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Abstract

This paper tests for periodic breaks in the unconditional variance of stock return data on two Chinese stock return market indexes. Using the modified ICSS algorithm, we observe three breaks in Shanghai Stock Exchange composite index and Shenzhen Stock Exchange composite index series. We document the policy changes related to the Chinese stock market and explain that the Chinese stock market is largely influenced by government policy.

1. Introduction

China's stock market has developed significantly over the past 20 years. The two major stock markets, Shanghai and Shenzhen securities exchanges, opened on December 19, 1990 and July 3, 1991, respectively. The official public issue of the first stock issuance can be traced back to 1984, in which Feile Acoustics sold 10,000 shares at RMB50 per share. From a house consisting of only five listed companies, China's domestic stock market has become the second largest equity market in the world, valued at $3.21 trillion as of July 15, 2011. The investigation of the Chinese stock market has been a topic of great interest in recent years. Not only because of China's growing importance in the world economy, but also because the stock market with "Chinese characteristics" shows particular patterns that may not be explained by the former experiences of developed equity markets.

The purpose of this paper is to investigate the volatility of the two major stock return indexes in Shanghai and Shenzhen. The ability to accurately model and forecast asset returns volatility has important implications in a number of areas of finance, including risk management, portfolio management, and the pricing of derivative securities. Thus, it is not surprising that a large empirical literature has been developed concerning what is the most appropriate model in which to obtain reliable volatility forecasts (for a recent survey of the literature see Poon and Granger (2003, 2005)). Due predominantly to the prevalence of 'volatility clustering' in asset returns, the generalized autoregressive conditional heteroskedastic (GARCH) model of Engle (1982) and Bollerslev (1986) has become the major framework through which to model and forecast stock market volatility. An assumption typically made by researchers is the existence of a stable GARCH process, or a constant unconditional variance, when forecasting volatility. However, the assumption of a constant unconditional variance has been called into question.

Periodic breaks in the unconditional variance of asset returns have important implications for volatility modeling and forecasting using GARCH models.[1] Mikosch and Stărică (2004b) demonstrate temporal variation in the unconditional variance using estimates from a rolling GARCH model. The cumulative evidence from this extant literature demonstrates that the presence of either occasional structural breaks or a slowly changing unconditional variance will result in the apparent existence of long memory when analyzed using models that assume a constant unconditional mean volatility level, such as the GARCH model. The fitted GARCH processes used for forecasting asset return volatility are typically very persistent and a failure to account for structural breaks in the unconditional variance of asset returns may lead to the fitting of GARCH models that are too persistent, which can have adverse effects on volatility forecasts. Furthermore, fitted GARCH models that neglect structural breaks can fail to track changes in the unconditional variance and thus produce forecasts that systematically under- or overestimate volatility on average for long periods of time. In summary, structural breaks have potentially important implications for forecasting the volatility of asset returns.[2] The study of structural breaks in the variance of Chinese stock returns has deeper implications. It is believed that government policies and regulations play an important role in the operation of China's stock market, as the market has become more mature and more integral to international markets since China jointed WTO.

[1] Earlier research by Diebold (1986), Hendry (1986), and Lamoureux and Lastrapes (1990), as well as more recent research by Lobato and Savin (1998), Diebold and Inoue (2001), Granger and Hyung (2004), Mikosch and Stărică (2004a) and Hillebrand (2005) all show that failing to account for structural breaks in the unconditional volatility of asset returns can lead to sizable upward biases in the degree of persistence in estimated GARCH models. Also see Kim and Kon (1999) and Granger and Hyung (2004). Intuitively, over-estimating the degree of persistence in volatility by failing to account for structural breaks is related to the argument made by Perron (1989) in the context of unit root testing: failure to account for periodic breaks in the mean (or linear trend) of a stationary series can lead one to over-estimate the degree of persistence in the series and fail to reject the null hypothesis of a unit root (Type II error).

[2] In the context of exchange rate return volatility forecasting, West and Cho (1995) speculate that the forecasting performance of GARCH models could be improved by allowing for structural breaks in the unconditional variance.

