CREATES

Center for Research in Econometric Analysis of Time Series

CREATES Research Paper 2008-15

Testing for Expected Return and Market Price of Risk in Chinese A-B Share Market: A Geometric Brownian Motion and Multivariate GARCH Model Approach

Jie Zhu

School of Economics and Management
University of Aarhus
Building 1322, DK-8000 Aarhus C
Denmark

Aarhus School of Business
University of Aarhus

Handelshøjskolen
Aarhus Universitet

UNIVERSITY OF
COPENHAGEN

Testing for Expected Return and Market Price of Risk in Chinese A-B Share Market: A Geometric Brownian Motion and Multivariate GARCH Model Approach*

Jie Zhu†
University of Aarhus and CREATES

March 4, 2008

Abstract

There exist dual-listed stocks which are issued by the same company in some stock markets. Although these stocks bare the same firm-specific risk and enjoy identical dividends and voting policies, they are priced differently. Some previous studies show this seeming deviation from the law of one price can be solved due to different expected return and market price of risk for investors holding heterogeneous beliefs. This paper provides empirical evidence for that argument by testing the expected return and market price of risk between Chinese A and B shares listed in Shanghai and Shenzhen stock markets. Models with dynamic of Geometric Brownian Motion are adopted, multivariate GARCH models are also introduced to capture the feature of time-varying volatility in stock returns. The results suggest that the different pricing can be explained by the difference in expected returns between A and B shares in Chinese stock markets. However, the difference between market prices of risk is insignificant for both markets if GARCH models are adopted.

JEL classifications: C1; C32; G12

Keywords: China stock market; market segmentation; expected return; market price of risk; GBM; GARCH

*I gratefully acknowledge the financial support from the Center for Research in Econometric Analysis of Time Series, CREATES, funded by the Danish National Research Foundation. I would also like to thank Bent Jesper Christensen, Carsten Sørensen, David Allen, Hongfei Jin, an anonymous referee, and participants at the Conference Time Series Econometrics, Finance and Risk, the 4th China International Conference on Finance and the 6th Global Conference on Business and Economics for helpful comments. The support from Shanghai Stock Exchange data service is greatly appreciated. Any remaining errors are my own.

†Address correspondence: Jie Zhu, School of Economics and Management, Building 1323, University of Aarhus, DK-8000 Aarhus C, Denmark. E-mail: jzhu@econ.au.dk

1 Introduction

Some equity markets, including developed and emerging ones, allow listed companies to issue different types of stocks. It is common that these stocks share the same firm-specific risk and in most cases also enjoy the same dividend and voting policy, the only difference between these shares is the restriction to investors, i.e. who can own the stocks. One typical adoption is to segment investors by their citizenship, for example, a company can issue two types of stocks, one is available to domestic investors and the other is otherwise identical but only available to foreign investors. Such kind of segmented issuance strategy has attracted a lot of research interests, partly because of the interest in studying which benefits can be obtained from the strategy, and more importantly, because of the arising of so-called pricing puzzle problem. It is called a puzzle in some sense because these shares often have different market prices, yet they are completely identical except for holding by different investors. Hietala (1989) provides a pioneering paper in this area by analyzing data for Finnish stock market and concludes that there is significant price premium for foreign investors. Later Lam & Pak (1993) investigate Singaporean market, followed by Bailey (1994), Bailey & Jagtiani (1994), Stulz & Wasserfallen (1995) and Domowitz, Glen & Madhavan (1997) for studies of China, Thailand, Switzerland and Mexico markets respectively. Most of these research confirms the findings by Hietala (1989): foreign investors are willing to pay higher price than domestic ones, i.e. there exists foreign price premium, except Bailey (1994) for the case of China. All of these studies agree that there is significant price difference between shares offered to domestic and foreign investors. Later on, Bailey, Chung & Kang (1999) provide a survey on 11 countries, they conclude that the stock markets in all of these countries include segmentation restrictions, and foreign investors are usually facing a higher price compared to domestic ones. A lot of attentions have been paid to find out the reasons for the pricing difference. Hietala (1989) and some others find that the difference is contributed to different required return between domestic and foreign investors, but Bailey et al. (1999) find little empirical evidence supporting this conclusion and argue that the difference is due to market liquidity, asymmetric information available to investors and some other firm-specific factors. Stulz & Wasserfallen (1995) conclude that the different demand elasticity for securities between domestic and foreign investors can largely explain the pricing difference.

The case for Chinese stock market is more interesting. Contrary to most other stock markets which have foreign price premium, the Chinese stock market allows foreign investors to pay a much lower price than domestic ones. Bailey (1994) is the first one to notice this issue and he concludes that this foreign price discount can hardly be explained by the correlation between B shares (which are available for foreign investors and have price discount compared to A shares, which are only available for domestic investors, more details in Section 2) returns and international stock index returns. From then, an increasing number of papers are contributed on this topic, trying to explain the issue through either theoretical or empirical approaches. For example, Fernald & Rogers (2002) illustrate theoretically that the B-share discount is consistent with CAPM, it is due to higher expected return required by foreign investors. Su (1999) agrees with this conclusion via empirical approaches, he claims that the spread between the expected domestic and foreign share excess returns is related to differences in individual shares' market beta coefficients. In the same year, Gordon & Li (1999) state that the B-share discount is consistent with different demand elasticity holding by domestic and foreign investors and conclude that domestic investors have more inelastic demand for stocks, which is also supported by Sun & Tong (2000) and Diao & Levi (2005). Karolyi & Li (2003) analyze the time series of stock data prior to and after February 19, 2001, on which date domestic investors are allowed to trade B shares. Their conclusion is that B-share discount is closely related to market capitalization and substantial past-return momentum but unrelated to the firm's risk and liquidity attributes. There are also some papers which propose other explanations for price differences. For example, Sarkar, Charkravarty & Wu (1998), Chui & Kwok (1998), Chen, Lee & Rui (2001) and Yang (2003) investigate the information held by domestic and foreign investors and state that the B-share discount is due to information asymmetry between segmented investors. However, these papers fail to reach agreement on which investors, foreign ones or domestic ones, are better informed. Recently, Mei, Scheinkman & Xiong (2005) attribute the puzzle to the different speculative motives between different investors via empirical analysis.

Thus up to now, there are a number of papers contribute to the solution of B-share discount problem in Chinese Stock Market, yet the conclusion is still ambiguous. Furthermore most of these researches are focusing on studying price differences directly, applying asset pricing models and comparing different beta coefficients. This paper tries to make contribution to the existing literature by studying expected returns in A and B shares instead of studying prices directly. There are several reasons to make this approach interesting: 1) It is straightforward to show that expected return and price are closely related, studying differences in expected return is more or less equal to studying price differences. 2) Enough data is now available to make sure that the estimated expected returns are asymptotically unbiased. 3) By applying appropriate models, we can decompose expected return into different factors and thus study the effect of these factors on price differences separately.

The Geometric Brownian Motion is adopted as a benchmark and we show that under this assumption the price difference is consistent with difference in expected returns. In addition, we know that market price of risk measures the trade-off between risk and return of an asset, i.e. the increase of expected returns demanded per additional unit of risk. Basak (2005) argues that investors holding heterogeneous beliefs will have different market price of risk even for the same investment. Since A and B shares have the same payoff streams but are held by different investors, we can test their market price of risk to see whether an investor's belief matters for the price difference. The intuition behind the analysis is straightforward: since the corresponding A and B shares are issued by the same company and have identical voting policy and dividend right, if we take the company-specific fundamentals as given and assume that the prices of the corresponding A share and B share are derived from the fundamentals, then their market price of risk should be identical: since they share the same company-specific risk, if investors view the firm-specific risk as the only risk they bear, then they should have the same market price of risk; on the other hand if the market price of risk is different, it indicates that although sharing the same firm-specific risk, A and B shares are considered to be in different market risk levels and thus are expected to have different excess returns for investors. Furthermore, besides the comparison of market price of risk for individual A-B couples, we can also stack all A shares or B shares returns and test the averaged market price of risk for the two groups. This test is robust to the individual result since it takes average of the individual estimators and thus provides us more intuitive results for A and B shares as a whole.

No previous studies have tried to describe the dynamics of stock prices in time series models for Chinese stock market. This may be partly due to the lack of enough data. As suggested by Hwang & Pedro (2006), a relatively large sample is necessary to approximate the asymptotic distribution of the estimators and related t-statistics in GARCH-class models, which is a luxury condition for pioneering studies of the Chinese stock market since the market has resumed at the beginning of 1990s. However the market has developed for 16 years and sufficient data is now available, it will be interesting to estimate these time series dynamic models. In the following context, the stock prices are assumed to behave as Geometric Brownian Motion (GBM) by adopting different forms for drift and volatility terms. First we estimate the constant drift and volatility, then decompose the drift term into risk-free rate and market price of risk multiplying volatility. The market price of risk is assumed to be constant and time independent. The couples of the corresponding A- and B-share returns are assumed to follow Bivariate Normal Distribution and Maximum Likelihood Method is adopted to estimate the parameters, t-statistics are provided to show the significance of the difference between market price of risk for the pairs. Next in order to capture the time-varying property of volatility, multivariate GARCH model with Dynamic Conditional Correlation (GARCH-DCC) is applied to estimate the volatility term and t-test is re-done based on this new specification.

The rest of the paper is organized as follows: Section 2 gives a brief background of Chinese Stock Market, in Section 3 the econometric methodology is presented, Section 4 describes the data and reports the empirical results and Section 5 concludes.

2 The Chinese Stock Market and Twin Shares

Some literature has provided detailed reviews on China's stock market. For those who are interested in this topic, Green (2004) will be a good reference.

The Chinese stock market is relatively young, yet it develops fast with its specific characteristics. The two stock exchanges, Shanghai Stock Exchange (SSE) and Shenzhen Stock Exchange (SZE) were launched in 1990 and 1991 respectively. Since then the stock market has undergone a rapid development. The Shanghai Stock Exchange, for example, with only 8 listed stocks when it was open to investors, has developed into a market with 837 listed companies and 996 listed securities by the end of 2004, similar story holds for the Shenzhen Stock Market, which has 536 listed companies and 673 listed securities by the end of 2004. The total stock market value including both Exchanges reaches $457 billion. Table 1 presents market overview for both Exchanges.

Table 1 about here

As discussed by Mei et al. (2005) and some others, one characteristic for Chinese stock market is that it is highly government-controlled and the market is at most a partially privatized one. The Chinese Securities Regulatory Commission (CSRC), which is under direct leadership of State Council, is fully responsible for the administration of security market, especially for IPOs and seasoned stock offerings (SEOs). Chinese companies need approval from CSRC to sell their equity and to be listed, the process will be affected by some non-market factors and it is not unusual for a company to wait several years before it is allowed to be listed. Such kind of strict restrictions prevent companies from taking advantage of favorable market conditions to sell their shares. Similarly, companies are also prohibited to buy back their own shares when stock price falls below the fundamental value due to the restriction of Chinese Corporate Law. On the other hand, many of the listed companies are the former State-Owned Enterprises (SOEs). Before being listed, these companies are 100% owned by the State. When they go public, a majority share of equity is still kept by the State, usually accounting for no less than 50%. In addition, most companies will also hold retained shares for legal persons (companies) and internal employees. In total the State-retained shares, legal person shares and employee shares will account for 60% – 70% of equity and only the rest goes to market and is publicly traded.

