018	-0.004	-0.151	0.000
			P-value	0.000		0.000	0.935	0.632	0.104	0.001	0.775	0.009	0.386
			TRUE	YES		YES	NO	NO	NO	YES	NO	YES	NO
GUANGZHOU SHIP	CH600685	HK317	value	-0.865	-8.210	-0.096	0.213	-0.032	0.000	0.049	-0.006	-0.045	0.001
			P-value	0.000		0.000	0.000	0.366	0.796	0.000	0.844	0.197	0.366
			TRUE	YES		YES	YES	NO	NO	YES	NO	NO	NO
TSINGTAO BREW	CH600600	HK168	value	-2.628	19.634	-0.076	-0.028	-0.003	-0.001	0.010	0.013	-0.001	0.000
			P-value	0.000		0.000	0.160	0.841	0.024	0.414	0.745	0.937	0.747
			TRUE	YES		YES	NO	NO	YES	NO	NO	NO	NO
CSR	CH601766	HK1766	value	1.397	-9.563	-0.088	-0.182	0.009	0.000	0.037	0.048	-0.070	0.000
			P-value	0.121		0.000	0.000	0.514	0.655	0.001	0.036	0.000	0.285
			TRUE	NO		YES	YES	NO	NO	YES	YES	YES	NO
CHINA COAL	CH601898	HK1898	value	-7.514	39.733	-0.076	0.093	0.025	0.000	0.005	0.028	-0.003	0.000
			P-value	0.013		0.000	0.000	0.089	0.766	0.658	0.260	0.822	0.563
			TRUE	YES		YES	YES	NO	NO	NO	NO	NO	NO
BEIJING N STAR	CH601588	HK0588	value	10.720	-17.431	-0.075	-0.139	0.047	0.000	-0.035	-0.016	-0.097	0.000
			P-value	0.038		0.000	0.012	0.315	0.722	0.161	0.827	0.040	0.832
			TRUE	YES		YES	YES	NO	NO	NO	NO	YES	NO
CHALCO	CH601600	HK2600	value	4.705	-25.041	-0.083	-0.023	0.040	0.000	0.030	0.003	-0.023	-0.001
			P-value	0.004		0.000	0.180	0.047	0.963	0.000	0.883	0.256	0.770
			TRUE	YES		YES	NO	YES	NO	YES	NO	NO	NO
CHINA RAILWAY	CH601390	HK0390	value	-0.697	-2.029	-0.105	-0.128	0.005	0.000	0.047	0.014	-0.081	0.000
			P-value	0.000		0.000	0.000	0.717	0.179	0.000	0.546	0.000	0.968
			TRUE	YES		YES	YES	NO	NO	YES	NO	YES	NO

Table 6. Continue

CHONGQING IRON	CH601005	HK1053	value	-0.916	-3.124	-0.081	-0.030	-0.055	0.000	0.044	0.001	-0.051	0.000
			P-value	0.009		0.000	0.303	0.092	0.774	0.000	0.968	0.115	0.361
			TRUE	YES		YES	NO	NO	NO	YES	NO	NO	NO
AIR CHINA	CH601111	HK0753	value	0.768	-6.502	-0.087	-0.057	0.013	0.000	0.024	0.015	-0.131	0.000
			P-value	0.157		0.000	0.001	0.576	0.742	0.000	0.334	0.000	0.834
			TRUE	NO		YES	YES	NO	NO	YES	NO	YES	NO
GUANGSHEN RAIL	CH601333	HK0525	value	-3.739	5.558	-0.062	-0.181	0.052	-0.001	0.000	0.069	0.048	0.000
			P-value	0.000		0.009	0.004	0.458	0.179	0.997	0.288	0.494	0.447
			TRUE	YES		YES	YES	NO	NO	NO	NO	NO	NO
PING AN	CH601318	HK2318	value	0.596	-49.963	-0.066	0.068	0.006	0.000	0.054	0.051	0.039	0.001
			P-value	0.050		0.000	0.000	0.520	0.916	0.000	0.166	0.000	0.483
			TRUE	NO		YES	YES	NO	NO	YES	NO	YES	NO

First, we selected 1 minute date, 10：35~11：30, in each day from 2008-2009 as sample and processed the unit root and cointegration test on 44 crossing-listed companies with sufficient data. If these data indicated a co integration relation, we would reconnect these data each day by the method described earlier and estimate the coefficients by VECM adopted. Using the ***P-value*** as a criterion, we tested the results and found that the ***P-values*** of α_A and β_H in majority sample stocks are more than 0.05. Thus, we could not reject the null hypothesis that coefficients equal zero. The final results are shown in Table 6 above Furthermore, treaded 5 minute data at 10:30 in each day as daily data, I made a second round VCM model estimation. The result indicated that cause-effect reaction exited between samples with a cointegreation relationship. Table 6

