The random walk hypothesis for Chinese stock markets: Evidence from variance ratio tests

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The random walk hypothesis for Chinese stock markets: Evidence from variance ratio tests[*]

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Abstract

This study examines the random walk hypothesis for the Shanghai and Shenzhen stock markets for both A and B shares, using daily data over the period 1992–2007. The hypothesis is tested with new multiple variance ratio tests – Whang-Kim subsampling and Kim's wild bootstrap tests – as well as the conventional multiple Chow-Denning test. We find that Class B shares for Chinese stock exchanges do not follow the random walk hypothesis, and therefore are significantly inefficient. The Class A shares seem more efficient.

Keywords: Chinese stock markets; market efficiency; random walk hypothesis; variance ratio test.

JEL Classification: G14; G15; C14.

1 Introduction

China's stock market is a relatively new but increasingly important part of the Chinese financial system which is undergoing a structural shift from a heavily-regulated and almost exclusively bank-based system to one with much greater diversity of institutions including a vigorous and increasingly sophisticated stock market. The Chinese stock exchanges consist of two official markets[1]: the Shanghai Stock Exchange (SSE), located in the coastal city of Shanghai – the largest city and one of the financial centres in China, and Shenzhen Stock Exchange (SZE), situated in the southern city of Shenzhen which is the first and most important special economic zone in China neighboring Hong Kong. SSE was established on 26 November 1990 and started trading on 19 December of the same year, and SZE was established on 1 December 1990 and started trading on 3 July 1991. There are some differences between these two stock exchanges. First, the characteristics of companies listed in these two stock exchanges are different. While most companies listed on the SSE are large and state-owned, those on the SZE are small, joint ventures, and export-oriented. Second, the relative size of these two markets has been undergoing major changes, such as government policy shift[2].

SSE and SZE trade principally two classes of shares which are A and B shares[3]. A shares are denominated and traded in the local currency, Renminbi [RMB], and designed for domestic investors[4], and B shares are denominated in RMB but are subscribed and traded in foreign currencies, either the US dollars in the SSE or the HK dollars in the SZE. Since February 2001, B shares have been opened to domestic Chinese investors holding US or HK dollars. This policy change has greatly stimulated the trading of B-shares and accelerated the market integration process of A-share markets with B-share markets and the international stock markets. There are substantial different characteristics in the market for these two types of shares. Of

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[1] See Ma and Chung (1993) and Xia, Lin and Grub (1992), among others, for a review on the history and development of China's stock market.

[2] See Xu (2000) for a discussion on the microstructure of the Chinese stock market.

[3] Additional types of shares include C-shares, H-shares and N-shares. C-shares can only be traded among Chinese state institutions, enterprises and departments with a legal person status. H-shares and N-shares are available only to foreign investors, and represent the shares listed on the Hong Kong Stock Exchange and the New York Stock Exchange, respectively. See Seddighi and Nian (2004) for a discussion on the different types of shares in the Chinese stock market.

[4] Rules governing the ownership of A-shares have also recently been relaxed. Specifically, foreign institutional investors who are approved by the Chinese government (known as Qualified Foreign Institutional Investors) are now permitted to trade A-shares. However, any capital invested and any related income cannot be repatriated for 3 years (Wang, Burton and Hanah, 2004).

these two types of shares listed on the domestic exchanges, A share trades dominate, both in terms of size and level of activity. Indeed, the average volume traded in Class A is approximately 40 times the average volume traded in Class B, therefore the Class A shares should be more liquid. Furthermore, the main investors in Class A shares are individuals while Class B shares are mainly owned by large foreign institutional investors[5]. Moreover, foreign investors in the Chinese stock markets may be at an informational disadvantage relative to domestic Chinese investors (information asymmetry) due to language barriers, different accounting standards and the lack of reliable information about local firms (Chakravarty et al., 1998; Chan et al., 2006). Chinese companies that are listed as B shares are subject to more strict disclosure requirements and they are generally more financially stable than A share companies. Finally, the returns to A and B shares have behaved quite differently, for example, Chen et al. (2001) argued that A shares are over-priced and that the returns to B shares move more closely with market fundamentals than do those for A share prices. All these factors may imply different efficiency behavior between the A and B shares.