Another interesting feature in Chinese stock market is the twin shares issue. In order to keep the stabilization of the domestic capital market, yet meanwhile being able to attract foreign investors to the domestic market (as argued in Fernald & Rogers (2002)), CSRC establishes separate classes of shares for domestic Chinese residents and foreigners. Other than for who can own them and by which currencies are traded, the shares are legally identical, with the same voting rights and dividends. Domestic-only shares (known as A shares) are listed in either Shanghai or Shenzhen; foreign-only shares (B shares) are listed in the same market where the corresponding A share is listed[1] and cross-listing is not allowed. In 2004 there are 86 companies have issued both A and B shares. In both markets A shares are traded in Chinese Yuan and B shares are traded in US Dollar in Shanghai and traded in Hong Kong Dollar in Shenzhen. Foreigners cannot trade in A shares and domestic investors are not allowed to trade in B shares.[2]

The relatively short time of development, the strict capital constraints to foreign investors, the at-most partially privatization and some other specific characteristics of Chinese stock market make it weakly correlated with other major equity markets in the world. As early as in 1994, at the beginning period of the market, Bailey states that the A shares and B shares "exhibit little association with instruments for international risk premiums". It is interesting to see whether the situation has changed afterward. Table 2 presents the estimated correlations between index returns, the indices selected from Chinese stock market are Shanghai A-share Index (SHA), Shanghai B-share Index (SHB), Shenzhen A-share Index (SZA) and Shenzhen B-share Index (SZB). The other indices are selected from major stock markets in the world: Hong Kong Hang Seng Index, Japan Nikkei 225 Index, US S&P 500 and Germany Dax Index, two from Asian markets, one from American and another one from European.

[1]Some foreign-only shares are also listed in Hong Kong stock exchange (H shares) or New York stock exchange (N shares). However H shares and N shares are not allowed to be listed in Shanghai or Shenzhen. Thus they are not included in the study in this paper.

[2]In February 2001, China announced and implemented plans to allow domestic investors to trade in B shares as long as they hold authorized foreign currencies account. In 2003 institutional foreign investors were allowed to trade in A shares if they were approved to do so by CSRC and got the title as Qualified Foreign Institutional Investors (QFII). However, the qualification process of QFII is strict and limited, in addition, due to the capital control, there are restrictions with regarding to free conversion between Chinese Yuan and Foreign currencies. Thus some constraints still exist for across-board trading between A and B shares.

Table 2 about here

From Table 2, we can see that there is a relatively higher correlation between SHA and SHB, yet SZA and SZB have a weaker correlation. The correlations between other major indices are much higher than the correlations between these major indices and Chinese indices, but there is no significant difference between the correlations of Chinese A-share indices and the other major indices compared to the correlations of Chinese B-share indices and the other major indices. This result is somewhat similar to Bailey's (1994) conclusion but with a little difference. In that paper, he considers the correlations between Chinese indices and other world market indices up to then, suggesting that "B shares have considerable diversification value but are not entirely segmented from global financial conditions", yet here we can see there is no distinguished difference of the diversification value between A shares and B shares, if foreign investors are also able to invest in A shares.

The pricing deviation between A and B shares arises from the fact that almost all B shares are priced at a great discount compared to corresponding A shares. Define the market-value weighted B-share discount at time t (MVWBSD_t) as follows:

$$MVWBSD_t = \sum_{i=1}^{n} \frac{\text{market value of stock } i_t}{\text{total market value}_t} \frac{S_{Bi,t} - S_{Ai,t}}{S_{Ai,t}} \quad (1)$$

Where n is the number of stocks, $S_{Ai,t}$ and $S_{Bi,t}$ are A and B share price of stock i at time t.[3]

Figure 1 about here
Figure 2 about here

Figure 1 and Figure 2 depict the market-value weighted B-share discount from Jan. 1, 1997 to Jun. 30, 2005, using the daily data. The figures are obtained by applying (1) to calculate the B-share discount. From the figures we can see that B shares are traded at a lower price than A shares over the whole period, the B-share discount reaches its deepest fall in 1999, which is -0.87 and -0.82 for Shanghai and Shenzhen market respectively,

[3] Since A and B shares are traded in different currencies, in order to make their prices comparable, before calculating the B-share discount, I first convert B shares' prices at time t into Chinese yuan according to the corresponding spot exchange rate at time t.

which means that B shares are priced less than 20% of A shares on average at that time. Also note that the absolute value of discount decreases drastically after February 2001 due to the policy release that allows domestic investors to trade B shares. We can also observe that although the dynamics are similar, the B-share discount is larger for Shanghai than for Shenzhen, both for the extreme values and for average movements. Anyway it is obvious that there exists significant B-share discount. In next section I will present a model which tries to explain the B-share discount by analyzing expected returns for A and B shares.

3 Methodology Approach

3.1 The Dynamic Setup of Stock Prices

Consider a company issues A and B shares, assume the dynamics of both shares satisfy the following Stochastic Differential Equations (SDE):

$$dS_{At} = \mu(t, S_{At})dt + \sigma(t, S_{At})dW_{At} \quad (2)$$

$$dS_{Bt} = \mu(t, S_{Bt})dt + \sigma(t, S_{Bt})dW_{Bt} \quad (3)$$

and

$$dW_{At}dW_{Bt} = \rho dt$$

S_{At} and S_{Bt} are the prices of A and B shares respectively, $\mu(t, S_t)$ and $\sigma(t, S_t)$ denote the drift and volatility of stock price process and both are deterministic function of t and S_t, W_{At} and W_{Bt} are the corresponding Wiener process for A and B shares, and ρ is the correlation coefficient between them.

Generally speaking it is hard to solve the SDEs analytically. However in some cases it can be done if we assume some specific form for $\mu(t, S_t)$ and $\sigma(t, S_t)$. The most widely-used model is based on the assumption that stock prices follow Geometric Brownian Motion (GBM), in that case, the SDEs (2) and (3) can be expressed as

$$dS_{At} = \mu_A S_{At}dt + \sigma_A S_{At}dW_{At} \quad (4)$$

$$dS_{Bt} = \mu_B S_{Bt}dt + \sigma_B S_{Bt}dW_{Bt} \quad (5)$$

and again

$$dW_{At}dW_{Bt} = \rho dt$$

i.e. both the drift and volatility terms are constant. we can solve (4) and (5) to get the following solutions:

$$S_{AT} = S_{At}\exp[(\mu_A - \frac{1}{2}\sigma_A^2)(T-t) + \sigma_A(W_{AT} - W_{At})] \quad (6)$$

$$S_{BT} = S_{Bt}\exp[(\mu_B - \frac{1}{2}\sigma_B^2)(T-t) + \sigma_B(W_{BT} - W_{Bt})] \quad (7)$$

From which we can obtain:

$$E_t[S_{AT}] = S_{At}\exp[\mu_A(T-t)] \quad (8)$$

$$E_t[S_{BT}] = S_{Bt}\exp[\mu_B(T-t)] \quad (9)$$

Now suppose that at some finite future time T the firm will go to liquidation (note that we don't know when T will come, but we assume that T is a finite horizon instead of going to infinity). At time T the firm will liquidate all of its assets and since A and B shares are principally equal, it must hold that $S_{AT} = S_{BT}$.

Using the condition $S_{AT} = S_{BT}$ combined with (8) and (9),[4] we can get that at the time t, the price ratio between A and B shares can be expressed as:

$$\frac{S_{At}}{S_{Bt}} = \exp[(\mu_B - \mu_A)(T-t)] \quad (10)$$

Thus the price difference is closely related to the difference in expected returns. As μ_A and μ_B are regarded as the expected return, we can consider $\mu_B - \mu_A$ as the difference in the expected return between A and B shares. Please note that in this case the usual arbitrage argument doesn't hold, i.e. buy the cheap B share and sell the expensive A share and then wait until the time T arrives. The reason is that investors don't know when the liquidation time T will come. If they know T exactly, then they can implement the strategy and such kind of arbitrage will eliminate the price difference between A and B shares. However since T is unknown, it is costly to perform such strategy since the price discount may become larger before T arrives and investors will lose money. Thus the price difference can exist for a long time. This limit of arbitrage argument is similar to the one that is used by Jong, Rosenthal & Dijk (2004) to investigate the price discount for the

[4] I am grateful to Carsten Sørensen to point out this relation.

shares of dual-listed companies in several stock markets. Another feature in Chinese stock market may also contribute to the rejection of arbitrage is the lack of equity derivative markets and restriction on short-selling. As emphasized in Scheinkman & Xiong (2003) and Hong, Scheinkman & Xiong (2006), the short-sale constraints prevent arbitrageurs to sell over-valued shares and thus limit their arbitrage ability. So the price difference can exist for a long time without arbitrage opportunity before T arrives.

The argument that the price difference is driven by the difference in the drift $\mu_B - \mu_A$ and time to liquidation $T - t$ seems to be similar to the argument advised by Fernald & Rogers (2002). In that paper, they argue that since the stock price can be expressed by using the famous Gordon's (1962) model:

$$P_t = D_t \int_0^{\infty} e^{gs} e^{-rs} ds = \frac{D_t}{r - g} \tag{11}$$

where P_t is the stock price at time t, D_t is the dividend at time t, g is the growth rate of dividend and r is the appropriate discount rate. Since A and B shares have the same dividend, so that both D_t and g are the same for the corresponding A and B shares, the difference in price is only contributed to the difference in the discounted rate r. However, compared to their results, there is some difference here: in our setup, the price difference depends not only on the different in expected returns, i.e. $\mu_B - \mu_A$, but also on the time to liquidation $T - t$.

In the following procedure, we assume that the time to liquidation $T - t$ is a constant number, our interest is to test the difference in expected returns $\mu_B - \mu_A$, and furthermore if it is significant, whether this difference is caused by different market price of risk for A and B shares.

In order to estimate the parameters $\mu_A, \mu_B, \sigma_A, \sigma_B$ and ρ, the Maximum Likelihood Estimation Method is adopted. From (4) and (5) we know that the pair of log price follows the Bivariate Normal Distribution:

$$\begin{pmatrix} r_{A,t} \\ r_{B,t} \end{pmatrix} \tilde{} N \begin{pmatrix} (\mu_A - \frac{1}{2}\sigma_A^2)\Delta t, \sigma_A^2 \Delta t \\ (\mu_B - \frac{1}{2}\sigma_B^2)\Delta t, \sigma_B^2 \Delta t \end{pmatrix}, r_{A,t} = \log S_{A,t} - \log S_{A,t-\Delta t}, r_{B,t} = \log S_{B,t} - \log S_{B,t-\Delta t}$$

then the joint pdf for $r_{A,t}, r_{B,t}$ is

$$f(r_{At}, r_{Bt}; \boldsymbol{\theta}) = \frac{1}{2\pi\sigma_A\sigma_B\Delta t\sqrt{1-\rho^2}} \exp\{-\frac{1}{2(1-\rho^2)}[\frac{(r_{At} - (\mu_A - \frac{1}{2}\sigma_A^2)\Delta t)^2}{\sigma_A^2 \Delta t} -$$

$$2\rho\frac{(r_{At}-(\mu_A-\frac{1}{2}\sigma_A^2)\Delta t)(r_{Bt}-(\mu_B-\frac{1}{2}\sigma_B^2)\Delta t)}{\sigma_A\sigma_B\Delta t}+\frac{(r_{Bt}-(\mu_B-\frac{1}{2}\sigma_B^2)\Delta t)^2}{\sigma_B^2\Delta t}]\} \tag{12}$$

and $\boldsymbol{\theta}$ is the parameter vector:

$$\boldsymbol{\theta}=(\mu_A,\mu_B,\sigma_A,\sigma_B,\rho)$$

The conditional log likelihood function of $r_{A,t}, r_{B,t}$ is therefore:

$$l_t(r_{A,t},r_{B,t};\boldsymbol{\theta})=-\log(2\pi)-\log(\sigma_A)-\log(\sigma_B)-\log(\Delta t)-\frac{1}{2}\log(1-\rho^2)-\frac{1}{2(1-\rho^2)}$$

$$[\frac{(r_{A,t}-(\mu_A-\frac{1}{2}\sigma_A^2)\Delta t)^2}{\sigma_A^2\Delta t}-2\rho\frac{(r_{A,t}-(\mu_A-\frac{1}{2}\sigma_A^2)\Delta t)}{\sigma_A}$$

$$\frac{(r_{B,t}-(\mu_B-\frac{1}{2}\sigma_B^2)\Delta t)}{\sigma_B\Delta t}+\frac{(r_{B},_t-(\mu_B-\frac{1}{2}\sigma_B^2)\Delta t)^2}{\sigma_B^2\Delta t}] \tag{13}$$

The log likelihood function of the whole data series is

$$L(r_{A,1},r_{B,2},...,r_{A,T},r_{B,T};\boldsymbol{\theta})=\sum_{t=1}^{T}l_t(r_{A,t},r_{B,t};\boldsymbol{\theta}) \tag{14}$$

The maximum likelihood estimator is therefore the choice of parameters $\boldsymbol{\theta}$ that maximize (14).

