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

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

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ABSTRACT

There exists the phenomenon of so-called dual listed stocks in some security markets: companies are allowed to issue different types of stocks facing segmented investors. Although these stocks share the same firm-specific risk, and enjoy identical dividend and voting policy, the price of these different types of stocks is not the same and the so-called pricing puzzle arises. Some previous studies show this seemingly 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-share stocks. Models with dynamic of Geometric Brownian Motions 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 the expected return and market price of risk between A and B shares in Chinese stock markets. However, the significance of the difference between market prices of risk becomes disappearing for both markets if GARCH models are used.

JEL Classification: C1, C32, G12
Keywords: China, stock market, market segmentation, expected return, market price of risk, GBM, GARCH

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1. INTRODUCTION

Some equity markets, including both developed and emerging ones, allow listed companies to issue different types of stocks. It is common that these stocks, which are issued by the same company, share the same firm-specific risk and in most cases also enjoy the same dividend and voting policies, 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 citizenships, that is, 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 gained from the segmentation, and more importantly, because of the arising of so-called pricing puzzle problems. It is called a puzzle in some sense because these shares 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 are significant price premium for foreign investors. Later Lam and Pak (1993) investigate Singaporean market, followed by Bailey (1994), Bailey and Jagtiani (1994), Stulz and Wasserfallen (1995) and Domowitz et al (1997) for studies of China, Thailand, Switzerland and Mexico markets respectively. Most of these studies confirm the conclusion found 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 are significant price differences between shares offered to domestic and foreign investors. Later on, Bailey et al (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 for the shares issued by the same company, 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 and Wasserfallen (1995) conclude that the different demand elasticity for securities between domestic and foreign investors can largely explain the different pricing.

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, to be discussed in detail later) returns and international stock index returns. From then, an increasing number of papers are produced on this topic, trying to explain the issue either through theoretical or empirical approaches. For example, Fernald and Rogers (1998, 2002) illustrate theoretically that the B-share discount is consistent with CAPM, it is due to higher expected return holding 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 betas. However, in the same year, Gordon and 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. Later, Sun and Tong (2000) and Diao and Levi (2005) also show that the discount can be explained by different demand elasticity. Karolyi and Li (2003) analyze the time series of stock data between and after Feb. 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 that propose other explanations for price differences. For example, Sarkar, Charkravarty and Wu (1998), Chen, Lee and Rui (2001), Chui and Chuck (1998) 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 et al (2005) attribute the puzzle to the different speculative motives between different investors by empirical analysis.

Thus up to now, there are a number of papers contribute to the resolution of B-share discount problem in Chinese Stock Market, yet the conclusion is still ambiguous. This paper tries to add some contributions to the solution of this foreign price discount problem by offering an empirical estimation of expected return and market price of risk for the price dynamics of A and B shares. The Geometric Brownian Motion is adopted as a benchmark and we show that under this assumption the price difference is consistent with the difference in expected returns. Furthermore we know that market price of risk measures the tradeoff between risk and return of an asset, i.e. the increase of expected returns demanded per additional unit of risk. Suleyman Basak (2005) argues that investors holding heterogeneous beliefs will have different market price of risk even for the same investments. Since A and B shares have the same payoff streams but are held by different investors, we can test their market prices of risk to see whether investors' beliefs matter 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 dividends rights, 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 highly correlated: 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, otherwise if the market price of risk is not equal, 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 averages 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 continuous time for Chinese stock market. Since enough data have been collected for continuous time estimation, it is a suitable way to perform the test in this approach. Thus in the paper, the stock prices are assumed to follow 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 riskfree 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 stock returns are first assumed to follow Bivariate Normal Distribution and Maximum Likelihood Methods are adopted to estimate the parameters, also t-test is provided to test the significance of the difference between market price of risk for the pairs. Finally in order to capture the time-varying property of volatility, Multivariate GARCH model with Dynamic Conditional Correlation is used to estimate the volatility term and test is re-done based on GARCH model.

The rest of the paper is organized as follows: Section 2 introduces a brief background of Chinese Stock Market, in Section 3 the methodology adopted 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 literatures have provided rather complete and elegant reviews on this emerging equity market. Green (2004) has written a book named The Development of China's Stock market, 1984-2002: Equity Politics and Market Institutions, for those who has interest in learning more, this book will be a good reference.

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

<Insert Table 1 about here>

As discussed in Mei et al.(2005) and some other papers, 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 values 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 to public, a majority share of equity will still be 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. Totally the State-retained shares, legal person shares and employee shares will account for 60%-70% of equity and only the rest goes to the 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 (1998)), 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 are listed in the same market where the corresponding A share is listed[2] 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 legally trade in A shares and domestic residents are not allowed to trade in B shares[3].

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[2] 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.

[3] 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 freely exchange between Chinese Yuan and Foreign currencies. Thus some constraints still exist for across-board trading between A and B shares.

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 to 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". The situation hasn't changed much up to now. Table 2 gives out the correlation coefficients among index-return series, the indices selected from Chinese stock market are Shanghai A-share Index, Shanghai B-share Index, Shenzhen A-share Index and Shenzhen B-share Index. The other indices are selected from major stock markets in the world: Hong Kong Hang Seng Index, Tokyo Nikkei225 Index, US S&P500 and Frankfurt Dax Ind, two from Asian market, one from America and another one from Europe.

<Insert Table 2 about here>

From Table 2, we can see that there are relatively higher correlations between the pairs of SHA and SHB, SZA and SZB, also notice that SHA and SHB are highly positively correlated, yet SZA and SZB are strongly negatively correlated. The correlations among other major indices are much larger than the correlations between these major indices and Chinese indices, but there is no significant difference between the correlations of Chinese A shares indices and the major indices compared to the correlations of Chinese B shares indices and the major indices. This result is somewhat similar to Bailey's conclusion in 1994 but with a little difference. In that paper, he argues the correlations between Chinese indices and other world market indices, at that time, suggest 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 the corresponding A shares. Define the market-value weighted B share discount at time t ($MVWBSD_t$) as follows:

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

Where n is the number of stocks, $S_{Ai,t}$ and $S_{Bi,t}$ are the A and B share price of stock i at time t.[4]

.<Insert Figure 1 about here>

<Insert 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 first calculating the

[4] 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 converted B shares prices at t into Chinese yuan according to the spot exchange rates at t.