Since their establishment, the two exchanges expanded rapidly and operated in a continually changing regulatory environment. China's stock market is now the second largest in Asia, behind only Japan. The speculation is that China's securities market has the potential to rank among the top four or five in the world within the coming decade (Ma and Folkerts-Landau, 2001).

In this paper we analyze the efficiency of the Chinese stock markets[6]. The literature on market efficiency and stock market predictability is vast, as researchers have been discussing this theme in depth for the past decades (see Fama, 1970; 1991; Fama and French, 1988, Lo and MacKinlay, 1988; among others). A capital market is considered as efficient if stock prices at any time fully reflect all available and relevant information. Therefore, given only past price and return data, the current price is the best predictor of the future price, and the price change or return is expected to be zero. This the essence of the weak-form efficient market hypothesis [EMH], which implies a random walk. It is this random-walk implication of the EMH which is most commonly

[5]Wang, Liu and Wang (2004) and Qiao, Li and Wong (2008) investigated interactions between Chinese A shares and B shares traded on SSE and SZE. They find evidence of causal relations between shares of the same type, i.e., between the two A (B) share markets, than those between shares of different types. Furthermore, Qiao et al. (2008) showed that since the implementation of liberal policy that allowed domestic investors to invest in B-share markets A-share markets tend to lead their B-share counterparts in the same stock exchange.

[6]See Chan, Fung and Thapa (2007) for a review and synthesis of the financial research on China.

tested in the empirical literature.

Various methodologies have been used to test the EMH for Chinese stock markets and obtained mixed results (see Table 1). Wu (1996), Laurence, Cai and Qian (1997) and Mookerjee and Yu (1999) applied serial correlation tests while Liu, Song and Romilly (1997), Groenewold, Tang and Wu (2003) and Seddighi and Nian (2004) employed unit root tests. However, Lo and MacKinlay (1989) showed that unit root and serial correlation tests are less powerful than variance-ratio [VR] test, especially in the presence of heteroscedasticy. Thus, Long, Payne and Feng (1999), Darrat and Zhong (2000), Ma and Barnes (2001), Lee, Chen and Rui (2001), Lima and Tabak (2004) and Fifield and Jetty (2008)[7] used the individual Lo-MacKinlay VR test but they did not find consensus on the weak-form efficiency for Chinese stock markets. Nevertheless, it is preferable to employ multiple VR tests rather than individual VR tests. Indeed, in practice, it is customary to examine the VR statistics for several holding periods (k) to test the random-walk hypothesis [RWH]. The null is rejected if it is rejected for some k value. As stressed by Chow and Denning (1993), this sequential procedure leads to size distortions and therefore they suggested multiple VR tests to avoid this problem. However, a well-known problem with the VR test is that the standard (individual and multiple) VR tests, which are tests based on asymptotic approximations, are biased (severe size distortions and low power) and right-skewed in finite samples, resulting in misleading statistical inference. Recently, Whang and Kim (2003) and Kim (2006) proposed two alternatives which do not rely asymptotic approximations by suggesting subsampling and wild bootstrap version of the Chow-Denning test, respectively.

We contribute to the literature by re-examining the weak form of the EMH, using daily Chinese stock market data. While numerous studies addressed issues in this area in the recent past, we extend the existing studies in two ways. First, this study is based on a much more extensive sample. We study daily data for the Shanghai and Shenzhen stock markets for both A and B shares over the period 1992–2007. This large sample provides us with a greater variety of information and should reflect the dramatic changes that have taken place in China's securities sector in the past decade. We also investigate the EMH over various sub-periods in order to analyze the effects of the important changes in the relationship between the banks and the stock market in 1996 and 2000 as well as those of the implementation of the new policy allowing

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[7]Lima and Tabak (2004) and Fifield and Jetty (2008) also employed the Cecchetti-Lam VR and the non-parametric Wright's VR tests, respectively.