3.2 Combination with Market Price of Risk

Next we consider to decompose the expected return into two parts: the risk-free rate and the market price of risk. It makes sense because both A and B shares are issued by the same company and virtually have the same voting rights and dividends, although they may have different expected returns, the difference may be caused by different risk-free rates or different volatilities. In other words, we want to test whether they have the same market price of risk.

Since A shares are traded in domestic currency and B shares are traded in foreign currency, more specifically, B shares in Shanghai market are traded in US Dollar and in Shenzhen market are traded in Hong Kong Dollar. Thus the risk-free rate we apply to estimate the market price of risk should also be different. For A shares, we shall apply the domestic risk-free rate, and for the B shares we shall apply the corresponding US and Hong Kong risk-free rate for Shanghai and Shenzhen respectively. We do this also because that there is relatively strict capital control between Chinese currency and foreign exchanges. Since A-share investors trade in Chinese currency, they can also invest in domestic risk-free assets, thus they will face a risk-free rate in Chinese Yuan. Alternatively, B-share investors in Shanghai stock exchange trade in US Dollar, they can instead earn a risk-free rate in US Dollar, for the same reason, B-share investors in Shenzhen stock market will face a risk-free rate in Hong Kong Dollar, see Ma (1996) for discussion of market segmentation.

Now the dynamics of stock prices can be written as follows:

$$dS_{At} = (r_{f,At} + \lambda_A \sigma_A) S_{At} dt + \sigma_A S_{At} dW_{At} \quad (15)$$

$$dS_{Bt} = (r_{f,Bt} + \lambda_B \sigma_B) S_{Bt} dt + \sigma_B S_{Bt} dW_{Bt} \quad (16)$$

$r_{f,At}$ and $r_{f,Bt}$ are the domestic and foreign risk-free rate at time t and λ_A and λ_B are the corresponding domestic and foreign market price of risk or market price of risk. If let $r^e_{A,t} = r_{A,t} - r_{f,At}$ and $r^e_{B,t} = r_{B,t} - r_{f,Bt}$, where $r_{A,t} = \log S_{A,t} - \log S_{A,t-\Delta t}$, and $r_{B,t} = \log S_{B,t} - \log S_{B,t-\Delta t}$, as the excess return for holding A- and B-share and assume that S_t and $r_{f,t}$ are independent, then we can see from (15) and (16) that $r^e_{A,t}$ and $r^e_{B,t}$ also follow Bivariate Normal Distribution, thus we can still adopt the maximum likelihood methods to estimate the parameters, as in section 3.1. The probability density function is the same as in (12), but we need to substitute the constant μ_A and μ_B in (12) with time-varying drift terms as in (15) and (16). However the volatility term remains constant, now the parameters need to be estimated are:

$$\boldsymbol{\theta} = (\lambda_A, \lambda_B, \sigma_A, \sigma_B, \rho)$$

We can use the log-likelihood function as in (14) to estimate the parameter vector $\boldsymbol{\theta}$ with $r_{fi,t} + \lambda_i \sigma_i$ as a substitute for μ_i, $i = A, B$.

3.3 Heteroskedastic Volatility and Multivariate GARCH Model

In this subsection we consider the time-varying case for both drift and volatility terms. In the preceding subsections it is assumed that stock returns follow normal distribution with constant volatility. However it is well known that, in general, asset returns do not follow homoskedastic distribution. Instead they are usually skewed and have excess kurtosis greater than zero. That is also why different GARCH models are frequently applied to capture the heteroskedastic feature for asset returns. However using univariate GARCH model in this paper doesn't seem to be suitable since we need to consider the correlations of return series between A and B shares because of their partly common sharing of the economic fundamentals derived from the same company. In other words we have to adopt a model that can capture such feature. Thus in this paper the Dynamic Conditional Correlation (DCC) GARCH model introduced by Engle (2002) is applied. The advantage of this model is that it allows time-varying correlation across the return series. The GARCH-DCC model keeps the flexibility and simplicity of univariate GARCH models while it is also able to address the feature of conditional correlations. It can be estimated in a simple way based on the log likelihood function. In this paper since we focus on the A-B share pairs, actually we only need the bivariate version of the model.

Take a couple of A-B shares returns, $\mathbf{r}_t = [r_{A,t}, r_{B,t}]'$, $i = A, B$, as before, we let stock prices S_t follow GBM, then since $\mathbf{r}_t$ is the log price difference, $\mathbf{r}_t$ follows Brownian Motion. However different with previous case, in this subsection we allow $\mathbf{r}_t$ has time-varying volatilities and dynamic conditional correlations. More specifically, let

$$\mathbf{r}_t = \mathbf{u}_t + \boldsymbol{\varepsilon}_t \tag{17}$$

where $\mathbf{u}_t$ is the mean of return and $\boldsymbol{\varepsilon}_t$ is the error term, we assume $\mathbf{u}_t$ can be expressed as follows:

$$\mathbf{u}_t = \boldsymbol{\mu}_t - \frac{1}{2}diag(\mathbf{H}_t) = \mathbf{r}_{f,t} + \boldsymbol{\lambda}[diag(\mathbf{H}_t)]^{\frac{1}{2}} - \frac{1}{2}diag(\mathbf{H}_t) \tag{18}$$

and $\boldsymbol{\varepsilon}_t|I_{t-1} \sim N(\mathbf{0}, \mathbf{H}_t)$, I_{t-1} is the information set at $t-1$, we can also write $\boldsymbol{\varepsilon}_t$ in the form: $\boldsymbol{\varepsilon}_t = \mathbf{H}_t^{\frac{1}{2}}\mathbf{Z}_t$ and $\mathbf{Z}_t \sim N(0, \mathbf{I}_2)$, $\mathbf{I}_2$ is a two-dimensional unit matrix with ones on its diagonal elements.

All of $\mathbf{u}_t, \boldsymbol{\varepsilon}_t, \boldsymbol{\mu}_t, \mathbf{r}_{f,t}$ and $\boldsymbol{\lambda}$ are two dimensional vectors and $\mathbf{H}_t$ is a two dimensional matrix. $\mathbf{u}_t$ represents the mean of returns, $\boldsymbol{\mu}_t$ is the drift term, $\mathbf{r}_{f,t}$ is the risk-free rate and $\boldsymbol{\lambda}$ is the market risk premium, their individual elements represent for the corresponding parameters for A and B shares respectively. $\mathbf{H}_t$ is the conditional variance-covariance matrix of the returns and it follows GARCH-DCC model (to be specified later).

(18) is a natural extension of the bivariate case discussed in subsection 3.2 but with the feature of the time-varying volatility. The only difference is that now we allow the conditional time-varying variance-covariance matrix of returns $\mathbf{H}_t$ instead of constant ones σ_A^2 and σ_B^2 in previous case. The diagonal elements of $\mathbf{H}_t, h_{AAt}$ and h_{BBt} correspond to σ_A^2 and σ_B^2, the off-diagonal elements h_{ABt} and h_{BAt} represent the covariance between returns. All of the elements of $\mathbf{H}_t$ are conditionally time-dependent.

In the case of GARCH-DCC model, the matrix of $\mathbf{H}_t$ is given by:

$$\mathbf{H}_t = \mathbf{D}_t \mathbf{R}_t \mathbf{D}_t \tag{19}$$

where $\mathbf{D}_t = diag(h_{ii,t}^{\frac{1}{2}}), i = A, B$; $\mathbf{R}_t = (\rho_{ij,t})_{2\times 2}, i, j = A, B$ and $\rho_{ii,t} = 1$

The variances follow univariate GARCH(1,1) (Bollerslev (1986)) respectively:

$$\begin{aligned} h_{AA,t} &= \omega_A + \gamma_A \epsilon_{A,t-1}^2 + \phi_A h_{AA,t-1} && (20) \\ h_{BB,t} &= \omega_B + \gamma_B \epsilon_{B,t-1}^2 + \phi_B h_{BB,t-1} && (21) \end{aligned}$$

Assume that the conditional covariance $q_{AB,t}$ between the standardized residuals, $\eta_{A,t}$ and $\eta_{B,t}$ also follows a GARCH(1,1) model:

$$q_{AB,t} = \overline{\rho}_{AB}(1 - \alpha - \beta) + \alpha q_{AB,t-1} + \beta \eta_{A,t-1} \eta_{B,t-1} \tag{22}$$

where $\eta_{A,t} = \varepsilon_{A,t}/h_{AA,t}^{\frac{1}{2}}$ and $\eta_{B,t} = \varepsilon_{B,t}/h_{BB,t}^{\frac{1}{2}}$ are the standardized residuals and $\overline{\rho}_{AB}$ as the unconditional correlation between $\varepsilon_{A,t}$ and $\varepsilon_{B,t}$.The conditional variances $q_{AA,t}$ and $q_{BB,t}$ are given out in the similar way while the unconditional correlation $\overline{\rho}_{AA}$ and $\overline{\rho}_{BB}$ are unity.

Please note in order to get consistent estimators and the mean reversion, it requires that all the parameters are positive and

$$\gamma_A + \phi_A < 1,\ \gamma_B + \phi_B < 1 \text{ and } \alpha + \beta < 1 \tag{23}$$

The estimator of conditional correlation between returns $\rho_{AB,t}$ is given by:

$$\rho_{AB,t} = \frac{q_{AB,t}}{\sqrt{q_{AA,t} q_{BB,t}}} \tag{24}$$

As suggested by Engle (2002), the log likelihood for the estimators can be expressed as:

$$\boldsymbol{\varepsilon}_t | I_{t-1} \tilde{\ } N(0, \mathbf{H}_t)$$

$$
\begin{aligned}
L &= -\frac{1}{2}\sum_{t=1}^{T}[n\log(2\pi)+\log|\mathbf{H}_t|+\boldsymbol{\varepsilon}_t'\mathbf{H}_t^{-1}\boldsymbol{\varepsilon}_t] \\
&= -\frac{1}{2}\sum_{t=1}^{T}[n\log(2\pi)+\log|\mathbf{D}_t\mathbf{R}_t\mathbf{D}_t|+\boldsymbol{\varepsilon}_t'\mathbf{D}_t^{-1}\mathbf{R}_t^{-1}\mathbf{D}_t^{-1}\boldsymbol{\varepsilon}_t] \\
&= -\frac{1}{2}\sum_{t=1}^{T}[n\log(2\pi)+2\log|\mathbf{D}_t|+\log|\mathbf{R}_t|+\boldsymbol{\eta}_t'\mathbf{R}_t^{-1}\boldsymbol{\eta}_t] \qquad (25)
\end{aligned}
$$

where $\boldsymbol{\eta}_t = (\eta_{A,t}, \eta_{B,t})'$ is the vector of the standardized residuals.