B share discount of individual pair and then averaging the individual discounts by using their market value as the weights. From the figures we can see that as a whole, B shares are traded at a lower price than A shares all the time, the absolute value of discount reaches its maximum in 1999, which is -0.87 and -0.82 for Shanghai and Shenzhen respectively, which means that B shares are priced less than one-fifth of A shares on a average. Also note that the absolute value of discount decreases drastically after Feb. 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 we will present a model which tries to explain the B-share discount due to different expected returns between investors.

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 respective A and B shares, $\mu(t, S_{At})$ and $\sigma(t, S_{At})$ capture the drift and volatility of stock price process and they 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 forms for $\mu(t, S_{At})$ and $\sigma(t, S_{At})$. 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 term are constant. we can solve Equation (4) and (5) to get the following solutions:

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

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

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, at then it must hold that $S_{At} = S_{Bt}$.

Now from Equation (6) and (7) we can get that at the time t, the price ratio between A and B shares can be expressed as:

$$\frac{S_{At}}{S_{Bt}} = \frac{S_{AT}}{S_{BT}} \exp[(\mu_B - v_A)(T-t) - \frac{1}{2}(\sigma_B^2 - \sigma_A^2)(T-t) + \sigma_B (W_{BT} - W_{Bt}) - \sigma_A (W_{AT} - W_{At})] \quad (8)$$

Using the condition $S_{AT} = S_{BT}$ and the property of Wiener process, the expectation of the price ratio at time t is as follows:

$$E_t[\frac{S_{At}}{S_{Bt}}] = \exp[(\mu_B - \mu_A)(T-t) + \sigma_A^2 (T-t) - \rho\sigma_A\sigma_B (T-t)] \quad (9)$$

Equation (9) can be decomposed into three parts: i) the scaled difference in drift $(\mu_B - \mu_A)(T-t)$, ii) the scaled A share variance $\sigma_A^2(T-t)$ and iii) the scaled A-B share covariance $\rho\sigma_A\sigma_B(T-t)$. Assume that $\sigma_A = \sigma_B$ and if the correlation coefficient ρ is close to one, then the expectation value of price ratio is mainly driven by the scaled difference in drift term, more specifically, the difference in drift $\mu_B - \mu_A$ and the time to liquidation $T-t$. Since A and B shares are issued by the same company and are otherwise identical except the investor constraints, it seems reasonable from the theoretical point of view to make such assumptions However it is also argued from empirical work that A and B shares have different volatility and are not highly correlated (later we will estimate these values). But even in that case, since usually the term $\sigma_A^2 - \rho\sigma_A\sigma_B$ will not have higher order than $\mu_B - \mu_A$, it is still true that the difference in drift contributes significantly to the price discount, at least as significant as the term $\sigma_A^2 - \rho\sigma_A\sigma_B$. The larger the difference between μ_B and μ_A or the farther the time to liquidation, the larger the price ratio. Since we assume that $T-t$ is a finite horizon, the drift difference $\mu_B - \mu_A$ will always contribute to the price discount. As μ_A and μ_B are regarded as the expected return, we can also consider $\mu_B - \mu_A$ as the difference in the expected return between A and B shares. Please notice 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 T will arrive. If they know exactly the time of liquidation, then they can implement the strategy and such 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 et al (2004) to investigate the price discount for the 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 of short sell. As emphasized in Scheinkman and Xiong (2003) and Hong, Scheinkman and Xiong (2004), the short-sale constraints prevent arbitrageurs to sell overvalued 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 $T-t$ also seems to be similar to the argument advised by Fernald and Rogers (2002). In that paper, they argue that since the stock price can be expressed by using the famous Gordon (1962)'s model:

$$P_t = D_t \int_0^\infty e^{gs} e^{-rs} ds = \frac{D_t}{r-g} \tag{10}$$

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 caused by the difference in the discounted rate r. 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 μ_A, μ_B, σ_A, σ_B and ρ, the Maximum Likelihood Estimation Method is adopted. From Equation (4) and (5) we know that the log price pair follows the Bivariate Normal Distribution:

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

Then the joint density function for $r_{A,t}$, $r_{B,t}$ is

$$f(r_{At,} r_{Bt}, \mathbf{\theta}) = \frac{1}{2\pi\sigma_A\sigma_B\Delta t\sqrt{1-\rho^2}} \exp\{-\frac{1}{2(1-\rho^2)}[\frac{(r_{At} - (\mu_{At} - \frac{1}{2}\sigma_A^2)\Delta t)^2}{\sigma_A^2 \Delta t}$$
$$+ \frac{(r_{Bt} - (\mu_{Bt} - \frac{1}{2}\sigma_B^2)\Delta t)^2}{\sigma_B^2 \Delta t} - 2\rho \frac{(r_{At} - (\mu_{At} - \frac{1}{2}\sigma_A^2)\Delta t)}{\sigma_A \Delta t} \frac{(r_{At} - (\mu_{At} - \frac{1}{2}\sigma_A^2)\Delta t)}{\sigma_B \Delta t}]\} \quad (11)$$

And $\mathbf{\theta}$ is the parameter vector:

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

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

$$\lambda_t(r_{At}, r_{Bt}, \mathbf{\theta}) = -\log(2\pi) - \log(\sigma_A) - \log(\sigma_B) - \log(\Delta t) - \frac{1}{2}\log(1-\rho^2) - \frac{1}{2(1-\rho^2)}$$
$$[\frac{(r_{At} - (\mu_{At} - \frac{1}{2}\sigma_A^2)\Delta t)^2}{\sigma_A^2 \Delta t} - 2\rho \frac{(r_{At} - (\mu_{At} - \frac{1}{2}\sigma_A^2)\Delta t)}{\sigma_A}$$
$$\frac{(r_{Bt} - (\mu_{Bt} - \frac{1}{2}\sigma_B^2)\Delta t)}{\sigma_B \Delta t} + \frac{(r_{Bt} - (\mu_{Bt} - \frac{1}{2}\sigma_B^2)\Delta t)^2}{\sigma_B^2 \Delta t}] \quad (12)$$

The log likelihood of the whole data series is

$$L(r_{A1}, r_{B1}, ..., r_{AT}, r_{BT}; \mathbf{\theta}) = \sum_{t=1}^{T} \lambda_t(r_{At}, r_{Bt}; \mathbf{\theta}) \quad (13)$$

The maximum likelihood estimator is therefore the choice of parameters θ that maximize the Equation (13)

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 rights and dividends, although they may have different expected returns, the difference maybe 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.