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domestic citizens to invest in B-share markets in 2001. Second, the weak form of the EMH is evaluated from new VR tests, which are more powerful than those applied in the previous studies. More precisely, we adopt multiple VR tests suggested by Whang and Kim (2003) and Kim (2006), in addition to the conventional Chow-Denning (1993) test, to examine the RWH for the Shanghai and Shenzhen stock markets.

The rest of this paper is organized as follows. Section 2 summarizes the characteristics of the data on Chinese stock markets. Section 3 discusses the variance ratio tests. Section 4 reports the empirical results. The conclusion is drawn in Section 5.

Insert Table 1 here

2 Data and summary statistics

The data used in this study are daily closing price stock indices for Chinese stock exchanges in Shanghai and Shenzhen for A and B shares. The data comes from Thomson Financial Datastream. The time period covered is from January 3 and February 24, 1992 to July 6, 2007 for the Shanghai A and the Shanghai B, respectively, and from October 5, 1992 to July 6, 2007 for the Shenzhen A and B.

Table 2 presents summary statistics for the stock returns calculated as the first differences in the logs of the stock price indexes. For the SSE, as shown in previous studies (e.g., Chakravarty et al., 1998; Groenewold et al., 2001), the A shares have higher returns than B shares. In contrast, the A-shares returns are slightly smaller than the B-shares returns for the SZE. All the returns are highly non-normal, i.e. showing evidence of significant positive skewness and excess kurtosis, as might be expected from daily stocks returns. The Lagrange Multiplier test for the presence of the ARCH effect indicates clearly that all stocks show strong conditional heteroscedasticity, which is a common feature of financial data.

Insert Table 2 here

3 The variance ratio tests

Since the seminal work of Lo and MacKinlay (1988, 1989) and Poterba and Summers (1988), the standard variance ratio [VR] test or its improved modifications have been widely used for testing market efficiency[8].

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[8]See Hoque, Kim and Pyun (2007) and Charles and Darné for a review.

The VR methodology consists of testing the random walk hypothesis [RWH] against stationary alternatives, by exploiting the fact that the variance of random walk increments is linear in all sampling intervals, i.e., the sample variance of k-period return is k times the sample variance of one-period return. The VR at lag k is then defined as the ratio between $(1/k)$th of the k-period return to the variance of the one-period return. Hence, for a random walk process, the VR should be equal to 1 for all values of k.

Let x_t be an asset return at time t, where $t = 1, \ldots, T$. It is assumed that x_t is a realization of the underlying stochastic process X_t, which follows a martingale difference sequence. This means that X_t's are serially uncorrelated, but are allowed to be conditionally or unconditionally heteroscedastic. Following Wright (2000), the VR statistic be written as

$$VR(x;k) = \left\{ (Tk)^{-1} \sum_{t=k}^{T} (x_t + \cdots + x_{t-k+1} - k\hat{\mu})^2 \right\} \div \left\{ T^{-1} \sum_{t=1}^{T} (x_t - \hat{\mu})^2 \right\} \qquad (1)$$

where $\hat{\mu} = T^{-1} \sum_{t=1}^{T} x_t$. This is an estimator for the unknown population VR, denoted as $V(k)$, which is the ratio of $1/k$ times the variance of the k-period return to the variance of the one-period return. If the stock return follows a random walk, the expected value of $VR(x;k)$ should be equal to unity for all horizons k. If this ratio is less than one at long horizons, then we have indications of negative serial correlation (mean-reversion) and ratios greater than one at long horizons implies positive serial correlation (mean-aversion).