In this paper we employ a *modified* version of the Inclan and Tiao (1994) iterative cumulative sum of squares (ICSS) algorithm to test for structural breaks in the volatility of the Chinese stock market using two major indices. Malik and Hassan (2004) examine shifts in volatility using the ICSS algorithm using weekly-Wednesday closing returns over the period January 1, 1992 to August 6, 2003, focusing on five major Dow Jones stock indexes (financial, industrial, consumer, health and technology sectors). They find that volatility is less persistent if regime shifts are accounted for than if they are not. Aggarwal, Inclan, and Leal (1999) also use the ICSS procedure to detect volatility shifts in stock returns in emerging markets and conclude that volatility persistence is overstated if these endogenously determined break points in volatility are not accounted for.[3]

This paper employs weekly data from 1990 to 2011 and finds that both the Shanghai and the Shenzhen stock market returns have undergone three structural breaks since inception. The critical dates for the Shanghai exchange are 10/20/1996, 12/08/2006, and 03/20/2009, and the critical dates for the Shenzhen exchange are 05/16/1997, 11/10/2006, and 03/20/2009. There are a few studies examining structural breaks in the volatility of Chinese stock returns. Chen and Huang (2002) apply the ICSS algorithm to analyze the Shenzhen index over the period 1993 to 2001. The ICSS algorithm is challenged by Sanso et al (2004) as it is only valid under the assumption that the error term is independent and identically distributed. When the error term follows the dependent process of a GARCH model, the ICSS algorithm is biased. Yang (2009) employs a modified ICSS algorithm to detect structural breaks in China and find three breaks

[3] Malik (2003) investigates five major exchange rates from January 1990 to September 2000 and finds lower persistence in volatility if the standard GARCH model is augmented with the determined breakpoints in volatility. Rapach and Strauss (2008) investigate the empirical importance of structural breaks for GARCH models of exchange rate volatility employing both in-sample and out-of-sample tests. They find significant evidence of structural breaks in the unconditional variance in seven of eight US dollar exchange rate return series over the period 1980-2005 implying an unstable GARCH process for these exchange rate series. They also find that the parameters of a GARCH(1,1) model of these series vary significantly over subsamples defined by the structural breaks.

(03/20/2000, 11/29/2006, 01/17/2008) for the Shanghai A market and one break (01/17/2008) in the Shenzhen A market, using data over the period 01/03/1997 to 05/07/2008. Liu et al. (2011), using marginal likelihoods to identify structural breaks in a stock market volatility model, identifies five regimes using data over the period 12/19/1990 to 10/31/2009. Li and Zhang (2006), employing the CU2SUM test on data between 1994 and 2004, find two breaks, while Chen and Huang (2002) find four breaks. Wang and Zhao (2010), using the modified ICSS algorithm on the data of the China Securities Index 300 covering the period between 01/04/2002 and 06/30/2008, report three structural breaks (on 06/24/2002, 11/29/2006, 01/18/2008). It is clear that the literature has not found any agreement on the break dates in volatility.

Our paper differs from the above studies in that it i) adopts a much longer time span of data relative to earlier studies, using the modified ICSS algorithm and most importantly, ii) presents an historical review of the Chinese stock market, and iii) links the three structural breaks that we find to government policies and thus illustrate policy or events corresponding to identified structural breaks. The rest of this paper is organized as follows: Section 2 reviews the Chinese Stock Market since 1984. Section 3 describes our econometric methodology. Section 4 describes the data and discusses our results. We also undertake additional analysis and provide a discussion regarding the implications of the results. Section 5 concludes.