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

$$dS_{At} = (r_{f,At} + \lambda_A \sigma_A) S_{At} dt + \sigma_A S_{At} dW_{At} \tag{14}$$

$$dS_{Bt} = (r_{f,Bt} + \lambda_B \sigma_B) S_{Bt} dt + \sigma_B S_{Bt} dW_{At} \tag{15}$$

$r_{f,At}$ 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. We can still adopt the maximum likelihood methods to estimate the parameters. The probability density function is the same as in Equation (11), but we need to substitute the constant μ_A and μ_B in Equation (11) with time-varying drift terms as in Equation (14) and (15). 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 loglikelihood function as in equation (13) to estimate the parameter vector $\boldsymbol{\theta}$ with substitute $r_{fi,t} + \lambda_i \sigma_i$ 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 the stock returns follow normal distribution with constant volatility. However it is well known that, in general, asset returns do not follow homoskedastic distributions. Instead they are usually skewed and have excess kurtosis greater than zero. That is also why different GARCH models are frequently used 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 common sharing of at least part of the economic fundamentals derived from the same company. In other words we have to adopt some model that can capture such feature. Thus in this paper the Dynamic Conditional Correlation (DCC) GARCH model suggested by Engle (2002) will be adopted. The advantage of this model is that it allows time-varying correlation across the returns series. The GARCH-DCC model keeps the flexibility and simplicity of univariate GARCH models while it is also able to capture the feature of conditional correlations. It can be estimated in a simple way based on the log likelihood function. In this paper since we only consider the A-B share pairs, actually we only need the bivariate version of the model.

Take a couple of A-B shares returns, $\mathbf{r}_t = [r_{A,t} + r_{B,t}]'$, $i = A, B$, we still assume $\mathbf{r}_t$ follows dynamic similar to GBM but with some time-varying volatilities, so that we can model $\mathbf{r}_t$ by some kind of GARCH-M model with time-varying volatilities which follow DCC model:

$$\mathbf{r}_t = \mathbf{u}_t + \boldsymbol{\varepsilon}_t \tag{16}$$

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:

$$\mathbf{u}_t = \boldsymbol{\mu}_t - \frac{1}{2} diag(\mathbf{H}_t) = \mathbf{r}_{f,t} + \boldsymbol{\lambda}[diag(\mathbf{H}_t)^{\frac{1}{2}}] - \frac{1}{2} diag(\mathbf{H}_t) \tag{17}$$

and $\boldsymbol{\varepsilon}_t | I_{t-1} \sim N(0, \mathbf{H}_t)$, I_{t-1} is the information set at $t-1$, we can also write in the form: $\boldsymbol{\varepsilon}_t = \mathbf{H}_t^{\frac{1}{2}} \mathbf{Z}_t$ and $\mathbf{Z}_t \sim N(0, I_2)$, 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 terms, $\mathbf{r}_{f,t}$ is the risk-free rates and $\boldsymbol{\lambda}$ is the market risk premia, 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).

Equation (17) 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 of returns $\mathbf{H}_t$ instead of constant ones σ_A^2 and σ_B^2 in previous cases. The diagonal elements of $\mathbf{H}_t$, $h_{AA,t}$ and $h_{BB,t}$ correspond to σ_A^2 and σ_B^2, the off-diagonal elements $h_{AB,t}$ and $h_{BA,t}$ represent the covariance between the returns. All of the elements of $\mathbf{H}_t$ are conditionally time-dependent.

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

$$\mathbf{H}_t = \mathbf{D}_t \mathbf{R}_t \mathbf{D}_t \tag{18}$$

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:

$$h_{AA,t} = \omega_A + \gamma_A \varepsilon_{A,t-1}^2 + \phi_A h_{AA,t-1} \tag{19}$$

$$h_{BB,t} = \omega_B + \gamma_B \varepsilon_{B,t-1}^2 + \phi_B h_{BB,t-1} \tag{20}$$

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:

$$q_{AB,t} = \overline{\rho}_{AB}(1 - \alpha - \beta) + \alpha q_{AB,t-1} + \beta \eta_{A,t-1} \eta_{B,t-1} \tag{21}$$

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

$$\gamma_A + \phi_A < 1,\ \gamma_B + \phi_B < 1 \text{ and } \alpha + \beta < 1 \tag{22}$$

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

$$\rho_{AB,t} = \frac{q_{AB,t}}{\sqrt{q_{AA,t} q_{BB,t}}} \tag{23}$$

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

$$\varepsilon_{t-1} | I_{t-1} \sim N(0, \mathbf{H}_t)$$

$$L = -\frac{1}{2} \sum_{t=1}^{T} [n \log(2\pi) + \log(\mathbf{H}_t) + \varepsilon_t' \mathbf{H}_t^{-1} \varepsilon_t]$$

$$= -\frac{1}{2} \sum_{t=1}^{T} [n \log(2\pi) + \log|\mathbf{D}_t \mathbf{R}_t \mathbf{D}_t| + \varepsilon_t' \mathbf{D}_t^{-1} \mathbf{R}_t^{-1} \mathbf{D}_t^{-1} \varepsilon_t]$$

$$= -\frac{1}{2} \sum_{t=1}^{T} [n \log(2\pi) + 2 \log|\mathbf{D}_t| + \log|\mathbf{R}_t| + \eta_t' \mathbf{R}_t^{-1} \eta_t] \tag{24}$$

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

We can maximize the log likelihood function of Equation (24)[5] via the parameters space to estimate the parameters. Totally there are 10 parameters to be estimated: $(\boldsymbol{\lambda}, \boldsymbol{\omega}, \boldsymbol{\gamma}, \boldsymbol{\varphi}, \alpha, \beta)$, where $\boldsymbol{\lambda} = (\lambda_A, \lambda_B)'$, $\boldsymbol{\omega} = (\omega_A, \omega_B)'$, $\boldsymbol{\gamma} = (\gamma_A, \gamma_B)'$, and $\boldsymbol{\varphi} = (\phi_A, \phi_B)'$. 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 changes results significantly or not.