We can maximize the log likelihood function of (25)[5] via the parameter space to estimate the parameters. Totally there are 10 parameters to be estimated: $(\boldsymbol{\lambda}, \boldsymbol{\omega}, \boldsymbol{\gamma}, \boldsymbol{\phi}, \alpha, \beta)$, where $\boldsymbol{\lambda} = (\lambda_A, \lambda_B)', \boldsymbol{\omega} = (\omega_A, \omega_B)'$, $\boldsymbol{\gamma} = (\gamma_A, \gamma_B)'$ and $\boldsymbol{\phi} = (\phi_A, \phi_B)'$. However, our main interest is focused on the estimators of market risk premia $\boldsymbol{\lambda}$. We should compare the estimators with those we get from the previous case to see whether the constant and time-varying volatility make results significantly changed or not.

4 Data and Empirical Results

4.1 Data Description

The Data is collected from Shanghai Stock Exchange Data Service. Currently there are 86 companies which have listed both A and B shares in the two stock exchanges. However not all of these companies are included in this study since the sample period starts from 1997 and the data for some companies is not available at that time. Furthermore some companies are delisted or suspended during the sample period so the data of these companies cannot be used either. Excluding these companies whose data is not available, finally 57 couples of A-B shares are used in current study, 32 from SSE and 25 from SZE. These pairs represent all the A and B shares which are continuously traded during the sample period, from January 4, 1997 to June 30, 2005 for a period of 8.5 years and about 2000 daily observations in total. As pointed out by Hwang & Pedro (2006) and others, a relatively large sample is necessary to approximate the asymptotic distribution of the estimators and related statistics in GARCH-class models. Daily observations for 8.5 years will satisfy this large-sample condition required by the model. Although applying weekly or

[5] As suggested in Engle (2002), the consistent estimates of all the parameters can be obtained by first estimating univariate models and then using the estimated parameters to calculate the standardized residuals and using the standardized residuals to estimate the parameters of the correlation process.

monthly observations will ease liquidity and other market microstructure problems, these low-frequency data will significantly reduce the number of observations and thus affect asymptotic properties of the estimates. Thus in this paper daily observation is adopted, which is also a usual case in estimating GARCH models. The price is adjusted for stock splits and dividends. For the risk-free rate, since the data on yield to maturity for short term treasury note from the Chinese bond market is not available for the whole sample period, the 3-month deposit rate in China is adopted as a proxy. For the risk-free rate for US. Dollar and Hong Kong Dollar, the rate for the 3-month U.S. treasury notes an3-month Hong Kong interbank offer rate are used. Also notice that A shares are traded in Chinese Yuan, but B shares in SSE are traded in U.S. Dollar and B shares in SZE are traded in Hong Kong Dollar. In order to calculate returns in a consistent way, first we need to adjust A and B share prices into the same currency. Here the daily exchange rates between Yuan and U.S. Dollar and Yuan and Hong Kong Dollar to are used to convert B-share prices into Chinese Yuan.[6]

4.2 Empirical Results

4.2.1 Constant Expected Return and Volatility

Table 3.1 and Table 3.2 present the estimation results of the drift, volatility as well as the correlation coefficient from (4) and (5) respectively.[7]

Table 3.1 about here
Table 3.2 about here

From the tables we can see several features of these estimated parameters. First notice that almost all the drift terms of B shares are larger than those of the corresponding A shares. The only exception is for one pair in SZE data: SPGO, but the t-value is not significant for the difference. The t-values in the parentheses tell us that the difference between the drift terms is quite significant for most couples. Actually for SSE, the difference of 27 pairs show the strong significance at the level of 5% or lower. For SZE, the result is similar, 22 of 25 pairs show significant difference between the drift terms. From the result we can convince that the expected returns of B shares are higher than those of A shares, as (10) suggests.

[6]Both Chinese Yuan and Hong Kong Dollar are pegged to U.S. Dollar during the sample period, thus the fluctuation of exchange rates has little effect on the return dynamics and hence can be ignored. This assumption is also adopted by most other papers that study this issue.

[7]The estimates for μ and σ in these two tables and following tables are annualized.

Secondly take a look of the volatility term. The annual volatility for all A and B shares are higher than that in matured markets. For example, Campbell, Lo & Mackinlay (1997) provide the estimated long-run annualized volatility in U.S. stock market and the value is below 0.3. However in our estimation, both SSE and SZE show much higher volatilities for all the shares. None of the estimates is below 30%, the largest value for SSE is above 50% and for SZE it is even higher. Such kind of high volatility is a feature for emerging market, as pointed out by many researchers. Take the short development period of Chinese stock market into consideration, we can regard the high volatility as a reflection of more fluctuation and speculation in investors' performance.

The more interesting thing is that most of the volatility terms of B shares are also higher than those of corresponding A shares. This result seems to be contradict with previous studies. For example, some researchers argue that B share market is less liquid than A share market and thus investors require liquidity premium in order to compensate for B shares, which partly contributes to the B share pricing puzzle. Since B shares are less liquid than A shares, it is reasonable to assume that the volatility of B shares is also less than the corresponding A shares. However this is not the case here. The result tells us that although most B shares have less trading volume than corresponding A shares, they have higher volatility. A possible explanation for this is that more institutional investors trade in B shares than in A shares, so it is easier for them to manipulate the B shares price and thus makes the price more volatile. Another reason which can also contribute to this issue is that in February of 2001 the policy for the B share investment restriction has been released and B share price fluctuates more frequently than A share around that time, which also increases the volatility.

In the last row I also present the averaged difference for drifts and volatilities. Both of them are positive and the t statistics show that they are significant for both markets. Thus it is safe to say that as a whole the expected return and volatility for B shares are higher than those for A shares.

Next let's pay some attention to the correlation coefficient. As argued, the correlation coefficient for most pairs are positive. This makes sense since the pair A and B shares are issued by the same company and at least they share some common risks, so their returns move in the same direction, yet for SZE there are two pairs have negative correlation, which means that A and B shares move in the opposite way. As a whole, the correlation between A and B shares are not high, this can be seen from the fact that most of the coefficient is less than 0.3. The largest value in SSE is 0.4205 and most of them in Shanghai market is around 0.2. The weak correlation becomes more obvious for SZE, in which the largest coefficient is around 0.1 and most of them are close to zero. This means that A and

B shares are two segmented markets and there are no highly correlated co-movements between them.

As mentioned earlier, in February 2001 the Chinese capital market regulator announces a policy to release the restrictions for domestic investors to trade in B shares. The policy was announced on February 19, 2001 and as a consequence, price of B shares raised dramatically in the following week after the announcement, which leads the price discount to be reduced to less than -40% immediately after the announcement (see Figure 1 and Figure 2). In order to testing the impact of this special event on results, the model is re-estimated for a subsample period, which starts from March 1, 2001 and thus excludes the large-jump days after the announcement. The estimation results are presented in Table 3.3 and Table 3.4.

Table 3.3 about here
Table 3.4 about here

It is obvious to see from these two tables that the difference in expected returns is positive and significant for most pairs for both Shanghai and Shenzhen markets, which is quite similar to the results for the full sample period. There are only one (Shanghai Vacuum Electronics) in Shanghai and two pairs (SPGO and FANGDA) in Shenzhen, which show insignificant differences. Most estimates for volatility are smaller in size compared to the full sample period, which indicates that the special event in February 2001 has increased volatility, however after the event, stock prices have less fluctuates than before and during the event. Also notice that correlation between A and B shares has increased after the event, especially for Shanghai market, which is natural since after the event domestic investors are allowed to invest in both A and B shares, thus increasing the correlation between these two types of assets.

The positivity and significance of the estimates for expected return differences for the subsample period indicate that the difference in expected return can't be explained by the special event. Thus in the following parts, we still do the estimation and present the result for the full sample period.

4.2.2 Market Price of Risk with Constant Volatility

Table 4.1 and Table 4.2 present the estimation result of the market price of risk and volatility term from (15) and (16) for SSE and SZE respectively.

Table 4.1 about here

Table 4.2 about here

The volatility term is the same as in the previous case, i.e. the result of Table 3.1 and Table 3.2. This is not surprise because the model just decomposes the drift term into risk-free rate plus the multiplication of the market price of risk and the volatility but leaves the volatility terms unchanged. It is the same case for the correlation coefficient so that estimation of ρ is not presented here, it is exactly the same as in Table 3.1 and 3.2. Let's focus on the estimation of λ. We have shown that B shares have higher expected return μ than the corresponding A shares. From Table 4.1 and Table 4.2 we see that it is also the same case for the market price of risk, i.e. that the difference between the market price of risk $\lambda_B - \lambda_A$ is positive for most pairs, but the significance level is not as strong as for the difference between expected returns $\mu_B - \mu_A$ in previous subsection. For SSE 19 of 32 pairs of the difference is significant, this accounts for 60% of the total pairs, but for SZE, the result is weaker, only 10 of 25 pairs confirm significance in the difference, which represents 40% of total pairs. However from the last row, in which the averaged difference results are presented, we can see that both of them are positive and significant at level of 1%, yet the t-values are smaller than those for expected returns. This means as a whole the market price of risk for B shares is higher than that for A shares. Although the result is not as strong as that for constant expected returns, as shown in Table 3.1 and Table 3.2.

The estimation results are consistent with some previous studies. For example as mentioned before, Su (1999) argues that cross-sectional variability in the spread between the expected domestic and foreign share excess return is related to difference in individual share's market beta, which plays the similar role as the market price of risk in our study. However there is still some difference between his paper and current one. First in this paper we estimate the market price of risk by a continuous time setup and a longer sample period as well as more shares are adopted. Second, in this paper the result is not as strong as in his paper, especially for SZE. It seems that foreign investors in SZE don's ask for significantly higher market price of risk for B shares, but investors in SSE do. One reason for this is that most foreign investors in SZE are from Hong Kong and they are more familiar and easier to get access to the Chinese stock market so that they don't require for higher market price of risk. On the contrary, according to language barrier and other factors, most foreign investors in SSE get less information than those from Hong Kong, so that they require a higher market price of risk in order to hold B shares.

4.2.3 Market Price of Risk with GARCH-DCC Model

As discussed before, the assumption of normal distribution is not suitable for asset returns. In this subsection we apply the GARCH-DCC model to the sample data as discussed in Subsection 3.3. All the GARCH parameters for the individual univariate GARCH models, i.e. the parameters $\omega_A, \gamma_A, \phi_A$ and $\omega_B, \gamma_B, \phi_B$ in (20) and (21) are significant for most shares, this also holds for the parameters for correlation dynamics, that is, α and β in (22)[8]. This justifies that GARCH-DCC model is suitable to describe the dynamics of volatility.

The results for the market price of risk estimations are presented in the following tables:

Table 5.1 about here
Table 5.2 about here

Notice that most of the estimation of market price of risk becomes much smaller compared to those values in Table 4.1 and Table 4.2. This is not surprising because most of the fluctuations in the return series have now been absorbed by time-varying volatility terms, the constant market price of risk is contributed much less to explain the volatilities. The most interesting thing for us is that the difference of market price of risk between A and B shares now becomes insignificant for all couples, although for most couples, the difference is still positive. For SSE, 27 couples have positive difference and for SZE the number is 14, these numbers account for 84% and 56% for total couples respectively. In the last row, it tells us that in both markets, the averaged difference of the market price of risk between A and B shares is still positive, but the t-statistics for SZE is not significant.