2. Review of China's Stock Market

The stock market in China from 1986 to the present has experienced tremendous change as well as a large amount of rent-seeking behavior. The first stock share of China's stock market, Feile Acoustics, was issued in December 1984 in Shanghai. In 1986, the Shenzhen government was the first to make regulations standardizing the process by which enterprises could be recognized as shareholding companies. Shenzhen Development Bank (SDB) became the first company that publicly offered their shares in 1987. And, when SDB announced their dividend plan (RMB 7 per share) for the 1988 financial year, it became a turning point in China's experiment with stock markets. The stock price skyrocketed from RMB40 to RMB120 in half a year. The investors learned that stock can appreciate "and with this, they acquired the speculative habits" (Walter and Howie; 2006, pg 6). The early stage of experimentation with corporate forms and securities was entirely unregulated. The Over-the-Counter (OTC) markets at that time were inconvenient and black markets flourished. On December 19, 1990, the Shanghai Stock Exchange (SHSE) was opened to provide formal central registration of stocks and competitive pricing systems and the Shenzhen Stock Exchange's opening (SZSE) followed several months later. The State Council put an announcement of restrictions on the shareholding experiment and limited the opportunity to the state sectors. The concern that the property of the state would be sold out or privatized brought out a system that defined shares in terms of the relationship between the shareholders and the state and then made any state-related shares non-tradable. These special regulations ensure that the government maintains control over the listed companies. Three different share categories were created. Any State-Owned Enterprise (SOE) converting into a shareholding company would have to divide up its share capital into three sections. About one-third of shares can be publicly issued, owned by either public retail investors or employees of a company who have invested their own wealth in the company. This part of the shares can be freely traded and known as public shares. About one-third of the company's equity is made up of state shares. These shares are owned by State Council, authorized representatives of the state's investment in the company. Legal person shares make up the final third of the company's equity. They are allocated to SOEs, institutions, or authorized social groups with legal person status. Both state shares and legal person shares cannot be traded on the stock market. This equity structure guaranteed that the state maintained their large controlling interest. "As a result, the market has evolved into a dysfunctional halfway house, where neither public officials nor private shareholders enjoy effective control over most listed firms, and few in management have incentives to help their firms create value" (Green 2003 pg. 118).

The first major regulation of the stock market occurred in late 1990. The early stage of development of China's stock market is filled with stories of price manipulations. However, young capital markets are often poorly regulated because officials may lack of experience and expertise. Scandals like 8.10 riot and 327 treasury-bond futures forced the government to make policies and make regulations more efficient.[4] The Chinese Securities Regulatory Commission (CSRC) gained their authority through the establishment of regulatory institutions in 1996, the year that trading volume at the SZSE dramatically increased from RMB 382.4 million in 1995 to RMB 4.9 billion. A mass of bank deposits were illegally lent to securities companies and invested in the stock market. These transactions were implicitly approved by two stock exchanges. At the end of the year, the government responded forcefully with the announcement of "Twelve Gold Shields" policies aimed at regulating the markets.[5] Later in December, an editorial article titled "On correctly understanding the current stock market" published in the *People's Daily* spoke of share prices as "abnormal and irrational" and warned against the highly speculative nature of the current market. Shanghai and Shenzhen exchanges reinstituted a 10% daily trading range for all listed stocks. Since 1998, much improvement has taken place in the quality of regulation. However, more progress needs be made. With the exception of very serious

[4] The "8.10" Shenzhen stock riot breaks out in reaction to a badly managed initial public offering on August 10, 1992. 327 T-bond futures scandal refers to the event in which Wanguo, one of the biggest securities agencies, attempted to manipulate market prices by selling contracts exceeding its limitation. China has banned bond futures ever since.

[5] Fei Yue, a well-known Chinese military leader in the Song Dynasty, received "Twelve Gold Shields" from the emperor calling him back to the capital.

cases that are publicly censured, no one has been imprisoned due to price manipulation or inside trading.