4. DATA AND EMPIRICAL RESULTS

4.1 Data Description

The Data is collected from Shanghai Stock Exchange and Shenzhen Stock Exchange Data Service. Currently there are 86 companies, which have both listed 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 of 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 this paper, 32 from SSE and 25 from SZE. These pairs represent all the A-B shares which are continuously traded during the sample period, which runs from the beginning of 1997 to the June of 2005, totally lasts for eight and half years. The daily close price of these shares are collected and there are about 2000 observations in total. The price is also adjusted for missing value or stock dividends. For the riskfree rate, since I can't find the data on yield to maturity for short term treasury note for the whole sample period from the Chinese bond market, the 3-month deposit rate in China is adopted as a proxy for the riskfree rate. For the riskfree rate for US. dollar and Hong Kong dollar, the rate for the 3-month U.S. treasury notes and 3-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 I used the daily exchange rate between Yuan and U.S. dollar and Yuan and Hong Kong dollar to convert B share prices into Chinese Yuan.[6]

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[5] As argued 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

[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 it is safe to ignore. This assumption is also adopted by most other papers that study this issue.

4.2 Empirical Results

4.2.1 Constant Expected Return and Volatility

Table 3.1 and 3.2 present the estimation results of the drift, volatility as well as the correlation coefficient for the Equation (4) and (4) respectively.

<Insert Table 3.1 about here>

<Insert 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 statistic is not significant for the difference. The t-statistics 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 couples show the strongly significant at the level of 5%.or below. For SZE, the result is similar, 22 of 25 pairs show significantly difference between the drift terms. From the result we can convince that the expected returns of B shares are larger than those of A shares, as the model suggests.

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 et al. (1997) provide the estimated volatility in U.S. stock market and the number is below 0.3. However in our estimation, both SSE and SZE show much higher volatilities for all the shares. None of the estimations is below 30%, the largest value for SSE is above 50% and for SZE the figure is even higher. Such kind of high volatility is a feature for developing market, as argued by many papers. 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 larger than the corresponding A shares. This result seems to be contradicting with previous studies. For example, some papers 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, this 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 in our estimation. The result tells us that although most B shares have less trading volume than A shares yet they have higher volatility. The reason for this is that maybe the ratio of institutional investors in B shares is higher 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 that can also contribute to this issue is that in Feb. 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, this 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 tell us they are significance 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.

Finally let's pay some attentions to the correlation coefficient. As argued, the correlation coefficients 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. However for SZE there are two pairs whose correlation coefficients are negative, it means that A and B shares move in the opposite way. However the correlation between A and B shares are not strong, this can be seen from the fact that most of the coefficient is less than 03. The largest figure in SSE is 0.4205 and most of them in this 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 comovements between them.

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 for Equation (14) and (15) for SSE and SZE respectively.

<Insert Table 4.1 about here>

<Insert 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 no surprise because the model just decomposes the drift term into riskfree rate plus the multiplication of the market price of risk and the volatility but leaves the volatility terms untouched. It is the same case for the correlation coefficient so that I didn't provide the result of ρ here, it is exactly the same one 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 can see that it is also the same case for the market price of risk, that is to say that the difference between the market price of risk $\lambda_B - \lambda_A$ is positive for most pairs, but the individual significance is not so strong compared to the difference between the expected returns $\mu_B - \mu_A$. 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 not so strong, only 10 of 25 pairs show significant in the difference, this 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-statistics are smaller than those for expected returns. This means as a whole the market price of risk for B shares is still higher than that for A shares. Although the result is not as robust 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 returns is related to differences in individual share's market betas, which plays the similar role as the market price of risk in our study. However there are still some differences between his paper and this one. First in this paper we estimate the market price of risk by a continuous setup and a longer sample period as well as more shares data are adopted. Second, in this paper the result is not as significant 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 reasonable assumption 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 Model

However as discussed before, normal distribution assumption is not suitable for return series. Next I perform the GARCH-M 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 ω_A, γ_A, ϕ_A and ω_B, γ_B, ϕ_B in Equation (19) and (20) are significant for most shares, this also holds for the parameters for correlation dynamics, that is, α and β in Equation (21).[7]

This means 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:

<Insert Table 5.1 about here>

<Insert Table 5.2 about here>

Notice that most of the estimation of market price of risk becomes much smaller to their corresponding parts in previous tables. This is not surprise because we can imagine that most of the fluctuations in the return series have been absorbed by time-varying volatility parts, the constant market price of risk is contributed much less to explain the volatilities. The most interest thing for us is that the difference of market price of risk between A and B shares now becomes insignificant for all couple stocks, 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, the averaged difference 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

[7] 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.

difference can be explained by different 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, but some don't, this happens in SZE. However if we adopt GARCH-DCC model to do the same work, then property of higher B share market price of risk largely disappears for individual twin shares. Thus it is safe to say that the 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 used to correct the heteroskedasticity in volatilities, this property disappears. Please also notice that the two markets behaves a little 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 closer expected returns as to domestic ones. All in all, the empirical results lead to the conclusion that the price discount can be explained by different expected returns for different investors, but it cannot be contributed to the difference in market price of risk for these twin shares.

5. CONCLUSION

This paper investigates the behavior of the corresponding stock prices in two segmented markets: the stock prices of A and B shares for domestic and foreign investors. The AB-share pair is issued by the same company, has the same voting rights and the same dividend, yet A and B shares 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 used to describe the dynamic of the stock prices and illustrates that the price discount can be explained by the different expected returns, i.e. B shares have higher expected returns than A shares. The empirical test is consistent with the model for both markets. Furthermore the higher B share expected returns not only come from the higher riskfree rate and higher volatility, the market price of risk of B shares is also higher than the corresponding A shares, however the result in SSE is more significant than the result in SZE. As a final part, 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. Actually for individual shares, the difference between the market price of risk is very close to zero and the t-statistics are quite insignificant. The result is more obvious for Shenzhen market. This means that the estimation result of higher market price of risk is largely caused by the heteroskedasticity of volatility, such property of higher market price of risk disappears when a suitable time-varying volatility model is implemented.

The main attention of this paper is paid to test the difference in expected returns and market price of risk for A and B shares, but the paper doesn't explore the reason why A and B shares have different expected returns. Further study may be focused on this interesting topic. As some previous papers present, liquidity premium, demand elasticity, asymmetric information, all of them may be reasons for the difference, it is also possible that the difference is caused by other factors. Another extension of the paper is to try different function forms of market risk premium, a time-varying market price of risk which can be dependent on different state variables will be a good candidate and it is also interesting to compare the path of these market prices of risks for different corresponding twin shares.