Lo and MacKinlay (1988) proposed the asymptotic distribution of $VR(x;k)$ by assuming that k is fixed when $T \rightarrow \infty$. They show that under the assumption of conditional heteroscedasticity, then under the null hypothesis that $V(k) = 1$, the test statistic $M(x;k)$ is given by[9]

$$M(x;k) = \frac{VR(x;k) - 1}{\phi^*(k)^{1/2}} \qquad (2)$$

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[9]Lo and MacKinlay (1988) also propose a test statistic under the assumption of homoscedasticity. We focus only on VR statistic which is robust under heteroscedasticity since, as shown in Section 3, all the data display heteroscedasticity.

follows the standard normal distribution asymptotically, where

$$\phi^*(k) = \sum_{j=1}^{k-1} \left[\frac{2(k-j)}{k} \right]^2 \delta(j)$$

$$\delta(j) = \left\{ \sum_{t=j+1}^{T} (x_t - \hat{\mu})^2 (x_{t-j} - \hat{\mu})^2 \right\} \div \left\{ \left[\sum_{t=1}^{T} (x_t - \hat{\mu})^2 \right]^2 \right\}$$

3.1 Chow and Denning (1993) tests

Chow and Denning (1993) provide a multiple VR test for the joint null hypothesis $V(k_i) = 1$ for $i = 1, \ldots, m$ against the alternative that $V(k_i) \neq 1$ for some holding period k_i. The (heteroscedasticity-robust) test statistic can be written as

$$MV(x;k_i) = \sqrt{T} \max_{1 \leq i \leq m} |M(x;k_i)| \qquad (3)$$

This is based on the idea that the decision regarding the null hypothesis can be made based on the maximum absolute value of the individual VR statistics. The statistic follows the studentized maximum modulus [SMM] distribution with m and T degrees of freedom, i.e. $SMM(\alpha, m, T)$, where m is the number of k values, whose critical values are tabulated in Stoline and Ury (1979). When T is large, the null hypothesis is rejected at α level of significance if the $MV(x;k_i)$ statistic is greater than the $[1 - (\alpha^*/2)]$th percentile of the standard normal distribution where $\alpha^* = 1 - (1 - \alpha)^{1/m}$.

3.2 Whang and Kim (2003) test

Whang and Kim (2003) develop a multiple VR test which uses a subsampling technique of Politis, Romano and Wolf (1997), which is a data-intensive method of approximating the sampling distribution.

To test the joint null hypothesis that $V(k_i) = 1$ $(i = 1, \ldots, m)$ against $V(k_i) \neq 1$ (for some k_i), Whang and Kim (2003) consider the statistic

$$MV_T = \sqrt{T} g_N(x_1, \ldots, x_T) \qquad (4)$$

where $g_t(x_1, \ldots, x_T) = \max_{1 \leq i \leq m} |M_r(x;k_i)|$ with $M_r(x;k_i) = VR(x;k_i) - 1$, and $VR(x;k)$ is as defined in (1). The sampling distribution function for the MV_T statistic is written as

$$G_T(x) = P\left(\sqrt{T}g_t(x_1,\ldots,x_T) \leq x\right)$$

They show that the asymptotic null distribution of the statistic is that of a maximum of a multivariate normal vector with unknown covariance matrix, which is complicated to estimate. Therefore, they propose to approximate the null distribution by means of the subsampling approach.

Consider a subsample $(x_t,\ldots,x_{t-b+1})$ of size b for $t = 1,\ldots,T-b+1$. The statistic MV_T calculated from the subsample is denoted as $g_{T,b,t} = g_b(x_t,\ldots,x_{t-b+1})$. Then, $G_T(x)$ is approximated by the distribution function obtained by the collection of $g_{T,b,t}$'s calculated from all individual subsamples. It can be written as

$$\hat{G}_{T,b}(x) = (T-b+2)^{-1}\sum_{t=0}^{T-b+1} l\left(\sqrt{b}g_{T,b,t} \leq x\right)$$

where $l(.)$ is the indicator function that takes 1 if the condition inside the bracket is satisfied and 0 otherwise.