Starting in 2001, the government realized that the poor equity structure of listed companies were the cause of the market's serious problems and tried to readdress the problems by reducing non-tradable shares. These attempts led to a collapse of the tradable market over the next four years that resulted in a loss of more than 50% of the value of market capitalization. The discussion was stopped and the plan was cancelled at that time. The topic was not discussed again until 2005, the year that CSRC introduced a new policy, which they hoped to be the final solution to the problem of segmented markets. Under this new policy, the controlling shareholders of listed companies were meant to reach an agreement with A-share shareholders over the amount of compensation to be paid in return for making non-tradable shares tradable. As CSRC said, "the non-tradable shares reform is to optimize the governance structure of company, solidify the mutual interest ground of all shareholders, promote the listed companies to use various innovative financial tools to improve the capital operation efficiency, optimize the capital structure, bring in better investment returns." (Li and Zhang 2007, pg. 3) It is clear that the reform was aimed at improving corporate governance and operation efficiency. Equity markets entered a bull market in 2006 just following the point where most companies reached an agreement for share structure resolution. From 2009, most stated owned non-tradable shares became tradable in the markets. Unfortunately, the bull market had already ended by that time. The answer to the question of whether non-tradable shares reform improved market efficiency is still not clear.

3. Econometric Methodology[6]

3.1. Modified Iterative Cumulative Sum of Squares Algorithm

It has been shown that structural breaks in conditional variance have important implication for the estimation of and predictions from GARCH models of stock returns. Not accounting for structural breaks in the parameters of a GARCH model may induce upward biases in measures of persistence. Neglecting structural breaks in parameters will also lead to inaccurate forecasts of stock return volatility. The current paper investigates the existence of multiple structural breaks in GARCH (1,1) models of Chinese stock returns using weekly data over the period 1991 to 2011. This provides us with structural breaks in the unconditional variance of Chinese stock returns. We employ a modified version of the Inclan and Tiao (1994) iterated cumulative sum of squares algorithm that allows for dependent processes.

Following Rapach and Strauss (2008) we let $R_t = 100 \log(P_t / P_{t-1})$ denote the continuous return for a stock index from time t - 1 to t, where P_t is the value of the index at time t, and let $r_t = R_t - \mu$, where μ is the constant (unconditional) mean of R_t[7]. Assume that we observe r_t for $t = 1, \ldots, T$. Inclan and Tiao (1994) develop a cumulative sum of squares statistic that can be used to test the null hypothesis that the unconditional variance of r_t is constant for $k = 1, \ldots, T$ against the alternative hypothesis of a break in the unconditional variance at some point in the sample. The statistic is given by:

$$IT = \sup_k \left| (T/2)^{0.5} D_k \right| \qquad (1)$$

where $D_k = (C_k/C_T) - (k/T)$ and $C_k = \sum_{t=1}^{k} r_t^2$ for k=1,….,T. The IT statistic applies when $r_t \sim$

[6] This section draws from Rapach, Strauss and Wohar (2008).

[7] Qu and Perron (2007) employ a multivariate regression based procedure in which they allow for a change in mean as well as allowing for a change in the disturbance variance/covariance matrix. This is a different strand of break point literature from that conducted in this paper. Here we are interested in a GARCH model that allows for multiple structural breaks in unconditional variance.

iid N(0, σ_r^2). When the null hypothesis is rejected, the value of k that maximizes $|(T/2)^{0.5}D_k|$ serves as the estimate of the break date.

One possible drawback of relying on the *IT* statistic is that it is designed for *iid* processes; however, many return processes appear to be characterized by temporal dependencies, such as the autocorrelation in conditional volatility captured by GARCH models. A number of studies, including Andreou and Ghysels (2002), de Pooter and van Dijk (2004), and Sanso et al. (2004), show that the original *IT* statistic can be substantially oversized for dependent processes, including GARCH processes.[8] In order to allow for r_t to follow a variety of dependent processes (including GARCH processes) under the null hypothesis, a non-parametric adjustment can be applied to the original *IT* statistic; see, for example, Kokoszka and Leipus (1999), Lee and Park (2001), and Sanso et al. (2004). In order to allow for dependence processes under the null hypothesis, the ICSS procedure can instead be based on the *AIT* statistic which employs a non-parametric adjustment based on the utilizes a Bartlett Kernel, and which we designate as the 'modified ICSS algorithm'. Finite sample critical values for *AIT* can be generated by simulation methods. Inclan and Tiao (1994) show that a modified statistic that allows for non-iid data series is given as $AIT = \sup_k \left|T^{0.5}G_k\right|$ where $G_k = \hat{\lambda}^{-0.5}\left[C_k - (K/T)C_T\right]$.