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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

Table 2: Correlation Test for Different Index Returns

Return Series	Correlation with return on (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	-0.87901	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

The market-value weighted B-share discount in Shanghai stock market

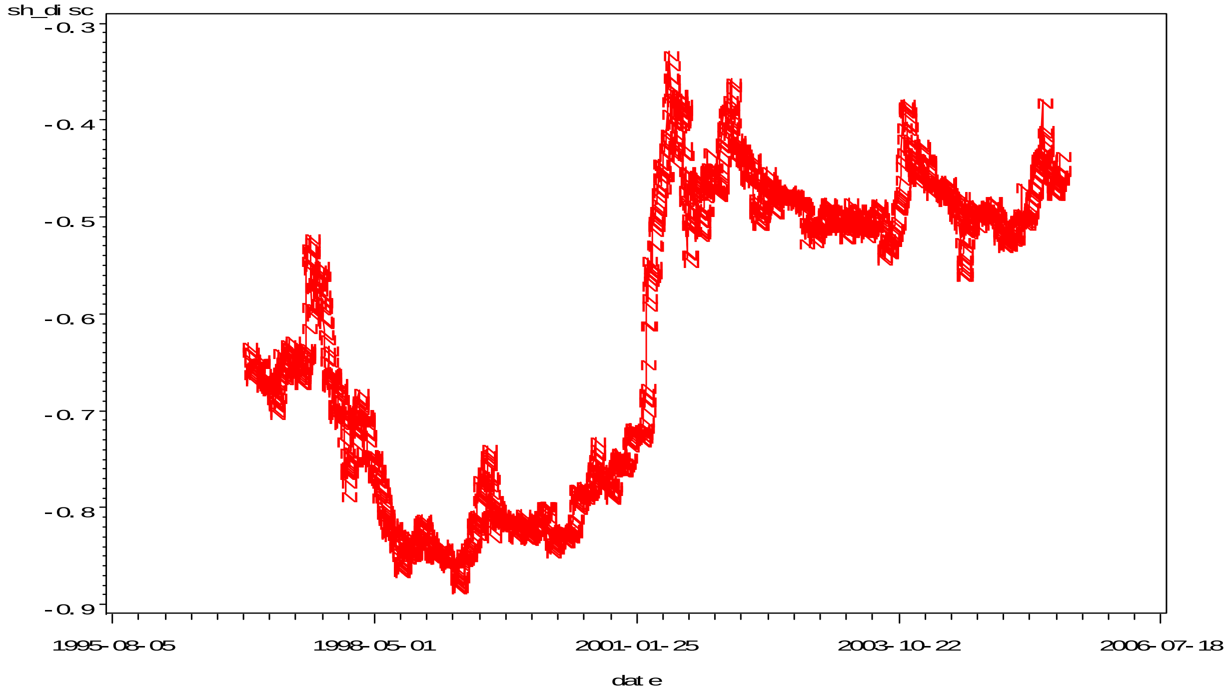

Figure 2

The market-value weighted B-share discount in Shenzhen stock market

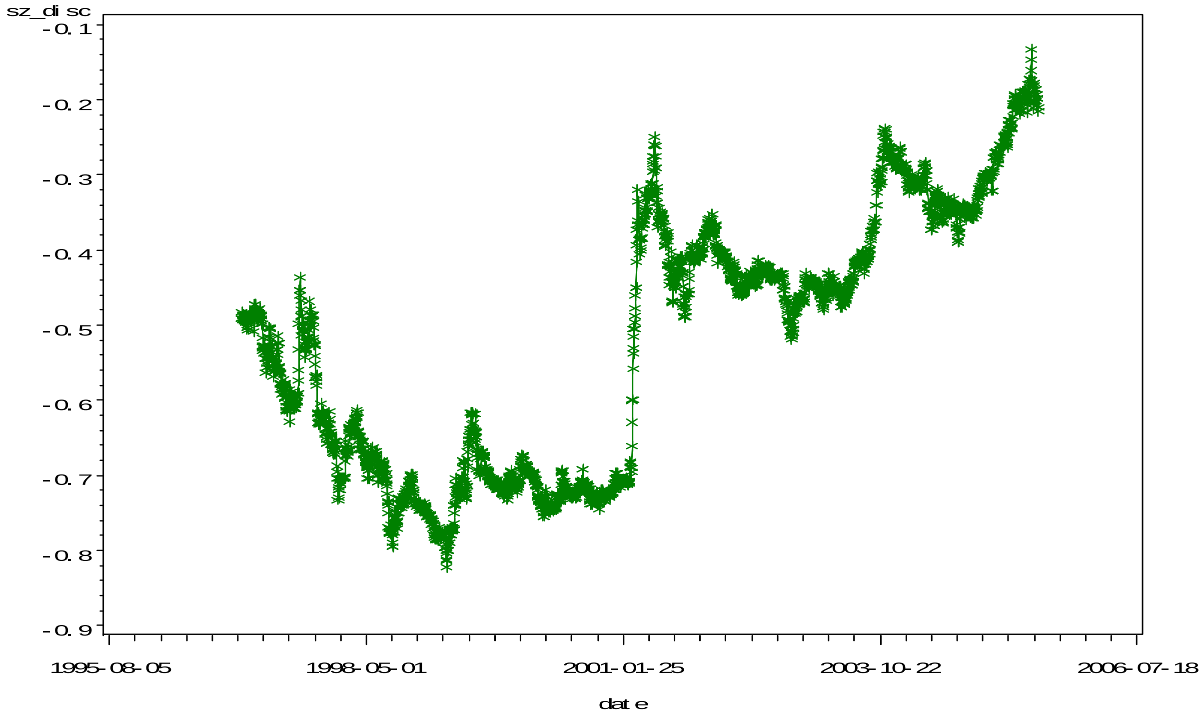

Table 3.1: Constant expected return and volatility estimation for SSE (totally 32 couples)