The $100(1-\alpha)\%$ critical value for the test can be calculated as the $(1-\alpha)$th percentile of $\hat{G}_{T,b}$, while the p-value of the test is estimated as $1 - \hat{G}_{T,b}(MV_T)$. The null hypothesis that $V(k_i) = 1$ $(i = 1,\ldots,m)$ is rejected at the level of significance α if the observed MV_T is greater than this critical value or if the p-value is less than α. To implement the subsampling technique, a choice of block length b should be made. Whang and Kim (2003) recommend that a number of block lengths from an equally spaced grid in the interval of $[2.5T^{0.3}, 3.5T^{0.6}]$ be taken. However, they find that the size and power properties of their test are not sensitive to the choice of the block length.

3.3 Kim (2006) test

Kim (2006) uses the wild bootstrap which is a resampling method that approximates the sampling distribution of the VR test statistic, and is applicable to data with unknown forms of conditional and unconditional heteroscedasticity (Mammen, 1993).

The wild bootstrap is applied to Chow-Denning, $MV(x;k_i)$, VR test. The wild bootstrap test based on $MV(x;k_i)$ can be conducted in three stages as below

(i) Form a bootstrap sample of T observations $x_t^* = \eta_t x_t$ $(t = 1,\ldots,T)$ where η_t is a random sequence with $E(\eta) = 0$ and $E(\eta^2) = 1$.

(ii) Calculate $MV^* = MV(x^*;k_i)$, the $MV(x^*;k_i)$ statistic obtained from the bootstrap sample generated in stage (i).

(iii) Repeat (i) and (ii) sufficiently many, say m, times to form a bootstrap distribution of the test statistic $\{MV(j)\}_{j=1}^{m}$.

The bootstrap distribution $\{MV(j)\}_{j=1}^{m}$ is used to approximate the sampling distribution of the $MV(x;k_i)$ statistic. The p-value of the test can be obtained as the proportion of $\{MV(j)\}_{j=1}^{m}$ greater than the $MV(x;k_i)$ statistic calculated from the original data. Following Kim (2006) we use the standard normal distribution for η_t to implement the wild bootstrap test[10].

4   Empirical findings

Table 3 reports the multiple VR test results. The test statistic is displayed for the Chow-Denning (MV) test, while the p-values are reported for the Kim (MV^*) and Whang-Kim (WK) tests. The holding periods (k_i's) considered are (2, 5, 10, 20, 40). As advocated by Deo and Richardson (2003), we use relatively short holding periods when testing for the mean reversion using VR tests. For the wild bootstrap test (MV^*), the number of bootstrap replications m is set to 1000.

The WK test shows rejection of RWH for the four Chinese stock markets, as the p-values are less than 1%. The MV and MV^* confirm this result but only for B shares in the SSE and the SZE. Therefore, the Class B shares do not follow the RWH, which suggests that institutional investors do not play a role in explaining results of weak form efficiency tests. This result is similar to those obtained by Lima and Tabak (2004). Contrary to the WK test, the MV and MV^* tests accept the null hypothesis of efficiency for the Class A shares. Moreover, Kim (2006) shows that the MV^* test gives higher power than the WK test, except when the sample size is very small[11].

This result allows to conclude, with caution, that the Class A shares seem to follow the RWH. In this case, liquidity and market capitalization may play a role in explaining results of weak form efficiency tests. The results on the Class A shares contrast with those obtained by Darrat and Zhong (2000), Ma and Barnes (2001) and Lee, Chen and Rui (2001) who reject the RWH for Class A shares in the SSE and the SZE. This can be explained by the fact that these authors employed the individual Lo-MacKinlay VR test rather than multiple VR tests[12]. Consequently, Class B shares seem to be less

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[10]Kim (2006) reports that other choices provided qualitatively similar sample results.

[11]The Monte Carlo experiment results reported in Whang and Kim (2003) confirm that their VR test show excellent power in very small samples.