The weaker or disappearing significance for market price of risk difference between the twin shares is interesting. We have shown that under GBM, B shares have higher expected returns than A shares for all the pairs, for both SSE and SZE. This means that the price difference can be explained by difference in expected returns for investors. The estimation for market price of risk under the same model gives us consistent but weaker conclusion if compared to the result of expected return estimations. Most couples have higher market price of risk for B shares, only a few couples don't, which happens in SZE. However if we apply a GARCH-DCC model for the same data, then higher B-share market price of risk largely disappears for individual twin shares. Thus it is safe to say that the

[8]Since the main interest in this paper is to compare the difference in market price of risk, I don't present the estimation results for these parameters, yet they are available upon request.

seemingly higher market price of risk for B shares is caused by the incapability of the model to capture the time-varying feature of volatility, when models are applied to correct the heteroskedasticity in volatilities, this property disappears. Please also note that the two markets behave differently, SZE seems to be less segmented than SSE, i.e. the results for difference between expected returns, market price of risk for SZE are always weaker than those for SSE. As argued before, this may be caused by the foreign investors in SZE hold more information than the foreign investors in SSE, so they require similar expected returns as to domestic ones. All in all, the empirical results confirm that price discount is closely related to different expected returns, however there is no significant difference between market price of risk for these twin shares.

5 Conclusion

This paper investigates the behavior of the corresponding stock prices in segmented markets: the stock prices of A and B shares for domestic and foreign investors. The A and B shares are issued by the same company, have the same voting rights and the same dividends, yet they are held by different investors and priced differently. The B shares are priced at a significant discount compared to the corresponding A shares. The Geometric Brownian Motion model is adopted to describe the dynamic of the stock prices. In the homoskedastic volatility case, the price discount can be explained by the higher expected returns for B shares. Furthermore the higher market price of risk of B shares is also contributed to the higher expected return. The result is held for both Shanghai and Shenzhen markets, however it is more obvious in Shanghai market than in Shenzhen market. As a next step, GARCH-DCC model is implemented to describe the dynamics and estimate the market price of risk. It is not obvious that individual B shares investors hold higher market price of risk than A share investors, although for Shanghai market the averaged difference for market price of risk is still positive and significant. For individual shares, the difference between the market price of risk is very close to zero and insignificant. The result is more obvious for Shenzhen market. It shows that the estimation result of higher market price of risk is partly caused by the heteroskedasticity in volatility, such property of higher market price of risk disappears when a suitable time-varying volatility model is implemented.

The main focus of this paper is on testing the difference in expected returns and market price of risk for A and B shares, it doesn't investigate why A and B shares have different expected returns. Future work may be related to this interesting topic. As some previous papers present, liquidity premium, demand elasticity, asymmetric information, all of them may contribute to the difference. Another extension of the paper is to try different function forms for market risk premium, a time-varying market price of risk which can be dependent on different state variables will be a potential candidate and it is also interesting to compare the dynamics of market price of risk for different corresponding twin shares.

References

Bailey, W. (1994), 'Risk and return on China's new stock markets: Some preliminary evidence', *Pasific-Basin Finance Journal* **2**, 243–260.

Bailey, W., Chung, Y. P. & Kang, J. K. (1999), 'Foreign ownership restrictions and equity price premiums: What drives the demand for cross-border investments?', *Journal of Financial and Quantitative Analysis* **34**, No. 4.

Bailey, W. & Jagtiani, J. (1994), 'Foreign ownership restrictions and stock prices in the Thai capital market', *Journal of Financial Economics* **36, 1**, 57–87.

Basak, S. (2005), 'Asset pricing with heterogeneous beliefs', *Journal of Banking and Finance* **29**, 2849–2881.

Bollerslev, T. (1986), 'Generalized autoregressive conditional heteroskedasticity', *Journal of Econometrics* **31**, 307–327.

Campbell, J. Y. C., Lo, A. W. & Mackinlay, A. C. (1997), 'The econometrics of financial markets', *Princeton University Press* .

Chen, G. M., Lee, B. S. & Rui, O. (2001), 'Foreign ownership restrictions and market segmentation in China's stock markets', *Journal of Financial Research* **24**, 133–155.

Chui, A. C. W. & Kwok, C. C. Y. (1998), 'Cross-autocorrelation between A shares and B shares in the Chinese stock market', *Journal of Financial Research* **21**, 333–353.

Diao, X. F. & Levi, M. (2005), 'Stock ownership restriction and equilibrium asset pricing: The case of China', *EMF Conference* .

Domowitz, I., Glen, J. & Madhavan, A. (1997), 'Market segmentation and stock prices: Evidence from an emerging market', *Journal of Finance* pp. 1059–1086.

Engle, R. E. (2002), 'Dynamic conditional correlation: A sinmple class of multivariate generalized autoregressive conditional heteroskedasticity models', *Journal of Business and Economics Statistics* **20**, 339–350.

Fernald, J. & Rogers, J. H. (2002), 'Puzzles in the Chinese stock market', *Review of Economics and Statistics* **84**, 416–432.

Gordon, M. (1962), 'The investment, financing and valuation of the corporation', *Homewood* **II**.

Gordon, R. H. & Li, W. (1999), 'Government as a discriminating monopolist in the financial market: The case of China', *NBER Working Paper, No. 7110* .

Green, S. (2004), 'The development of China's stock market, 1984-2002: Equity politics and market institutions', *RoutledgeCurzon, Talyor and Francis Group* .

Hietala, P. (1989), 'Asset pricing in partially sgemented markets: Evidence from the Finnish markets', *Journal of Finance* **44**, 697–718.

Hong, H., Scheinkman, J. & Xiong, W. (2006), 'Asset float and speculative bubbles', *Journal of Finance* **61**, 1073–1117.

Hwang, S. & Pedro, V. P. (2006), 'Small sample properties of GARCH estimates and persistence', *The European Journal of Finance* **12, 7**, 473–494.

Jong, A. D., Rosenthal, L. & Dijk, M. A. (2004), 'The limits of arbitrage: Evidence from dual-listed companies', *EFA 2004 Maastricht Conference paper, No 4695* .

Karolyi, G. A. & Li, L. F. (2003), 'A resolution of the Chinese discount puzzle', *Working Paper at Ohio State University* .

Lam, S. S. & Pak, H. S. (1993), 'A note on equity market segmentation: New tests and evidence', *Pacific-Basin Finance Journal* **1, 3**, 263–276.

Ma, X. H. (1996), 'Capital controls, market segmentation and stock prices: Evidence from the Chinese stock market', *Pasific-Basin Finance Journal* **4**, 219–239.

Mei, J. P., Scheinkman, J. A. & Xiong, W. (2005), 'Speculative trading and stock prices: Evidence from Chinese A-B share premia', *NBER Working Paper* **No. 11362**.

Sarkar, A., Charkravarty, S. & Wu, L. F. (1998), 'Information asymmetry, market segmentation, and the pricing of cross-listed shares: Theory and evidence from Chinese A and B shares', *Journal of International Financial Markets* **8**, 325–356.

Scheinkman, J. & Xiong, X. (2003), 'Overconfidence and speculative bubbles', *Journal of Political Economy* **111**, 1183–1220.

Stulz, R. M. & Wasserfallen, W. (1995), 'Foreign equity investment restrictions and shareholder wealth maximization: Theory and evidence', *Review of Financial Studies* **8**, 1019–1057.

Su, D. W. (1999), 'Ownership restrictions and stock prices: Evidence from Chinese markets', *The Financial Review* **34, 2**, 37–55.

Sun, Q. & Tong, W. H. (2000), 'The effect of market segmentation on stock prices: The China syndrome', *Jouranl fo Banking and Finance* **24, 12**, 1875–1902.

Yang, J. (2003), 'Market segmentation and information asymmetry in Chinese stock markets: A VAR analysis', *The Financial Reivew* **38, 4**, 591–609.

Table 1: Chinese Stock Market Overview

Year	*Listed Companies*	*Listed Companies with A shares*	*Listed Companies with B shares*	*Listed Companies with both A and B shares*	*Stock Market Value (billion Yuan)**	*Stock negotiable Market Value (billion Yuan)*	*Funds Raised by Listings (billion Yuan)*
1992	53	35		18	104.8		9.41
1993	183	143	6	34	353.1	86.2	37.5
1994	291	227	4	54	369.1	96.9	32.7
1995	323	242	12	58	347.4	93.8	15.0
1996	530	431	16	69	984.2	286.7	42.5
1997	745	627	25	76	1752.9	520.4	129.4
1998	851	727	26	80	1950.6	574.6	84.2
1999	949	822	26	82	2647.1	821.4	94.5
2000	1088	955	28	86	4809.1	1608.8	210.3
2001	1160	1025	24	88	4352.2	1446.3	125.2
2002	1224	1085	24	87	3832.9	1248.5	96.2
2003	1287	1146	24	87	4245.8	1317.9	135.8
2004	1377	1236	24	86	3705.5	1168.8	114.2

* As per Oct. 24, 2005, 1 US Dollar = 8.0709 Chinese Yuan
Source: The Statistical Yearbook of China (2005), China Statistical Press

Table 2: Correlation Test for Different Index Returns

Return Series	*Correlations on daily returns (Jan. 4, 2000 – Jun. 30, 2005)*							
	SH A	SHB	SZA	SZB	HangSeng	Nikkei225	S&P500	Dax
SHA	1							
SHB	0.65890	1						
SZA	0.19078	0.14140	1					
SZB	0.22720	0.27336	0.1548	1				
Hang Seng	0.11530	0.17748	0.06807	0.02320	1			
Nikkei225	0.04558	0.04272	0.01823	0.02385	0.37682	1		
S&P500	-0.02829	0.00251	0.05986	-0.05695	0.18835	0.15994	1	
Dax	0.00721	0.02490	0.03571	-0.01379	0.35233	0.27380	0.52785	1

SHA: Shanghai A-share Index, SHB: Shanghai B-share Index
SZA: Shenzhen A-share Index, SZB: Shenzhen B-share Index
Hang Seng: Hong Kong Hang Seng Index, Nikkei225: Tokyo Nikkei 225 Index
S&P500: Standard & Poor 500 Index Dax: Frankfurt Stock Exchange Index

Figure 1

Figure 2

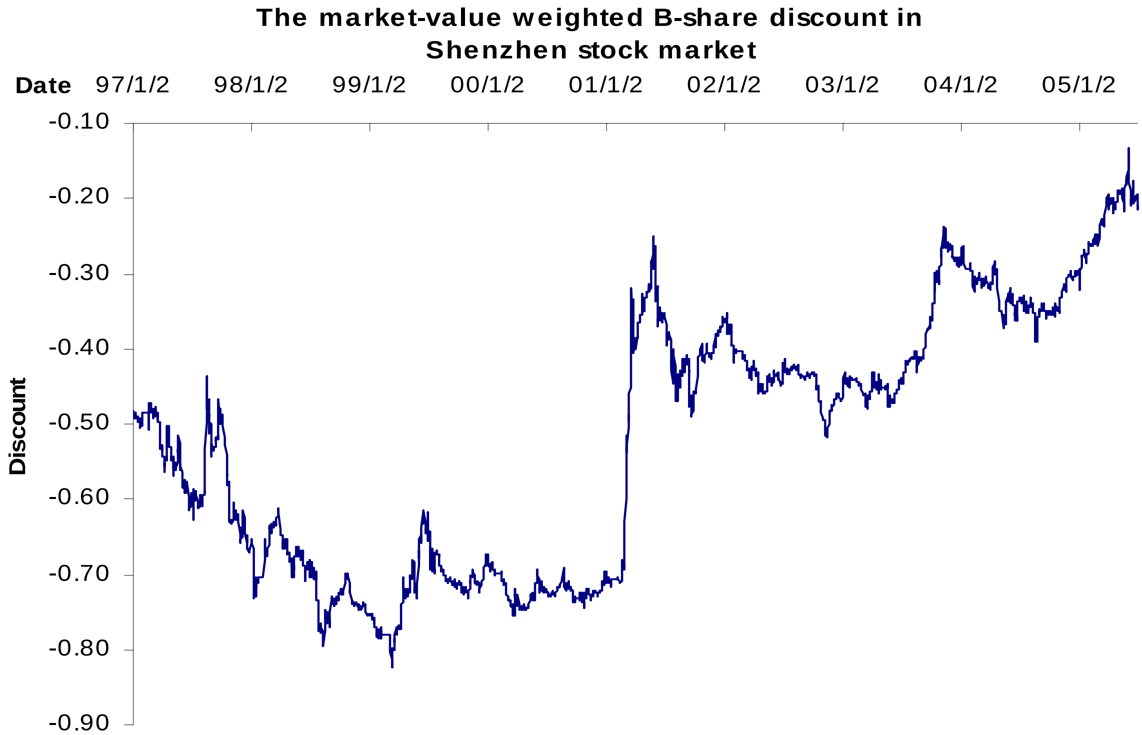

Table 3.1: Constant expected return and volatility estimation for SSE (Jan. 4, 1997 – Jun. 30, 2005)