	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 (2.312)**	0.0193 (0.521)	0.2308
Shanghai Erfangji	0.0519	0.4570	0.1214	0.5208	0.0695 (5.383)***	0.0638 (1.734)*	0.2400
Dazhong Taxi	-0.0415	0.4142	0.0965	0.5462	0.1381 (11.341)***	0.1320 (3.204)***	0.4205
Yongsheng Stationery	0.0739	0.4361	0.0953	0.4659	0.0214 (2.512)**	0.0298 (0.673)	0.1754
China First Pencil	0.0076	0.4075	0.0456	0.4901	0.0380 (2.680)***	0.0826 (2.236)**	0.1735
China Textile Machinery	0.0752	0.4368	0.1076	0.4848	0.0325 (2.947)***	0.0481 (1.458)	0.1931
Shanghai Rubber Belt	0.0723	0.4384	0.1293	0.4785	0.0569 (5.611)***	0.0400 (0.933)	0.1433
Shanghai Chlor Alkai	0.0029	0.4226	0.0727	0.5009	0.0698 (5.275)***	0.0784 (1.963)**	0.1533
Shanghai Tire & Rubber	0.0021	0.4152	0.0644	0.5297	0.0623 (4.135)***	0.1145 (2.986)***	0.1447
Shanghai Refrigerator	0.0274	0.4130	0.1160	0.5066	0.0887 (7.334)***	0.0935 (2.288)**	0.2435
Jinqiao Export & Import	-0.0415	0.3863	0.0695	0.4598	0.1110 (9.450)***	0.0735 (2.033)**	0.2258
Outer Gaoqiao	-0.0584	0.3793	0.0419	0.4364	0.1002 (8.269)***	0.0571 (1.743)*	0.2353
JinJiang Investment	0.0622	0.4112	0.1834	0.4960	0.1212 (10.02)***	0.0848 (2.311)**	0.2401
Forever Bicycle	0.1046	0.4371	0.2296	0.5929	0.1250 (8.087)***	0.1558 (0.334)	0.0885
Phoenix Bicycle	0.0388	0.4526	0.1346	0.5416	0.0958 (6.947)***	0.0890 (1.748)*	0.2002
Shanghai Haixing Group	0.0063	0.4608	0.0546	0.5346	0.0483 (3.125)***	0.0738 (0.264)	0.1840
Yaohua Pilkington Glass	0.0013	0.3965	0.1132	0.5216	0.1119 (7.592)***	0.1251 (1.139)	0.1269
Shanghai Diesel Engine	0.0117	0.3778	0.1062	0.4895	0.0945 (7.197)***	0.1117 (3.031)**	0.1800
Sanmao Textile	0.0080	0.4779	0.1024	0.5032	0.0944 (6.287)***	0.0253 (0.362)	0.1924
Shanghai Friendship Shop	0.0211	0.4270	0.1483	0.5086	0.1271 (9.266)***	0.0816 (1.337)	0.2619
Industrial Sewing Machine	0.0411	0.4619	0.1476	0.5195	0.1065 (4.266)***	0.0576 (0.958)	0.1704
Shang-Ling Refrigerator	0.0172	0.4246	0.1175	0.4921	0.1003 (7.337)***	0.0676 (1.282)	0.1664
Baoxin Software	0.1507	0.4311	0.2854	0.6333	0.1347 (8.241)***	0.2022 (0.371)	0.1237
Shanghai Merchandise Trading	0.0989	0.4315	0.1707	0.4936	0.0718 (5.221)***	0.0621 (1.561)	0.1318
Communication Equipment	0.0190	0.4591	0.0818	0.5095	0.0628 (4.934)***	0.0504 (1.280)	0.3262
Lujiazui Development	-0.1228	0.3638	0.0000	0.4589	0.1228 (11.09)***	0.0951 (2.455)**	0.2883
Huaxin Cement	0.0203	0.4023	0.1422	0.5138	0.1219 (8.907)***	0.1115 (3.007)***	0.1992
Jinjiang Hotel	0.0592	0.4133	0.1532	0.5064	0.0940 (7.909)***	0.0931 (2.523)**	0.2949
Huan Dian	-0.0616	0.4056	0.0189	0.5014	0.0805 (6.364)***	0.0958 (0.898)	0.2106
Huan Yuan Textile	-0.0851	0.3830	0.0589	0.5293	0.1440 (11.50)***	0.1463 (3.248)***	0.2877
DongfangCommunication	-0.1363	0.4263	-0.0238	0.4812	0.1125 (9.159)***	0.0550 (1.683)*	0.2731
Huangshan Travel	-0.0550	0.3537	0.1465	0.4871	0.2015 (16.73)***	0.1334 (3.816)***	0.2163
Averaged Difference					0.091983 (12.57)***	0.0859 (11.92)***	

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 (totally 25 couples)

	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 (12.75)***	0.1353 (0.4555)	0.1122
CSG	-0.00491	0.4835	0.1502	0.6750	0.1551 (9.114)***	0.1915 (0.4941)	0.1023
KONKA Group	-0.0811	0.3869	-0.0287	0.4674	0.0524 (3.893)***	0.0805 (2.013)**	0.0091
Victor Onward	0.082672	0.4793	0.0838	0.5516	0.0012 (0.242)	0.0723 (1.577)	0.0064
CWH	0.17758	0.3910	0.2554	0.5023	0.0778 (5.517)***	0.1113 (2.138)**	0.0093
CMPD	0.014488	0.3933	0.1057	0.4588	0.0912 (7.049)***	0.0655 (1.749)*	0.0215
FIYTA	-0.05164	0.4315	0.0035	0.5224	0.0551 (4.126)***	0.0909 (0.953)	0.0284
ACCORD PHARM.	0.002789	0.4905	0.1114	0.6168	0.1086 (6.531)***	0.1263 (0.813)	0.0493
SPGO	0.008034	0.4737	0.0076	0.5396	-0.0005 (-0.181)	0.0659 (1.477)	0.0325
NSRD	0.05795	0.4394	0.1789	0.5253	0.1210 (8.222)***	0.0859 (0.437)	0.0311
CIMC	0.055974	0.5091	0.1499	0.5983	0.0939 (5.785)***	0.0893 (0.314)	0.0127
STHC	0.065603	0.4785	0.1170	0.5782	0.0514 (3.370)***	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 (3.671)***	0.0885 (1.79)*	0.0269
SEGCL	-0.07874	0.4599	-0.0490	0.5161	0.0297 (3.215)***	0.0562 (0.821)	0.0225
SJZBS	-0.06514	0.4239	-0.0454	0.4874	0.0198 (1.669)*	0.0636 (1.894)*	0.0461
SWAN	-0.18962	0.3675	-0.0622	0.4754	0.1274 (9.83)***	0.1080 (2.551)**	-0.0179
LIVZON GROUP	0.023494	0.4251	0.0973	0.5173	0.0738 (4.984)***	0.0922 (1.813)*	0.0011
HFML	-0.11996	0.4135	-0.0340	0.5208	0.0860 (6.136)***	0.1073 (2.174)**	0.0198
GED	-0.03112	0.4323	0.0543	0.5119	0.0854 (6.032)***	0.0796 (0.326)	0.0268
FSL	0.020734	0.3132	0.1081	0.4071	0.0874 (7.684)***	0.0939 (2.882)***	0.0279
JMC	0.06722	0.4257	0.3037	0.7982	0.2365 (12.17)***	0.3725 (0.453)	0.0146
SANONDA	-0.08059	0.4040	-0.0325	0.4969	0.0481 (3.604)***	0.0930 (2.305)**	0.0007
CHANGCHAI	-0.07327	0.4105	-0.0361	0.4843	0.0372 (2.370)***	0.0738 (1.996)**	-0.0041
CHANGAN AUTO	-0.02019	0.4048	0.1553	0.5694	0.1755 (11.00)***	0.1647 (2.395)**	0.0159
Averaged Difference					0.0811 (6.522)***	0.1077 (8.318)***	