3.2. GARCH Model

The canonical GARCH(1,1) model is well known and only briefly outlined here. The basic model is given by:

$$r_t = h_t^{0.5}\varepsilon_t, \tag{3}$$

$$h_t = \omega + \alpha r_{t-1}^2 + \beta h_{t-1}, \tag{4}$$

[8] Size distortions increase with the sample size.

where ε_t is i.i.d. with mean zero and unit variance. In order to ensure that the conditional variance, h_t, is positive, we require $\omega > 0$ and $\alpha, \beta \geq 0$. The GARCH(1,1) process specified in equations (3) and (4) is stationary if $\alpha + \beta < 1$. If $\alpha + \beta = 1$, then one has the integrated GARCH(1,1) or IGARCH(1,1) model of Engle and Bollerslev (1986). For a stationary GARCH(1,1) process, the unconditional variance for e_t is given by $\omega/(1-\alpha-\beta)$. Note that when $\alpha = 0$ in equation (4), β is unidentified (and set to zero), so that $h_t = \omega$ and e_t is characterized by conditional homoskedasticity. The GARCH(1,1) model is often estimated using quasi-maximum likelihood estimation (QMLE), where the likelihood function corresponding to $e_t \sim N(0,1)$ is used and the restrictions $\omega > 0$ and $\alpha, \beta \geq 0$ are imposed, and we follow this in the present paper. QMLE parameter estimates can be shown to be consistent and asymptotically normal under certain conditions; see, for example, Ling and McAleer (2003) and Jensen and Rahbek (2004).

4. Data and Breakpoint Results

Our weekly data are obtained from Shanghai Stock Exchange (SSE) center, Shanghai Stock Exchange (SSE) composite index and Shenzhen Stock Exchange (SZSE) center, Shenzhen Stock Exchange (SZSE) component index. These two indices are well integrated and developed since the beginning of China's equity markets. The data for the SSE composite index range from 12/28/1990 to 4/18/2011 including 1,058 observations. The data for the SZSE component index range from 04/13/1991 to 4/18/2011 including 1,042 observations.

Descriptive statistics for these two markets are reported in Table 1 and Table 3. These statistics demonstrate the usual properties of weekly financial returns data, namely a small mean dominated by a large standard deviation and evidence of non-normality with (typically negative) skewness and excess kurtosis, which reveal data as characterized by a large number of large shocks (with more negative than positive large shocks). The mean of weekly return is relatively small compared to the standard deviation. For the SSE index, the skewness and kurtosis are both large, partially because the market shows extreme changes in certain days. For example, on 05/21/1992, the index skyrocketed from 616.99 to 1266.49. On the other hand, the skewness and kurtosis of the SZSE index are relatively small, though still large enough to reveal that a mass of large shocks has affected the market mean. These tables also report significant evidence of ARCH effects through the usual LM test.

The results of the breakpoint tests described in Section 3 are reported in Table 2 and Table 4. These tables also report the GARCH(1,1) model estimates and thus present the degree of volatility persistence and the level of unconditional volatility. The breakpoint information and the level of volatility is also reported in Figures 1. In analyzing these results there are two broad characteristics we want to focus upon. First, what is the existence and timing of breaks as well as the level of mean volatility in each identified regime? Second, what are the implications of these breaks for the estimated GARCH models and the degree of persistence in particular? Taking the first issue, both Shanghai and Shenzhen stock markets have had three structural breaks in their history. The critical dates for Shanghai exchange are 10/20/1996, 12/08/2006, and 03/20/2009, and the critical dates for Shenzhen exchange are 05/16/1997, 11/10/2006, and 03/20/2009. These results differ from previous studies, suggesting that using a longer span of data as we do will change the date of the volatility breaks. For the Shanghai stock index (Table 2, Panel B) when breaks in volatility are accounted for, GARCH affects disappear in subsamples 2, 3 and 4. Similarly, for the Shenzhen Stock Index (Table 4, Panel B) when volatility breaks are accounted for GARCH effects disappear for subsamples, 1, 3 and 4. These are the expected results.