	A-share		*B-share*				
	μ_A	σ_A	μ_B	σ_B	μ_B - μ_A	σ_B - σ_A	ρ
Shanghai Vacuum Electronics	0.1118	0.4619	0.1532	0.4812	0.0415** (2.31)	0.0193 (0.521)	0.2308
Shanghai Erfangji	0.0519	0.4570	0.1214	0.5208	0.0695*** (5.38)	0.0638* (1.73)	0.2400
Dazhong Taxi	-0.0415	0.4142	0.0965	0.5462	0.1381*** (11.3)	0.1320*** (3.20)	0.4205
Yongsheng Stationery	0.0739	0.4361	0.0953	0.4659	0.0214** (2.51)	0.0298 (0.673)	0.1754
China First Pencil	0.0076	0.4075	0.0456	0.4901	0.0380*** (2.68)	0.0826** (2.24)	0.1735
China Textile Machinery	0.0752	0.4368	0.1076	0.4848	0.0325*** (2.95)	0.0481 (1.46)	0.1931
Shanghai Rubber Belt	0.0723	0.4384	0.1293	0.4785	0.0569*** (5.61)	0.0400 (0.933)	0.1433
Shanghai Chlor Alkai	0.0029	0.4226	0.0727	0.5009	0.0698*** (5.28)	0.0784** (1.96)	0.1533
Shanghai Tire & Rubber	0.0021	0.4152	0.0644	0.5297	0.0623*** (4.14)	0.1145*** (2.99)	0.1447
Shanghai Refrigerator	0.0274	0.4130	0.1160	0.5066	0.0887*** (7.33)	0.0935** (2.29)	0.2435
Jinqiao Export & Import	-0.0415	0.3863	0.0695	0.4598	0.1110*** (9.45)	0.0735** (2.03)	0.2258
Outer Gaoqiao	-0.0584	0.3793	0.0419	0.4364	0.1002*** (8.27)	0.0571* (1.74)	0.2353
JinJiang Investment	0.0622	0.4112	0.1834	0.4960	0.1212*** (10.0)	0.0848** (2.31)	0.2401
Forever Bicycle	0.1046	0.4371	0.2296	0.5929	0.1250*** (8.09)	0.1558 (0.334)	0.0885
Phoenix Bicycle	0.0388	0.4526	0.1346	0.5416	0.0958*** (6.95)	0.0890* (1.75)	0.2002
Shanghai Haixing Group	0.0063	0.4608	0.0546	0.5346	0.0483*** (3.13)	0.0738 (0.264)	0.1840
Yaohua Pilkington Glass	0.0013	0.3965	0.1132	0.5216	0.1119*** (7.59)	0.1251 (1.14)	0.1269
Shanghai Diesel Engine	0.0117	0.3778	0.1062	0.4895	0.0945*** (7.20)	0.1117*** (3.03)	0.1800
Sanmao Textile	0.0080	0.4779	0.1024	0.5032	0.0944*** (6.29)	0.0253 (0.362)	0.1924
Shanghai Friendship Shop	0.0211	0.4270	0.1483	0.5086	0.1271*** (9.27)	0.0816 (1.34)	0.2619
Industrial Sewing Machine	0.0411	0.4619	0.1476	0.5195	0.1065*** (4.27)	0.0576 (0.958)	0.1704
Shang-Ling Refrigerator	0.0172	0.4246	0.1175	0.4921	0.1003*** (7.34)	0.0676 (1.28)	0.1664
Baoxin Software	0.1507	0.4311	0.2854	0.6333	0.1347*** (8.24)	0.2022 (0.371)	0.1237
Shanghai Merchandise Trading	0.0989	0.4315	0.1707	0.4936	0.0718*** (5.22)	0.0621 (1.56)	0.1318
Communication Equipment	0.0190	0.4591	0.0818	0.5095	0.0628*** (4.93)	0.0504 (1.28)	0.3262
Lujiazui Development	-0.1228	0.3638	0.0000	0.4589	0.1228*** (11.1)	0.0951** (2.46)	0.2883
Huaxin Cement	0.0203	0.4023	0.1422	0.5138	0.1219*** (8.91)	0.1115*** (3.01)	0.1992
Jinjiang Hotel	0.0592	0.4133	0.1532	0.5064	0.0940*** (7.91)	0.0931** (2.52)	0.2949
Huan Dian	-0.0616	0.4056	0.0189	0.5014	0.0805*** (6.36)	0.0958 (0.898)	0.2106
Huan Yuan Textile	-0.0851	0.3830	0.0589	0.5293	0.1440*** (11.5)	0.1463*** (3.25)	0.2877
DongfangCommunication	-0.1363	0.4263	-0.0238	0.4812	0.1125*** (9.16)	0.0550* (1.68)	0.2731
Huangshan Travel	-0.0550	0.3537	0.1465	0.4871	0.2015*** (16.7)	0.1334*** (3.82)	0.2163
Averaged Difference					0.09198*** (12.6)	0.0859*** (11.9)	

H_0: μ_B - μ_A =0, σ_B-σ_A =0, the values in the parentheses are the t-statistics
* Significance level of 10%, ** Significance level of 5%, *** Significance level of 1%

Table 3.2 Constant expected return and volatility estimation for SZE (Jan. 4, 1997 – Jun. 30, 2005)

	A-share		*B-share*				
	μ_A	σ_A	μ_B	σ_B	μ_B-μ_A	σ_B-σ_A	ρ
Vanke B	-0.01775	0.4974	0.1407	0.6327	0.1584*** (12.8)	0.1353 (0.456)	0.1122
CSG	-0.00491	0.4835	0.1502	0.6750	0.1551*** (9.11)	0.1915 (0.494)	0.1023
KONKA Group	-0.0811	0.3869	-0.0287	0.4674	0.0524*** (3.89)	0.0805** (2.01)	0.0091
Victor Onward	0.082672	0.4793	0.0838	0.5516	0.0012 (0.242)	0.0723 (1.58)	0.0064
CWH	0.17758	0.3910	0.2554	0.5023	0.0778*** (5.52)	0.1113** (2.14)	0.0093
CMPD	0.014488	0.3933	0.1057	0.4588	0.0912*** (7.05)	0.0655* (1.75)	0.0215
FIYTA	-0.05164	0.4315	0.0035	0.5224	0.0551*** (4.13)	0.0909 (0.953)	0.0284
ACCORD PHARM.	0.002789	0.4905	0.1114	0.6168	0.1086*** (6.53)	0.1263 (0.813)	0.0493
SPGO	0.008034	0.4737	0.0076	0.5396	-0.0005 (-0.181)	0.0659 (1.48)	0.0325
NSRD	0.05795	0.4394	0.1789	0.5253	0.1210*** (8.22)	0.0859 (0.437)	0.0311
CIMC	0.055974	0.5091	0.1499	0.5983	0.0939*** (5.79)	0.0893 (0.314)	0.0127
STHC	0.065603	0.4785	0.1170	0.5782	0.0514*** (3.37)	0.0996 (0.931)	0.0265
FANGDA	-0.02519	0.4373	-0.0196	0.5215	0.0055 (0.595)	0.0842* (1.92)	0.0259
SZIA	-0.05213	0.4667	-0.0015	0.5552	0.0506*** (3.67)	0.0885* (1.79)	0.0269
SEGCL	-0.07874	0.4599	-0.0490	0.5161	0.0297*** (3.22)	0.0562 (0.821)	0.0225
SJZBS	-0.06514	0.4239	-0.0454	0.4874	0.0198* (1.67)	0.0636* (1.89)	0.0461
SWAN	-0.18962	0.3675	-0.0622	0.4754	0.1274*** (9.83)	0.1080** (2.55)	-0.0179
LIVZON GROUP	0.023494	0.4251	0.0973	0.5173	0.0738*** (4.98)	0.0922* (1.81)	0.0011
HFML	-0.11996	0.4135	-0.0340	0.5208	0.0860*** (6.14)	0.1073** (2.17)	0.0198
GED	-0.03112	0.4323	0.0543	0.5119	0.0854*** (6.03)	0.0796 (0.326)	0.0268
FSL	0.020734	0.3132	0.1081	0.4071	0.0874*** (7.68)	0.0939*** (2.88)	0.0279
JMC	0.06722	0.4257	0.3037	0.7982	0.2365*** (12.2)	0.3725 (0.453)	0.0146
SANONDA	-0.08059	0.4040	-0.0325	0.4969	0.0481*** (3.60)	0.0930** (2.31)	0.0007
CHANGCHAI	-0.07327	0.4105	-0.0361	0.4843	0.0372*** (2.37)	0.0738** (2.00)	-0.0041
CHANGAN AUTO	-0.02019	0.4048	0.1553	0.5694	0.1755*** (11.0)	0.1647** (2.40)	0.0159
Averaged Difference					0.0811*** (6.52)	0.1077*** (8.32)	

H_0: μ_B - μ_A =0, σ_B-σ_A =0, =0, the values in the parentheses the t-statistics
* Significance level of 10%, ** Significance level of 5%, *** Significance level of 1%

Table 3.3: Constant expected return and volatility estimation for SSE (March. 1, 2001 – Jun. 30, 2005)