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	λ_B-λ_A	σ_B-σ_A
Shanghai Vacuum Electronics	0.2036	0.4619	0.3016	0.4813	0.0980 (1.2209)	0.0194 (0.521)
Shanghai Erfangji	0.1128	0.4570	0.2319	0.5208	0.1192 (1.4951)	0.0638 (1.734)*
Dazhong Taxi	-0.0611	0.4142	0.1647	0.5462	0.2257 (3.2462)***	0.1320 (3.204)***
Yongsheng Stationery	0.1285	0.4361	0.1962	0.4659	0.0676 (0.8171)	0.0298 (0.673)
China First Pencil	0.0179	0.4075	0.0919	0.4901	0.0740 (0.8910)	0.0826 (2.236)**
China Textile Machinery	0.1713	0.4368	0.2208	0.4848	0.0495 (0.6034)	0.0480 (1.458)
Shanghai Rubber Belt	0.1372	0.4384	0.2633	0.4785	0.1262 (1.4916)	0.0401 (0.933)
Shanghai Chlor Alkai	0.0060	0.4226	0.1440	0.5009	0.1380 (1.6432)	0.0783 (1.963)**
Shanghai Tire & Rubber	0.0042	0.4152	0.1205	0.5297	0.1163 (1.3769)	0.1145 (2.986)***
Shanghai Refrigerator	0.0633	0.4130	0.2280	0.5066	0.1647 (2.0763)**	0.0936 (2.288)**
Jinqiao Export & Import	-0.1128	0.3863	0.1520	0.4598	0.2648 (3.2983)***	0.0735 (2.033)**
Outer Gaoqiao	-0.1696	0.3793	0.1034	0.4364	0.2730 (3.4194)***	0.0571 (1.743)*
JinJiang Investment	0.1485	0.4112	0.3681	0.4960	0.2197 (2.7611)***	0.0848 (2.311)**
Forever Bicycle	0.2262	0.4371	0.3789	0.5929	0.1527 (1.7507)*	0.1558 (0.334)
Phoenix Bicycle	0.0700	0.4526	0.2490	0.5416	0.1790 (2.1896)**	0.0890 (1.748)*
Shanghai Haixing Group	-0.0131	0.4608	0.1066	0.5346	0.1196 (1.3795)	0.0738 (0.264)
Yaohua Pilkington Glass	0.0025	0.3965	0.2159	0.5216	0.2135 (2.5002)**	0.1251 (1.139)
Shanghai Diesel Engine	0.0299	0.3778	0.2158	0.4895	0.1859 (2.2417)**	0.1117 (3.031)***
Sanmao Textile	0.0286	0.4779	0.1951	0.5032	0.1664 (2.2035)**	0.0253 (0.362)
Shanghai Friendship Shop	0.0514	0.4270	0.2899	0.5086	0.2385 (3.0402)***	0.0816 (1.337)
Industrial Sewing Machine	0.1555	0.4619	0.2395	0.5195	0.0840 (1.0092)	0.0576 (0.958)
Shang-Ling Refrigerator	0.0191	0.4246	0.2424	0.4921	0.2232 (2.6761)***	0.0675 (1.282)
Baoxin Software	0.3487	0.4311	0.4498	0.6333	0.1010 (1.1817)	0.2022 (0.371)
Shanghai Merchandise Trading	0.2284	0.4315	0.3446	0.4936	0.1162 (1.3643)	0.0621 (1.561)
Communication Equipment	0.0406	0.4591	0.1595	0.5095	0.1189 (1.5865)	0.0504 (1.280)
Lujiazui Development	-0.3353	0.3638	-0.0036	0.4589	0.3317 (4.3055)***	0.0951 (2.455)**
Huaxin Cement	0.0495	0.4023	0.2757	0.5138	0.2262 (2.7645)***	0.1115 (3.007)***
Jinjiang Hotel	0.1556	0.4133	0.3046	0.5063	0.1490 (1.9452)*	0.0930 (2.523)**
Huan Dian	-0.1528	0.4056	0.0365	0.5014	0.1894 (2.3317)**	0.0958 (0.898)
Huan Yuan Textile	-0.2231	0.3830	0.1102	0.5293	0.3333 (4.3186)***	0.1463 (3.248)***
Dongfang Communication	-0.3205	0.4263	-0.0506	0.4812	0.2700 (3.4696)***	0.0549 (1.683)*
Huangshan Travel	-0.1566	0.3537	0.2994	0.4871	0.4560 (5.6536)***	0.1334 (3.816)***
Averaged Difference					0.1810 (10.85)***	0.0859 (11.92)***