[12]Our results are confirmed when we run the multiple VR tests over the same periods used by Darrat and Zhong (2000), Ma and Barnes (2001) and Lee, Chen and Rui (2001). The results are available upon request.

efficient than Class A shares. One possible explanation for the greater inefficiency of Class B shares is information asymmetry. In particular, foreign investors in Class B shares may have an information disadvantage relative to domestic investors trading Class A shares due to language barriers, different accounting standards and the lack of reliable information about local firms (Chakravarty et al., 1998; Chan et al., 2006).

Insert Table 3 here

As shown by Groenewold et al. (2003), the banks have a traditional importance in the Chinese financial system, and thus the important changes in the relationship between the banks and the stock market in 1996 and 2000 could have significant effects on the efficiency of the Chinese stock markets. More precisely, until 1996 banks had a dominant influence on the stock market. In 1996, regulations were further tightened by preventing banks from offering loans for stock transactions. The aim of these was to encourage independent competitive firms as brokers and sources of funds such as mutual funds independent of the banks. In early 2000 the 1996 regulations were reversed and banks resumed their positions as important sources of funds for stock investment (Surry, 2000). Moreover, in February 2001 the Chinese government adopted a more liberal policy that allowed domestic investors to invest in B-share markets, which were only available to foreign investors. This change could also affect the efficiency of the Chinese stock markets for B shares.
We investigated these questions by re-running the multiple VR tests for the Shanghai A and B shares and the Shenzhen A and B shares for the following subperiods: 06/10/1992–30/06/1996[13], 01/07/1996–31/12/1999, 01/01/2000–28/02/2001 and 01/03/2001–06/07/2007. The results are reported in Tables 4–7.

The results for Class A in both the Shanghai and Shenzhen stock exchanges show efficiency. The multiple VR tests find the non-rejection of RWH over the four subperiods[14]. Therefore, the changes in the relationship between the banks and the stock market do not affect the efficiency of Class A for Chinese stock markets. This result suggests that the exclusion of the banks have not improved the efficiency of the stock market. This is consistent with the liquidity explanation, that the banks are important sources of liquidity and that excluding them from involvement in the stock market may make for a more competitive and diversified brokerage industry in the long

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[13]The first subperiod begins in 03/01/1992 and 24/02/1992 for Shanghai A and B shares, respectively.

[14]Only the WK test reject RWH on the sub-period 2001–2007 for the two Class A shares and on the sub-period 1992–1996 for the Shanghai A share but the MV^* test gives higher power than the WK test (Kim, 2006).

run but in the short run reduces the amount of trading in the market and so slows the information diffusion (Groenewold et al., 2003).

The results for Class B in both the Shanghai and Shenzhen stock exchanges are mixed. The multiple VR tests reject the RWH over the sub-periods 1992–1996 and 1996–1999 while this hypothesis is not rejected over the sub-period 2000–2001, showing that the efficiency improved when banks permitted to re-enter the stock market in 2000. However, the RWH seems to be again rejected over the sub-period 2001–2007 after the B-shares opening to domestic Chinese investors, implying inefficiency during this period. This result should be taken with caution because the VR tests are close to their 5% significant level. Nevertheless, the test statistics of the multiple VR tests decreased after 2001 compared to before 2000, suggesting that the relaxation of restrictions on domestic investor participation in Class B shares has had a positive impact on pricing efficiency in the B-share market.

Insert Tables 4–7 here

5   Conclusion

This study has examined the weak-form efficiency of the Chinese stock markets, especially for the Shanghai and Shenzhen stock markets for both A and B shares, using new and conventional multiple variance ratio statistics. These tests, which are robust to heteroscedasticity, are the Whang-Kim's (2003) subsampling test and Kim's (2006) bootstrap test, which do not rely asymptotic approximations, as well as the Chow-Denning (1993) test. In addition, the paper investigated the impact on Chinese stock market efficiency following the changes in the relationship between the banks and the stock market as well as the regulatory change that widened the B-share market to include domestic investors.