	A-share		*B-share*				
	μ_A	σ_A	μ_B	σ_B	μ_B - μ_A	σ_B - σ_A	ρ
Shanghai Vacuum Electronics	-0.1466	0.4181	-0.1431	0.3747	0.003606 (0.511)	-0.04339 (-0.888)	0.6503
Shanghai Erfangji	-0.2290	0.3975	-0.1341	0.4047	0.09495*** (2.79)	0.007208 (0.144)	0.6277
Dazhong Taxi	-0.1743	0.2807	0.01318	0.3280	0.1875*** (5.88)	0.04731 (0.808)	0.4699
Yongsheng Stationery	-0.1715	0.3949	-0.1425	0.3469	0.02898 (0.861)	-0.04801 (-0.762)	0.5248
China First Pencil	-0.1791	0.3815	-0.08595	0.3749	0.09317*** (2.91)	-0.006636 (-0.128)	0.5702
China Textile Machinery	-0.1910	0.3804	-0.1144	0.3772	0.07667** (2.32)	-0.003202 (-0.071)	0.6054
Shanghai Rubber Belt	-0.3050	0.3901	-0.1494	0.3723	0.1556*** (4.32)	-0.01788 (0.294)	0.4368
Shanghai Chlor Alkai	-0.1755	0.4015	-0.1119	0.3974	0.06360* (1.77)	-0.004095 (-0.079)	0.6058
Shanghai Tire & Rubber	-0.1697	0.3808	-0.07441	0.4002	0.09527*** (2.89)	0.01941 (0.359)	0.5514
Shanghai Refrigerator	-0.05616	0.3963	0.09583	0.3917	0.1520*** (4.22)	-0.004634 (-0.086)	0.5875
Jinqiao Export & Import	-0.1687	0.3536	-0.03747	0.3487	0.1312*** (4.23)	-0.004970 (-0.100)	0.6239
Outer Gaoqiao	-0.2277	0.3451	-0.1086	0.3450	0.1191*** (4.11)	-0.0001134 (0.025)	0.5753
JinJiang Investment	-0.06206	0.3538	0.1018	0.3729	0.1639*** (5.85)	0.01910 (0.045)	0.5921
Forever Bicycle	-0.1096	0.3393	-0.007036	0.3469	0.1026*** (3.21)	0.007625 (0.130)	0.5533
Phoenix Bicycle	-0.4306	0.3958	-0.2072	0.4102	0.2233*** (5.19)	0.01443 (0.229)	0.5008
Shanghai Haixing Group	-0.1976	0.4614	-0.1716	0.5221	0.02605 (0.704)	0.06064 (1.17)	0.7926
Yaohua Pilkington Glass	-0.2122	0.3651	-0.02938	0.3938	0.1828*** (6.09)	0.02876 (0.548)	0.6315
Shanghai Diesel Engine	-0.08846	0.3435	0.04437	0.3497	0.1328*** (3.79)	0.006189 (0.071)	0.5370
Sanmao Textile	-0.2839	0.4347	-0.2433	0.3956	0.04063 (1.23)	-0.03912 (-0.561)	0.6337
Shanghai Friendship Shop	-0.1523	0.3635	0.08610	0.4036	0.2384*** (6.81)	0.04004 (0.481)	0.4980
Industrial Sewing Machine	-0.2264	0.4086	-0.1865	0.4153	0.03992 (1.14)	0.006731 (0.115)	0.6367
Shang-Ling Refrigerator	-0.2529	0.3414	-0.1450	0.3575	0.1079*** (3.27)	0.01610 (0.46)	0.6522
Baoxin Software	-0.09440	0.3507	-0.004842	0.3541	0.08956** (2.56)	0.003378 (0.063)	0.5757
Shanghai Merchandise Trading	-0.1209	0.3850	-0.05303	0.3846	0.06793** (2.00)	-0.0003855 (-0.007)	0.5602
Communication Equipment	-0.2309	0.3681	-0.08663	0.3505	0.1443*** (3.36)	-0.01766 (0.341)	0.5919
Lujiazui Development	-0.1971	0.3223	-0.04895	0.3393	0.1482*** (4.23)	0.01697 (0.343)	0.5838
Huaxin Cement	-0.1598	0.3604	0.002319	0.3886	0.1621*** (5.07)	0.02815 (0.544)	0.5982
Jinjiang Hotel	-0.04077	0.3521	0.08405	0.3381	0.1248*** (4.56)	-0.01398 (0.296)	0.5829
Huan Dian	-0.3050	0.3828	-0.1587	0.4114	0.1463*** (4.43)	0.02863 (0.454)	0.6794
Huan Yuan Textile	-0.2510	0.3397	-0.1586	0.3569	0.09237*** (2.98)	0.01721 (0.403)	0.5507
DongfangCommunication	-0.3898	0.3780	-0.3046	0.3376	0.08519*** (2.75)	-0.04041 (-0.855)	0.6466
Huangshan Travel	-0.07276	0.3267	0.02482	0.3364	0.09759*** (3.15)	0.009722 (0.206)	0.5619
Averaged Difference					0.1131*** (11.6)	0.004164 (0.945)	

H_0: μ_B - μ_A =0, σ_B -σ_A =0, the values in the parentheses are the t-statistics
* Significance level of 10%, ** Significance level of 5%, *** Significance level of 1%

Table 3.4 Constant expected return and volatility estimation for SZE (March. 1, 2001 – Jun. 30, 2005)

	A-share		*B-share*				
	μ_A	σ_A	μ_B	σ_B	μ_B-μ_A	σ_B-σ_A	ρ
Vanke B	-0.2044	0.5353	0.01818	0.5654	0.2226*** (7.42)	0.03012 (0.616)	0.2561
CSG	-0.3106	0.4571	0.1777	0.6345	0.4884*** (12.5)	0.1774 (0.375)	0.1566
KONKA Group	-0.2001	0.3484	-0.09599	0.3816	0.1041*** (3.47)	0.03319 (0.738)	0.1185
Victor Onward	-0.1891	0.3988	-0.1009	0.4580	0.08826** (2.39)	0.05917 (1.01)	0.1314
CWH	0.2484	0.3402	0.4082	0.4135	0.1597*** (4.99)	0.07328 (1.51)	0.1432
CMPD	-0.09162	0.3229	0.06121	0.3498	0.1528*** (5.09)	0.02690 (0.628)	0.1093
FIYTA	-0.2481	0.3550	-0.07083	0.4394	0.1772*** (5.54)	0.08431* (1.82)	0.1543
ACCORD PHARM.	-0.2880	0.3869	-0.05158	0.4303	0.2364*** (6.22)	0.04344 (0.658)	0.1845
SPGO	-0.1046	0.4599	-0.06569	0.4499	0.03899 (1.22)	-0.009947 (-0.188)	0.1264
NSRD	-0.1228	0.3341	0.1626	0.4164	0.2854*** (9.84)	0.08232 (1.21)	0.2417
CIMC	-0.07401	0.5636	0.1187	0.6014	0.1927*** (6.64)	0.03782 (0.860)	0.2422
STHC	-0.1673	0.4413	-0.04017	0.4921	0.1271*** (3.53)	0.05085 (0.889)	0.1288
FANGDA	-0.1521	0.4514	-0.1041	0.4400	0.04796 (1.50)	-0.01131 (-0.224)	0.1002
SZIA	-0.1759	0.4413	-0.08615	0.4694	0.08975** (2.64)	0.02818 (0.534)	0.1898
SEGCL	-0.1701	0.4251	-0.09929	0.4395	0.07087** (2.29)	0.01436 (0.251)	0.1505
SJZBS	-0.1735	0.3930	-0.06500	0.4391	0.1085*** (3.39)	0.04602 (1.16)	0.2456
SWAN	-0.2909	0.3649	-0.1688	0.3834	0.1220*** (4.07)	0.01852 (0.421)	0.1321
LIVZON GROUP	-0.1295	0.3624	0.07180	0.4026	0.2013*** (6.29)	0.04017 (0.830)	0.1321
HFML	-0.2480	0.3654	-0.09867	0.4072	0.1493*** (4.67)	0.04181 (0.704)	0.1073
GED	-0.1810	0.2508	0.03292	0.3349	0.2140*** (7.93)	0.08412* (1.91)	0.1464
FSL	0.0002773	0.2539	0.1262	0.3068	0.1260*** (5.04)	0.05298 (1.42)	0.1146
JMC	-0.02396	0.4122	0.1435	0.4289	0.1675*** (3.22)	0.01665 (0.308)	0.1496
SANONDA	-0.2306	0.4028	-0.05621	0.4548	0.1744*** (5.63)	0.05197 (1.07)	0.1573
CHANGCHAI	-0.1851	0.3793	-0.08086	0.4342	0.1042*** (3.47)	0.05490 (1.19)	0.2517
CHANGAN AUTO	0.02719	0.4111	0.2586	0.4787	0.2314*** (6.81)	0.06768 (1.28)	0.2258
Averaged Difference					0.1633*** (9.08)	0.04779 (1.31)	

H_0: μ_B - μ_A =0, σ_B-σ_A =0, =0, the values in the parentheses the t-statistics
* Significance level of 10%, ** Significance level of 5%, *** Significance level of 1%

Table 4.1 Market price of risk estimation for SSE (totally 32 pairs)

	A-share		*B-share*			
	λ_A	σ_A	λ_B	σ_B	$\lambda_B-\lambda_A$	$\sigma_B-\sigma_A$
Shanghai Vacuum Electronics	0.2036	0.4619	0.3016	0.4813	0.0980 (1.22)	0.0194 (0.521)
Shanghai Erfangji	0.1128	0.4570	0.2319	0.5208	0.1192 (1.50)	0.0638* (1.73)
Dazhong Taxi	-0.0611	0.4142	0.1647	0.5462	0.2257*** (3.25)	0.1320*** (3.20)
Yongsheng Stationery	0.1285	0.4361	0.1962	0.4659	0.0676 (0.817)	0.0298 (0.673)
China First Pencil	0.0179	0.4075	0.0919	0.4901	0.0740 (0.891)	0.0826** (2.24)
China Textile Machinery	0.1713	0.4368	0.2208	0.4848	0.0495 (0.603)	0.0480 (1.46)
Shanghai Rubber Belt	0.1372	0.4384	0.2633	0.4785	0.1262 (1.49)	0.0401 (0.933)
Shanghai Chlor Alkai	0.0060	0.4226	0.1440	0.5009	0.1380 (1.64)	0.0783** (1.96)
Shanghai Tire & Rubber	0.0042	0.4152	0.1205	0.5297	0.1163 (1.38)	0.1145*** (2.99)
Shanghai Refrigerator	0.0633	0.4130	0.2280	0.5066	0.1647** (2.08)	0.0936** (2.29)
Jinqiao Export & Import	-0.1128	0.3863	0.1520	0.4598	0.2648*** (3.30)	0.0735** (2.03)
Outer Gaoqiao	-0.1696	0.3793	0.1034	0.4364	0.2730*** (3.42)	0.0571* (1.74)
JinJiang Investment	0.1485	0.4112	0.3681	0.4960	0.2197*** (2.76)	0.0848** (2.31)
Forever Bicycle	0.2262	0.4371	0.3789	0.5929	0.1527* (1.75)	0.1558 (0.334)
Phoenix Bicycle	0.0700	0.4526	0.2490	0.5416	0.1790** (2.19)	0.0890* (1.75)
Shanghai Haixing Group	-0.0131	0.4608	0.1066	0.5346	0.1196 (1.38)	0.0738 (0.264)
Yaohua Pilkington Glass	0.0025	0.3965	0.2159	0.5216	0.2135** (2.50)	0.1251 (1.14)
Shanghai Diesel Engine	0.0299	0.3778	0.2158	0.4895	0.1859** (2.24)	0.1117*** (3.03)
Sanmao Textile	0.0286	0.4779	0.1951	0.5032	0.1664** (2.20)	0.0253 (0.362)
Shanghai Friendship Shop	0.0514	0.4270	0.2899	0.5086	0.2385*** (3.04)	0.0816 (1.34)
Industrial Sewing Machine	0.1555	0.4619	0.2395	0.5195	0.0840 (1.01)	0.0576 (0.958)
Shang-Ling Refrigerator	0.0191	0.4246	0.2424	0.4921	0.2232*** (2.68)	0.0675 (1.28)
Baoxin Software	0.3487	0.4311	0.4498	0.6333	0.1010 (1.18)	0.2022 (0.371)
Shanghai Merchandise Trading	0.2284	0.4315	0.3446	0.4936	0.1162 (1.36)	0.0621 (1.56)
Communication Equipment	0.0406	0.4591	0.1595	0.5095	0.1189 (1.59)	0.0504 (1.28)
Lujiazui Development	-0.3353	0.3638	-0.0036	0.4589	0.3317*** (4.31)	0.0951** (2.46)
Huaxin Cement	0.0495	0.4023	0.2757	0.5138	0.2262*** (2.76)	0.1115*** (3.01)
Jinjiang Hotel	0.1556	0.4133	0.3046	0.5063	0.1490* (1.95)	0.0930** (2.52)
Huan Dian	-0.1528	0.4056	0.0365	0.5014	0.1894** (2.33)	0.0958 (0.898)
Huan Yuan Textile	-0.2231	0.3830	0.1102	0.5293	0.3333*** (4.32)	0.1463*** (3.25)
Dongfang Communication	-0.3205	0.4263	-0.0506	0.4812	0.2700*** (3.47)	0.0549* (1.68)
Huangshan Travel	-0.1566	0.3537	0.2994	0.4871	0.4560*** (5.65)	0.1334*** (3.82)
Averaged Difference					0.1810*** (10.8)	0.0859*** (11.9)