With regard to the timing and impact of the volatility breaks, this can perhaps be most easily seen in Figures 1. Taking a global perspective of the results we can observe that there are four periods of market-wide volatility. First, there is a general decline in volatility around the end of 1996 with the establishment of the regulatory institutions. Before 1996, the regulatory power was not clearly defined among the Public Bank of China (PBOC) and the CSRC, or even local governments. The publication of the 1996 regulations delegated full authority and regulatory control to the CSRC over the markets. The improved regulations limited manipulation and inside trading which were prevalent at that time. Price volatility has been reduced since then. Second, there is an increase in volatility associated with both indices during 2006 – 2009. Most of SOEs reached their agreement on the compensation the end of 2006. After that, the Chinese stock markets then entered a bull market. The SSE Composite Index reached the historical high of 6,124 on October 16, 2007. The SZSE Component Index reached the historical high of 19,600 on October 10, 2007. However, the Consumer Price Index (CPI) as of October, 2007 was 6.5%, the highest in 11 years. Political Bureau of the Central Committee of the Communist Party of China started to control inflation and this led much volatility of the stock market. For instance, in 2007, central back increased the reserved rate 10 times over the year and raised interest rate 6 times. In addition, there are many positive shocks to the market since the gradual introduction of the Qualified Foreign Institutional Investor (QFII) since the end of 2002 and official market openness in August 2007 that the foreign investors are allowed to trade in Chinese stock markets. This results large amount of capital inflows from the foreign investors (Su, Ma and Wohar; 2012). These positive and negative shocks made large volatility over this period. Third, there is a decline in volatility for both indices at the end of 2008. The coming bear market was worsened by the subprime mortgage crisis. On December 31, 2008, the SSE Composite Index closed at 1,820 and the SZSE Component Index closed at 6,485. Both indices declined more than 60%. Both the Shanghai and Shenzhen market had their third structural break on March 20, 2009. In this last period, which lasted about two and half years, the SSE Composite Index increased 8.4% from 2281 to 2473, and the SZSE Component Index increased 22.1% from 8647 to 10561. The trading of investors had been in a downturn and investor confidence was hit by the economic slump. The co-movement of the market index and market capitalization has a break point at 2009 and after that market capitalization expanded much more than the growth of the market index. The first two structural breaks are consistent with some earlier studies and consistent with our expectation. No other research has identified the third break yet as this paper uses a longer time span data set.

Overall, the results that the Chinese stock market are largely influenced by government policy and are consistent with the findings of Chen et. al. (2008) and Huang et. al (2008) who examine the effect of government policy on the stock market. Chen et. al. (2008) investigates the effectiveness of two regulatory policy changes on the volatility dynamics of the Chinese A- and B-share markets. Their findings indicate that the government policy does have significant effect on the market. Huang et. al (2008) test for structural change on 234 constitute stocks of the Shanghai Shenzhen 300 Index (HS300). They examine two event windows for each stock along the reform structure designed by the CSRC and report results that indicate that reforms drive stock prices up in more than two-thirds of the cases.

In practice, our results suggest that market returns volatility is subject to structural breaks whereby the mean (or unconditional) level of volatility is subject to upward and downward shifts. These results suggest that in estimating and forecasting volatility one needs to take into account the structural breaks that cause both the mean level of volatility to change and the degree of volatility persistence to change. Ignoring both of these characteristics would inevitably lead to poor forecasts.