The results suggest that Class A shares appear more efficient than Class B shares, implying that liquidity, market capitalization and information asymmetry can play a role in explaining the weak-form efficiency. Class B shares for Chinese stock exchanges do not follow the random walk hypothesis and therefore are significantly inefficient, but they become efficiency after the re-entry of banks in the stock market. However, Class B shares seems to appear inefficient after the B-shares opening to domestic Chinese investors. Nevertheless, the entry of Chinese investors to the B-share market have positively impacted the B-share market efficiency. Further research should investigate the effects of the re-entry of banks and the entry of domestic investors on the efficiency of Class B shares.

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Table 1: Selected studies on the EMH for Chinese stock markets.

Studies	Sample	Methodologies	Comments
Wu (1996)	1992–1993 (M)	Serial correlation	EMH for Shanghai and Shenzhen (individual shares)
Laurence et al. (1997)	1993–1996 (D)	Serial correlation	EMH for A-shares but not for B-shares
Liu et al. (1997)	1992–1995 (D)	Dickey-Fuller unit root	EMH for Shanghai and Shenzhen
Mookerjee and Yu (1999)	1990–1993 (M)	Serial correlation and run	not EMH for Shanghai and Shenzhen
Long et al. (1999)	1992–1994 (W)	Lo-MacKinlay VR	EMH for Shanghai (A and B-shares)
Darrat and Zhong (2000)	1990–1998 (W)	Lo-MacKinlay VR	not EMH for Shanghai and Shenzhen (A-shares)
Ma and Barnes (2001)	1990–1998 (D, W, M)	Serial correlation, run and Lo-MacKinlay VR	not EMH for Shanghai (A and B-shares) and Shenzhen (B-shares)
Lee, Chen and Rui (2001)	1990–1997 (D)	Lo-MacKinlay VR	not EMH for Shanghai and Shenzhen (A and B-shares)
Groenewold et al. (2003)	1992–2001 (D)	Dickey-Fuller and Phillips-Perron unit root	EMH for Shanghai and Shenzhen (A and B-shares)
Seddighi and Nian (2004)	2000–2000 (D)	Serial correlation and Dickey-Fuller unit root	not EMH for Shanghai
Lima and Tabak (2004)	1992–2000 (D)	Lo-MacKinlay and Cecchetti-Lam VR	EMH for A-shares but not for B-shares
Fifield and Jetty (2008)	1996–2005 (D)	Lo-MacKinlay and Wright VR	EMH for A-shares but not for B-shares

Notes: D: daily; W: weekly; M: monthly. EMH: efficiency market hypothesis.

Table 2: Summary statistics of stock returns (1992–2007).

Stock market	Obs.	Mean (% daily)	SD (% daily)	Skewness	Kurtosis	ARCH(10)
Shanghai A	4047	0.0643	2.7442	6.0618*	151.9544*	23.0674**
Shanghai B	4011	0.0180	2.1851	0.3612*	8.5989*	545.2869*
Shenzhen A	3850	0.0355	2.2605	0.9071*	21.9627*	323.9831*
Shenzhen B	3850	0.0401	2.1536	0.3086*	10.6953*	657.5540*

Notes: The skewness and kurtosis statistics are standard-normally distributed under the null of normality distributed returns. ARCH(10) indicates the Lagrange multiplier test for conditional heteroscedasticity with 10 lags. * and ** means significant at 1% and 5% level, respectively.

Table 3: Multiple VR test results (1992–2007).