H_0: $\lambda_B-\lambda_A=0$, $\sigma_B-\sigma_A=0$, the values in the parentheses are the t-statistics

* Significance level of 10%, ** Significance level of 5%, *** Significance level of 1%

Table 4.2 Constant market price of risk and volatility estimation for SZE (totally 25 couples)

	A-share		*B-share*			
	λ_A	σ_A	λ_B	σ_B	λ_B-λ_A	σ_B-σ_A
Vanke B	-0.0364	0.4974	0.2213	0.6327	0.2577*** (2.90)	0.1353 (0.456)
CSG	-0.0108	0.4835	0.2239	0.6750	0.2347** (2.58)	0.1915 (0.494)
KONKA Group	-0.1946	0.3869	-0.0974	0.4673	0.0972 (1.06)	0.0804** (2.01)
Victor Onward	0.1719	0.4793	0.1507	0.5516	-0.0212 (-0.231)	0.0723 (1.58)
CWH	0.4243	0.3910	0.5385	0.5023	0.1142 (1.25)	0.1113** (2.14)
CMPD	0.0363	0.3933	0.2294	0.4588	0.1931** (2.13)	0.0655* (1.75)
FIYTA	-0.1112	0.4315	-0.0225	0.5224	0.0888 (0.983)	0.0909 (0.953)
ACCORD PHARM.	0.0851	0.4905	0.0855	0.6167	0.0004 (0.0047)	0.1262 (0.813)
SPGO	0.0163	0.4737	0.0127	0.5396	-0.0036 (-0.0402)	0.0659 (1.48)
NSRD	0.1287	0.4394	0.3380	0.5253	0.2093** (2.31)	0.0859 (0.437)
CIMC	0.1092	0.5091	0.2512	0.5983	0.1420 (1.54)	0.0892 (0.314)
STHC	0.1501	0.4785	0.1921	0.5782	0.0420 (0.463)	0.0997 (0.931)
FANGDA	-0.0589	0.4373	-0.0384	0.5215	0.0204 (0.225)	0.0842* (1.92)
SZIA	-0.1006	0.4667	-0.0280	0.5552	0.0726 (0.798)	0.0885* (1.79)
SEGCL	-0.1734	0.4599	-0.0944	0.5161	0.0790 (0.871)	0.0562 (0.821)
SJZBS	-0.1569	0.4239	-0.0914	0.4874	0.0655 (0.730)	0.0635 (1.89)*
SWAN	-0.5137	0.3675	-0.1396	0.4754	0.3741*** (4.04)	0.1079** (2.55)
LIVZON GROUP	0.0544	0.4251	0.1869	0.5173	0.1325 (1.44)	0.0922* (1.81)
HFML	-0.2936	0.4135	-0.0613	0.5208	0.2322** (2.56)	0.1073** (2.17)
GED	-0.0728	0.4323	0.1048	0.5119	0.1776** (1.96)	0.0796 (0.326)
FSL	0.0740	0.3132	0.2663	0.4071	0.1923** (2.12)	0.0939*** (2.88)
JMC	0.2083	0.4257	0.3604	0.7982	0.1521* (1.67)	0.3725 (0.453)
SANONDA	-0.1833	0.4040	-0.0985	0.4969	0.0848 (0.924)	0.0929** (2.31)
CHANGCHAI	-0.1792	0.4105	-0.0764	0.4843	0.1027 (1.12)	0.0738** (2.00)
CHANGAN AUTO	-0.0459	0.4048	0.2632	0.5694	0.3091*** (3.39)	0.1646** (2.40)
Averaged Difference					0.1340*** (6.05)	0.1077*** (8.32)

H_0: λ_B-λ_A =0, σ_B-σ_A =0, the values in the parentheses are the t-statistics
* Significance level of 10%, ** Significance level of 5%, *** Significance level of 1%

Table 5.1 Market price of risk estimation under GARCH model for SSE (totally 32 couples)

	A-share	*B-share*	
	λ_A	λ_B	λ_B-λ_A
Shanghai Vacuum Electronics	-0.00643	0.01244	0.01887 (0.838)
Shanghai Erfangji	-0.01407	-0.00146	0.01261 (0.415)
Dazhong Taxi	-0.06327	-0.03487	0.02840 (0.910)
Yongsheng Stationery	-0.01493	-0.05720	-0.04227 (-1.29)
China First Pencil	-0.01662	-0.02185	-0.00523 (-0.126)
China Textile Machinery	-0.00761	0.00889	0.01650 (0.545)
Shanghai Rubber Belt	-0.00379	-0.00571	-0.00193 (-0.0624)
Shanghai Chlor Alkai	-0.02473	-0.00804	0.01669 (0.462)
Shanghai Tire & Rubber	-0.03968	-0.00785	0.03183 (0.335)
Shanghai Refrigerator	-0.00890	0.00143	0.01033 (0.339)
Jinqiao Export & Import	-0.02675	-0.01386	0.01289 (0.425)
Outer Gaoqiao	-0.02912	-0.02005	0.00907 (0.299)
JinJiang Investment	-0.00317	0.01135	0.01452 (0.473)
Forever Bicycle	-0.00880	0.01785	0.02665 (0.869)
Phoenix Bicycle	-0.00875	0.45978	0.4685 (1.34)
Shanghai Haixing Group	-0.01541	-0.01755	-0.00214 (-0.0673)
Yaohua Pilkington Glass	-0.00961	-0.00127	0.00833 (0.258)
Shanghai Diesel Engine	-0.01536	0.00541	0.02077 (0.688)
Sanmao Textile	-0.01542	-0.01544	$-3.10\text{x}10^{-5}$ ($-8.00\text{x}10^{-4}$)
Shanghai Friendship Shop	-0.02747	0.01365	0.04112 (1.14)
Industrial Sewing Machine	-0.00607	0.00086	0.00693 (0.219)
Shang-Ling Refrigerator	-0.02044	-0.00653	0.01391 (0.467)
Baoxin Software	-0.00041	0.03650	0.03691 (1.15)
Shanghai Merchandise Trading	-0.01075	-0.00234	0.00841 (0.275)
Communication Equipment	-0.01325	0.01009	0.02335 (0.765)
Lujiazui Development	-0.04772	-0.00806	0.03966 (1.33)
Huaxin Cement	-0.01405	0.00531	0.01936 (0.642)
Jinjiang Hotel	-0.00384	0.00565	0.00949 (0.307)
Huan Dian	-0.02388	-0.02602	-0.00214 (-0.0688)
Huan Yuan Textile	-0.02954	-0.00989	0.01965 (0.642)
Dongfang Communication	-0.06302	-0.00459	0.05843 (1.95)*
Huangshan Travel	-0.02099	0.01517	0.03616 (1.19)
Averaged Difference			0.02986** (2.09)

H_0: $\lambda_B - \lambda_A = 0$, the values in the parentheses are the t-statistics

* Significance level of 10%, ** Significance level of 5%, *** Significance level of 1%

Table 5.2 Market price of risk estimation under GARCH model for SZE (totally 25 couples)

	A-share	B-share	
	λ_A	λ_B	λ_B-λ_A
Vanke	-0.01371	-0.03967	-0.02595 (-0.834)
CSG	-0.01566	0.00873	0.02440 (0.788)
KONKA Group	-0.05210	-0.01149	0.04061 (1.33)
Victor Onward	-0.01534	-0.01736	-0.00202 (-0.0665)
CWH	0.03713	0.03229	-0.00484 (-0.161)
CMPD	-0.01047	-0.00316	0.00730 (0.241)
FIYTA	-0.00748	-0.03090	-0.02342 (-0.778)
ACCORD PHARM.	-0.08462	-0.03489	0.04974 (1.67)
SPGO	-0.01113	-0.01254	-0.00141 (-0.0449)
NSRD	0.00984	0.00378	-0.00606 (-0.202)
CIMC	-0.06115	0.01777	0.07892 (1.18)
STHC	-0.01135	-0.01949	-0.00814 (-0.267)
FANGDA	-0.02192	-0.01279	0.00914 (0.298)
SZIA	-0.02018	-0.02309	-0.00291 (-0.0945)
SEGCL	-0.02639	-0.01325	0.01313 (0.426)
SJZBS	-0.01181	-0.02436	-0.01255 (-0.419)
SWAN	-0.04307	-0.01345	0.02963 (0.984)
LIVZON GROUP	-0.02431	0.00044	0.02475 (0.808)
HFML	-0.04538	-0.02756	0.01783 (0.590)
GED	-0.02416	-0.00757	0.01659 (0.522)
FSL	-0.01604	0.00526	0.02130 (0.717)
JMC	-0.00471	-0.07243	-0.06773 (-2.24)
SANONDA	-0.02709	-0.03016	-0.00307 (-0.102)
CHANGCHAI	-0.03806	-0.03396	0.00410 (0.135)
CHANGAN AUTO	0.00756	0.01099	0.00343 (0.116)
Averaged Difference			0.00731 (1.30)

H_0: $\lambda_B - \lambda_A = 0$, the values in the parentheses are the t-statistics

* Significance level of 10%, ** Significance level of 5%, *** Significance level of 1%

Research Papers 2008

CREATES
Center for Research in Econometric Analysis of Time Series

2008-02 Peter Reinhard Hansen: Reduced-Rank Regression: A Useful Determinant Identity

2008-03 Søren Johansen, Katarina Juselius, Roman Frydman and Michael Goldberg: Testing hypotheses in an I(2) model with applications to the persistent long swings in the Dmk/$ rate

2008-04 Olaf Posch: Explaining output volatility: The case of taxation

2008-05 Annastiina Silvennoinen and Timo Teräsvirta: Modelling Multivariate Autoregressive Conditional Heteroskedasticity with the Double Smooth Transition Conditional Correlation GARCH Model

2008-06 Annastiina Silvennoinen and Timo Teräsvirta: Multivariate GARCH models. To appear in T. G. Andersen, R. A. Davis, J.-P. Kreiss and T. Mikosch, eds. Handbook of Financial Time Series. New York: Springer.

2008-07 Changli He, Annastiina Silvennoinen and Timo Teräsvirta: Parameterizing unconditional skewness in models for financial time series

2008-08 Cristina Amado and Timo Teräsvirta: Modelling Conditional and Unconditional Heteroskedasticity with Smoothly Time-Varying Structure

2008-09 Søren Johansen and Bent Nielsen: An analysis of the indicator saturation estimator as a robust regression estimator

2008-10 Peter Christoffersen, Kris Jacobs, Christian Dorion and Yintian Wang: Volatility Components, Affine Restrictions and Non-Normal Innovations

2008-11 Peter Christoffersen, Kris Jacobs, Chayawat Ornthanalai and Yintian Wang: Option Valuation with Long-run and Short-run Volatility Components

2008-12 Tom Engsted and Stig V. Møller: An iterated GMM procedure for estimating the Campbell-Cochrane habit formation model, with an application to Danish stock and bond returns

2008-13 Lars Stentoft: Option Pricing using Realized Volatility

2008-14 Jie Zhu: Pricing Volatility of Stock Returns with Volatile and Persistent Components

2008-15 Jie Zhu: Testing for Expected Return and Market Price of Risk in Chinese A-B Share Market: A Geometric Brownian Motion and Multivariate GARCH Model Approach