Arbitrage test and results

To confirm the usefulness in adopting a general VECM, we made a test for arbitrage on 16 cross-listed firms that passed the unit root test and co integration test and have sufficient data, i.e., more than a 30 day time series. The arbitrage utilizes the values of ΔA_t and ΔH_t, counted by VEC M, as indicators to indicate what the transactions will be. These transactions originate from the equations of the model whose coefficients were estimated by equation (1) with varying groups of (5 days, 10 days, 20 days, 30 days, or 40 days). These values are then used to forecast the trend in the next trading day. For example, using the data from Nov.1, 2008 to Nov. 5, 2008 (5 days), we can anticipate the minute by minute trend on Nov.6, 2008. Similarly, we estimate rolling trend and assume a transaction costs of 100,000 (Chinese Currency) and 100,000 (Hong Kong Dollars). All the forecast s and transaction costs are based on historical data. . These assumptions are all used to make the arbitrage decisions and the trade days of the selected firms in different forecast groups are shown in Table 7 Below

Assuming the unit in the trade is on a per share basis, ignoring the commission and other transaction costs, and making the maximum trade

Table 7. VECM estimation under Daily data

Name	A code	H code	β	C	γ_A	α_A	β_A	c_A	γ_H	α_H	β_H	c_H
CHINA LIFE	CH601628	HK2628	-2.172	31.258	-0.012	-0.088	0.146	-0.068	0.016	0.068	-0.141	-0.022
CHINA COSCO	CH601919	HK1919	-1.686	2.846	-0.005	-0.151	0.416	-0.044	0.014	-0.039	0.181	-0.044
SINOPEC CORP	CH600028	HK386	-2.420	4.946	-0.028	0.000	0.018	-0.011	0.017	0.240	-0.108	-0.012
ANGANG NEWSTEEL	CH000898	HK347	-1.222	1.817	-0.011	-0.025	0.080	-0.027	0.029	0.075	-0.039	-0.030
CHINA MERCHANTS BANK	CH600036	HK3968	-1.295	5.402	-0.002	-0.089	0.137	-0.031	0.026	0.114	-0.114	-0.045
CHINA SOUTH AIR	CH600029	HK1055	-1.456	-1.105	-0.052	-0.034	0.047	-0.003	0.001	-0.013	-0.118	-0.014
CHINA SHENHUA ENERGY	CH601088	HK1088	-1.549	6.222	-0.028	0.037	0.177	-0.156	0.021	0.040	-0.033	-0.099
HUANENG POWER	CH600011	HK902	-2.126	3.824	-0.028	-0.030	-0.033	-0.007	0.020	-0.052	-0.006	-0.011
ZTE	CH000063	HK763	-1.050	-2.336	-0.006	-0.067	0.119	-0.010	0.061	-0.126	0.039	-0.037
CHINA EAST AIR	CH600115	HK670	-2.279	-1.907	-0.056	0.096	-0.100	-0.026	0.008	0.031	-0.115	-0.019
GUANGZHOU SHIP	CH600685	HK317	-1.567	0.314	-0.050	-0.064	0.122	-0.098	0.005	0.088	-0.033	-0.086
TSINGTAO BREW	CH600600	HK168	-1.503	4.064	-0.037	0.010	-0.018	-0.019	0.062	-0.076	0.004	-0.014
CSR	CH601766	HK1766	-1.451	0.799	-0.012	-0.095	0.052	0.012	0.064	-0.154	0.048	0.008
CHINA COAL	CH601898	HK1898	-0.992	-2.083	-0.041	-0.034	0.110	-0.056	0.014	-0.026	0.147	-0.048
BEIJING N STAR	CH601588	HK0588	-2.344	-0.979	-0.035	-0.059	0.210	-0.017	0.004	0.009	-0.048	-0.016
CHALCO	CH601600	HK2600	-2.422	4.399	-0.004	-0.048	0.321	-0.020	0.015	0.020	-0.047	-0.029
CHINA RAILWAY	CH601390	HK0390	-1.064	0.177	0.012	-0.191	0.134	-0.012	0.070	-0.266	0.131	-0.014
CHONGQING IRON	CH601005	HK1053	-1.738	-0.914	-0.020	-0.084	0.068	-0.010	0.021	0.065	-0.014	-0.007
AIR CHINA	CH601111	HK0753	-2.554	1.682	-0.044	-0.015	0.283	-0.008	0.005	-0.010	0.015	-0.011
GUANGSHEN RAIL	CH601333	HK0525	-1.771	1.441	-0.023	-0.091	0.087	-0.009	0.023	-0.041	-0.060	-0.011
PING AN	CH601318	HK2318	-1.718	39.072	-0.004	-0.139	0.215	-0.119	0.025	-0.026	-0.014	-0.054

in each transaction, we adopt the trading strategy to be as follows:

Under a bear position,

if ΔA_t （ΔH_t）>0, buy and take a full position;

if ΔA_t （ΔH_t）≤0，wait and take a bear position;

When under a full position,

if ΔA_t （ΔH_t）>0, hold and take a full position;

if ΔA_t （ΔH_t）≤0，sell and take a bear position;

After the data analysis and tests, about 52.33% of the samples contain positive profits per day and are shown in Table 8. Possibly, the difference between 52.33 and 50.00 % (2.33%) may be due to sample variation but considering the size of the difference and size of the sample, the probably is small that only variation caused the difference. Hence, we could alter the trading strategy to arrive at better results (those that are more profitable); we conclude at this point that arbitrage is applicable in these trading situations. The possibilities are almost endless at this point so we will simply conclude that arbitrage has significant affects. Table 8

CONCLUSIONS

This study focused on the interactivity between A- and H-shares prices in two geographically similar markets. The data selected are firms cross listed on both the Shanghai and Hong Kong equity exchanges. Using the analyses and methods of unit root, Granger causality and VECM, we attempted to simulate decisions made by investors in both exchanges. The arbitrage simulation did not result in a short term co integration of the two equity markets. In a sense, the influence of one market did not seem to affect transaction in the second equity market. These results are probably not surprising since the high frequency data appears to have long run relationships. The VECM also, indicated that the two markets do need a period to adjust to each other.

There are some technical problems concerning the time series studied. Of course, as time goes on, more firms will be cross-listed and hence, the addition data and increase the statistical degrees of freedom will result in definitive results. Longer periods of time can also be studied as data becomes universally available. We did not consider the asynchronous running time in both equity markets which may yield further evidence of an explanation about the stock prices of both A and H shares. Changes in the arbitrage rule may also yield additional information.

Table 8. The profit ratio of arbitrage test

Panel A: Simulation trade in A share market (the coefficient before hypothesis test)

Name	5 Day	10 Day	20 Day	30 Day	40 Day
ANGANG NEWSTEEL	0.13%	0.01%	-0.14%	0.37%	0.00%
HUANENG POWER	0.26%	0.62%	0.95%	0.75%	0.00%
TSINGTAO BREW	-0.16%	0.23%	-0.03%	-	-
CHINA MERCHANTS BANK	0.55%	0.85%	0.24%	-0.03%	-0.04%
AIR CHINA	0.17%	0.28%	1.18%	-	-
CHALCO	0.19%	-0.15%	-0.01%	0.08%	0.31%
CSR	-0.15%	0.26%	0.23%	-0.08%	-0.42%
PING AN	0.28%	0.52%	0.38%	0.71%	0.92%
CHINA LIFE	-0.18%	0.00%	0.18%	0.66%	-0.40%
CHINA SHENHUA ENERGY	0.01%	0.05%	0.06%	0.00%	0.00%
SINOPEC CORP	0.34%	0.33%	0.49%	0.53%	0.26%
CHINA COSCO	0.33%	0.70%	0.82%	0.34%	0.56%
CHINA RAILWAY	-0.22%	-0.15%	0.36%	-0.12%	0.00%
CHINA COAL	0.03%	0.02%	0.22%	-0.01%	0.21%
ZTE	0.49%	-0.07%	0.28%	0.00%	0.00%

Panel B: Simulation trade in A share market (the coefficient after hypothesis test)