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 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 (2.8964)***	0.1353 (0.4555)
CSG	-0.0108	0.4835	0.2239	0.6750	0.2347 (2.5771)**	0.1915 (0.4941)
KONKA Group	-0.1946	0.3869	-0.0974	0.4673	0.0972 (1.0636)	0.0804 (2.013)**
Victor Onward	0.1719	0.4793	0.1507	0.5516	-0.0212 (-0.2311)	0.0723 (1.577)
CWH	0.4243	0.3910	0.5385	0.5023	0.1142 (1.2492)	0.1113 (2.138)**
CMPD	0.0363	0.3933	0.2294	0.4588	0.1931 (2.1264)**	0.0655 (1.749)*
FIYTA	-0.1112	0.4315	-0.0225	0.5224	0.0888 (0.9827)	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 (1.477)
NSRD	0.1287	0.4394	0.3380	0.5253	0.2093 (2.3109)**	0.0859 (0.437)
CIMC	0.1092	0.5091	0.2512	0.5983	0.1420 (1.5444)	0.0892 (0.314)
STHC	0.1501	0.4785	0.1921	0.5782	0.0420 (0.4627)	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 (0.7979)	0.0885 (1.79)*
SEGCL	-0.1734	0.4599	-0.0944	0.5161	0.0790 (0.8706)	0.0562 (0.821)
SJZBS	-0.1569	0.4239	-0.0914	0.4874	0.0655 (0.7304)	0.0635 (1.894)*
SWAN	-0.5137	0.3675	-0.1396	0.4754	0.3741 (4.041)***	0.1079 (2.551)**
LIVZON GROUP	0.0544	0.4251	0.1869	0.5173	0.1325 (1.4372)	0.0922 (1.813)*
HFML	-0.2936	0.4135	-0.0613	0.5208	0.2322 (2.5573)**	0.1073 (2.174)**
GED	-0.0728	0.4323	0.1048	0.5119	0.1776 (1.9645)**	0.0796 (0.326)
FSL	0.0740	0.3132	0.2663	0.4071	0.1923 (2.1181)**	0.0939 (2.882)***
JMC	0.2083	0.4257	0.3604	0.7982	0.1521 (1.6735)*	0.3725 (0.453)
SANONDA	-0.1833	0.4040	-0.0985	0.4969	0.0848 (0.9237)	0.0929 (2.305)**
CHANGCHAI	-0.1792	0.4105	-0.0764	0.4843	0.1027 (1.1182)	0.0738 (1.996)**
CHANGAN AUTO	-0.0459	0.4048	0.2632	0.5694	0.3091 (3.3932)***	0.1646 (2.395)**
Averaged Difference					0.1340 (6.045)***	0.1077 (8.317)***

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 (0.8381)
Shanghai Erfangji	-0.01407	-0.00146	0.01261 (0.4148)
Dazhong Taxi	-0.06327	-0.03487	0.02840 (0.9096)
Yongsheng Stationery	-0.01493	-0.05720	-0.04227 (-1.294)
China First Pencil	-0.01662	-0.02185	-0.00523 (-0.1258)
China Textile Machinery	-0.00761	0.00889	0.01650 (0.5445)
Shanghai Rubber Belt	-0.00379	-0.00571	-0.00193 (-0.0624)
Shanghai Chlor Alkai	-0.02473	-0.00804	0.01669 (0.4615)
Shanghai Tire & Rubber	-0.03968	-0.00785	0.03183 (0.3346)
Shanghai Refrigerator	-0.00890	0.00143	0.01033 (0.3393)
Jinqiao Export & Import	-0.02675	-0.01386	0.01289 (0.4245)
Outer Gaoqiao	-0.02912	-0.02005	0.00907 (0.2991)
JinJiang Investment	-0.00317	0.01135	0.01452 (0.4729)
Forever Bicycle	-0.00880	0.01785	0.02665 (0.8688)
Phoenix Bicycle	-0.00875	0.45978	0.46853 (1.335)
Shanghai Haixing Group	-0.01541	-0.01755	-0.00214 (-0.0673)
Yaohua Pilkington Glass	-0.00961	-0.00127	0.00833 (0.2583)
Shanghai Diesel Engine	-0.01536	0.00541	0.02077 (0.6884)
Sanmao Textile	-0.01542	-0.01544	-0.00003 (-0.0008)
Shanghai Friendship Shop	-0.02747	0.01365	0.04112 (1.1396)
Industrial Sewing Machine	-0.00607	0.00086	0.00693 (0.2190)
Shang-Ling Refrigerator	-0.02044	-0.00653	0.01391 (0.4665)
Baoxin Software	-0.00041	0.03650	0.03691 (1.145)
Shanghai Merchandise Trading	-0.01075	-0.00234	0.00841 (0.2754)
Communication Equipment	-0.01325	0.01009	0.02335 (0.7653)
Lujiazui Development	-0.04772	-0.00806	0.03966 (1.332)
Huaxin Cement	-0.01405	0.00531	0.01936 (0.6415)
Jinjiang Hotel	-0.00384	0.00565	0.00949 (0.3065)
Huan Dian	-0.02388	-0.02602	-0.00214 (-0.0688)
Huan Yuan Textile	-0.02954	-0.00989	0.01965 (0.6419)
Dongfang Communication	-0.06302	-0.00459	0.05843 (1.952)*
Huangshan Travel	-0.02099	0.01517	0.03616 (1.187)
Averaged Difference			0.02986 (2.089)**

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 (-0.8342)
CSG	-0.01566	0.00873	0.02440 (0.7879)
KONKA Group	-0.05210	-0.01149	0.04061 (1.3258)
Victor Onward	-0.01534	-0.01736	-0.00202 (-0.0665)
CWH	0.03713	0.03229	-0.00484 (-0.1607)
CMPD	-0.01047	-0.00316	0.00730 (0.2410)
FIYTA	-0.00748	-0.03090	-0.02342 (-0.7779)
ACCORD PHARM.	-0.08462	-0.03489	0.04974 (1.6704)
SPGO	-0.01113	-0.01254	-0.00141 (-0.0449)
NSRD	0.00984	0.00378	-0.00606 (-0.2022)
CIMC	-0.06115	0.01777	0.07892 (1.1801)
STHC	-0.01135	-0.01949	-0.00814 (-0.2672)
FANGDA	-0.02192	-0.01279	0.00914 (0.2979)
SZIA	-0.02018	-0.02309	-0.00291 (-0.0945)
SEGCL	-0.02639	-0.01325	0.01313 (0.4263)
SJZBS	-0.01181	-0.02436	-0.01255 (-0.4188)
SWAN	-0.04307	-0.01345	0.02963 (0.9839)
LIVZON GROUP	-0.02431	0.00044	0.02475 (0.8076)
HFML	-0.04538	-0.02756	0.01783 (0.5903)
GED	-0.02416	-0.00757	0.01659 (0.5223)
FSL	-0.01604	0.00526	0.02130 (0.7174)
JMC	-0.00471	-0.07243	-0.06773 (-2.2379)
SANONDA	-0.02709	-0.03016	-0.00307 (-0.1017)
CHANGCHAI	-0.03806	-0.03396	0.00410 (0.1348)
CHANGAN AUTO	0.00756	0.01099	0.00343 (0.1156)
Averaged Difference			0.00731 (1.303)

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%

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