	MV	MV^*	WK					
			Block lengths					
			98	166	234	302	370	438
Shanghai A	2.020	0.092	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
Shanghai B	5.834*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
Shenzhen A	1.625	0.254	0.000*	0.000*	0.000*	0.004*	0.004*	0.000*
Shenzhen B	5.646*	0.000*	0.000*	0.000*	0.000*	0.000*	0.007*	0.034*

MV: Chow-Denning test; MV^*: Kim test; WK: Whang-Kim test; * means significant at 1% level. The 1% critical value for the Chow-Denning test is 3.022. Following Whang and Kim (2003), block lengths are chosen from an equally spaced grid in the interval $[2.5T^{0.3}, 3.5T^{0.6}]$.

Table 4: Multiple VR test results (1992–1996).

	MV	MV^*	WK					
			Block lengths					
			51	82	113	144	175	206
Shanghai A	1.920	0.129	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
Shanghai B	5.006*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
Shenzhen A	0.718	0.817	0.989	0.811	0.732	0.712	0.691	0.709
Shenzhen B	2.881**	0.001*	0.000*	0.000*	0.000*	0.000*	0.032*	0.060

MV: Chow-Denning test; MV^*: Kim test; WK: Whang-Kim test; * and ** mean significant at 1% and 5% level, respectively. The 1% and 5% critical values for the Chow-Denning test are 3.022 and 2.491, respectively. Following Whang and Kim (2003), block lengths are chosen from an equally spaced grid in the interval $[2.5T^{0.3}, 3.5T^{0.6}]$.

Table 5: Multiple VR test results (1996–1999).

	MV	MV^*	WK					
			Block lengths					
			46	73	100	127	154	181
Shanghai A	0.546	0.906	1.000	0.874	0.808	0.748	0.816	0.880
Shanghai B	3.215*	0.008*	0.000*	0.000*	0.000*	0.000*	0.000*	0.014*
Shenzhen A	1.518	0.286	0.000*	0.012*	0.102	0.080	0.050*	0.083
Shenzhen B	3.510*	0.004*	0.000*	0.000*	0.000*	0.000*	0.007*	0.019*

MV: Chow-Denning test; MV^*: Kim test; WK: Whang-Kim test; $*$ means significant at 1% level. The 1% critical value for the Chow-Denning test is 3.022. Following Whang and Kim (2003), block lengths are chosen from an equally spaced grid in the interval $[2.5T^{0.3}, 3.5T^{0.6}]$.

Table 6: Multiple VR test results (2000–2001).

| | MV | MV^* | WK | | | | | |
| | | | Block lengths | | | | | |
			26	39	52	65	78	91
Shanghai A	1.006	0.718	1.000	0.958	0.773	0.613	0.640	0.524
Shanghai B	0.693	0.858	1.000	1.000	0.984	0.916	0.756	0.774
Shenzhen A	0.911	0.758	1.000	1.000	0.972	0.811	0.707	0.627
Shenzhen B	0.617	0.934	1.000	1.000	0.881	0.529	0.582	0.628

MV: Chow-Denning test; MV^*: Kim test; WK: Whang-Kim test; * means significant at 1% level. The 1% critical value for the Chow-Denning test is 3.022. Following Whang and Kim (2003), block lengths are chosen from an equally spaced grid in the interval $[2.5T^{0.3}, 3.5T^{0.6}]$.

Table 7: Multiple VR test results (2001–2007).

| | MV | MV^* | WK | | | | | |
| | | | Block lengths | | | | | |
			62	101	140	179	218	257
Shanghai A	1.322	0.430	0.000*	0.000*	0.003*	0.001*	0.001*	0.000*
Shanghai B	2.590**	0.015*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
Shenzhen A	2.202	0.063	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*
Shenzhen B	2.454	0.018*	0.000*	0.000*	0.000*	0.000*	0.000*	0.000*

MV: Chow-Denning test; MV^*: Kim test; WK: Whang-Kim test; * and ** mean significant at 1% and 5% level, respectively. The 1% and 5% critical values for the Chow-Denning test are 3.022 and 2.491, respectively. Following Whang and Kim (2003), block lengths are chosen from an equally spaced grid in the interval $[2.5T^{0.3}, 3.5T^{0.6}]$.