Name	5 Day	10 Day	20 Day	30 Day	40 Day
ANGANG NEWSTEEL	0.25%	0.00%	-0.15%	0.38%	0.00%
HUANENG POWER	0.31%	0.64%	0.94%	0.71%	0.00%
TSINGTAO BREW	-0.16%	0.23%	-0.04%	-	-
CHINA MERCHANTS BANK	0.62%	0.80%	0.22%	-0.03%	-0.04%
AIR CHINA	0.12%	0.40%	1.13%	-	-
CHALCO	0.18%	-0.14%	0.00%	0.10%	0.32%
CSR	-0.17%	0.28%	0.21%	-0.08%	-0.46%
PING AN	0.29%	0.51%	0.39%	0.73%	0.96%
CHINA LIFE	-0.18%	0.00%	0.18%	0.66%	-0.40%
CHINA SHENHUA ENERGY	-0.07%	0.04%	0.06%	0.00%	0.00%
SINOPEC CORP	0.30%	0.34%	0.49%	0.53%	0.26%
CHINA COSCO	0.35%	0.71%	0.82%	0.33%	0.47%
CHINA RAILWAY	-0.21%	-0.14%	0.38%	-0.13%	0.00%
CHINA COAL	0.12%	0.02%	0.22%	-0.01%	0.17%
ZTE	0.40%	-0.12%	0.25%	0.00%	0.00%

Panel C: Simulation trade in H share market (the coefficient before hypothesis test)

Name	5 Day	10 Day	20 Day	30 Day	40 Day
ANGANG NEWSTEEL	0.15%	0.15%	-0.70%	-0.99%	-0.59%
HUANENG POWER	0.47%	0.01%	-0.68%	-0.20%	0.18%
TSINGTAO BREW	0.06%	-0.49%	-0.85%	-	-
CHINA MERCHANTS BANK	-0.04%	-0.11%	-0.12%	0.21%	0.18%
AIR CHINA	0.12%	0.37%	0.07%	-	-
CHALCO	-0.29%	-0.04%	0.41%	0.60%	-0.90%
CSR	0.01%	-0.35%	-0.56%	-0.51%	-0.91%
PING AN	0.53%	0.06%	0.50%	-0.15%	-0.25%
CHINA LIFE	-0.09%	-0.17%	0.19%	-0.15%	0.28%
CHINA SHENHUA ENERGY	0.27%	-0.10%	-0.36%	0.00%	0.00%
SINOPEC CORP	0.32%	-0.37%	-0.23%	0.00%	-0.07%
CHINA COSCO	-0.59%	0.76%	0.23%	-0.15%	-0.69%
CHINA RAILWAY	-0.04%	0.50%	-0.23%	0.40%	-0.72%
CHINA COAL	-0.06%	0.09%	-0.39%	-0.61%	-1.53%
ZTE	0.18%	0.65%	1.07%	0.69%	-0.07%

Panel D: Simulation trade in A share market (the coefficient after hypothesis test)

Name	5 Day	10 Day	20 Day	30 Day	40 Day
ANGANG NEWSTEEL	0.49%	0.01%	-0.55%	-0.68%	-0.59%
HUANENG POWER	-0.03%	0.18%	0.22%	0.54%	0.18%
TSINGTAO BREW	0.37%	-0.05%	0.00%	-	-
CHINA MERCHANTS BANK	0.02%	0.56%	-0.39%	0.48%	0.18%
AIR CHINA	0.11%	-0.09%	0.70%	-	-
CHALCO	-0.34%	-0.37%	-0.28%	0.64%	-0.90%
CSR	0.24%	0.01%	-0.60%	-0.23%	-0.91%
PING AN	0.02%	0.01%	0.95%	-0.14%	-0.25%
CHINA LIFE	-0.08%	0.02%	0.32%	-0.15%	0.28%
CHINA SHENHUA ENERGY	0.42%	0.47%	0.12%	0.59%	0.00%
SINOPEC CORP	-0.25%	-0.32%	-0.23%	0.00%	-0.07%
CHINA COSCO	-0.28%	0.55%	0.11%	-0.34%	-0.69%
CHINA RAILWAY	0.01%	-0.15%	0.11%	0.26%	-0.72%
CHINA COAL	0.07%	-0.26%	-0.28%	0.02%	-1.53%
ZTE	1.21%	0.97%	0.49%	0.24%	-0.07%

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Appendix

Steps in co integration test

Take two variables x_{1t} and x_{2t} for example, the main steps of the Engle-Granger co integration test are as follows:

STEP 1: Use the unit root test to inspect the stability test of variable and get a conclusion that most stock price have unit root.

STEP 2: If the result, after STEP 1, indicate that these two variables are equivalent non-stability series, I (1), we can take a regression,

$$x_{1,t} = c + \beta x_{2,t} + e_t$$

Then use OLS to estimate the coefficients and reserve the residual error, $\hat{e}_t$ of the sequence, that is,

$$\hat{e}_t = x_{1,t} - \hat{c} - \hat{\beta} x_{2,t}$$

STEP 3: Adopt unit root test and inspect for the stability of $\hat{e}_t$.