5. Summary and Conclusion

This paper employs weekly data from 1990 to 2011 to examine the structural breaks in the unconditional variance of stock return data on two Chinese stock return market indexes. Using the modified ICSS algorithm, we observe three breaks in both the Shanghai Stock Exchange composite index and the Shenzhen Stock Exchange composite index series. We find that both Shanghai and Shenzhen stock markets have had three structural breaks since inception. The critical dates for the Shanghai exchange are 10/20/1996, 12/08/2006, and 03/20/2009, and the critical dates for the Shenzhen exchange are 05/16/1997, 11/10/2006, and 03/20/2009. Our documentation of the policy changes related to the Chinese stock market indicates that the Chinese stock market is largely influenced by government policy. Knowing this has important implications to Chinese investors.

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Table 1. Summary Statistics – Shanghai Stock Index Returns.	
Mean	0.054 (0.014)
Standard deviation	4.521 (0.184)
Skewness	0.112 (0.285)
Excess kurtosis	3.932 (0.974)
Minimum	-22.630
Maximum	27.516
ARCH Lagrange multiplier (q = 2)	51.70 [0.000]
ARCH Lagrange multiplier (q = 10)	136.58 [0.000]

Note*:* Returns are defined as 100 times the log-difference of weekly index level. Heteroskedastic and autocorrelation consistent standard errors for the mean, standard deviation, skewness, and excess kurtosis are given in parentheses. ARCH Lagrange multiplier statistics correspond to a test of the null hypothesis of no ARCH effects from lag orders 1 through *q*. *P*-values are given in brackets; 0.000 indicates less than 0.0005.

Table 2. Quasi maximum likelihood estimation results for GARCH(1,1) models	
	Shanghai Index
A. GARCH(l,l) full sample estimation results, December 28 1990 to April 18 2011	
$\hat{\omega}$	0.746 (0.236)
$\hat{\alpha}$	0.162 (0.034)
$\hat{\beta}$	0.805 (0.037)
$\hat{\omega}/1-\hat{\alpha}-\hat{\beta}$	22.638 (7.497)
B. GARCH(1,l) estimation results for the sub-samples defined by the structural breaks	
Subsample 1	December 28 1990- October 20 1996
$\hat{\omega}$	2.205 (0.888)
$\hat{\alpha}$	0.196 (0.054)
$\hat{\beta}$	0.764 (0.053)
$\hat{\omega}/1-\hat{\alpha}-\hat{\beta}$	54.809 (35.065)
Subsample 2	October 21 1996- December 08 2006
$\hat{\omega}$	9.045 (0.733)
$\hat{\alpha}$	0.000 (0.000)
$\hat{\beta}$	0.000 (0.000)
$\hat{\omega}/1-\hat{\alpha}-\hat{\beta}$	9.045 (0.733)
Subsample 3	December 09 2006- March 20 2009
$\hat{\omega}$	30.313 (4.062)
$\hat{\alpha}$	0.000 (0.000)
$\hat{\beta}$	0.000 (0.000)
$\hat{\omega}/1-\hat{\alpha}-\hat{\beta}$	30.313 (4.062)
Subsample 4	March 21 2009- April 1 2011
$\hat{\omega}$	9.597(1.080)
$\hat{\alpha}$	0.000 (0.000)
$\hat{\beta}$	0.000 (0.000)
$\hat{\omega}/1-\hat{\alpha}-\hat{\beta}$	9.597 (1.080)
Note: Standard errors are given in parentheses.	

Table 3. Summary Statistics – Shenzhen Stock Index Returns.	
	Shenzhen Index
Mean	0.142 (0.147)
Standard deviation	4.771 (0.161)
Skewness	0.216 (0.213)
Excess kurtosis	2.761 (0.612)
Minimum	-25.155
Maximum	22.265
ARCH Lagrange multiplier (q = 2)	45.99 [0.000]
ARCH Lagrange multiplier (q = 10)	151.48 [0.000]

Note*:* Returns are defined as 100 times the log-difference of weekly index level. Heteroskedastic and autocorrelation consistent standard errors for the mean, standard deviation, skewness, and excess kurtosis are given in parentheses. ARCH Lagrange multiplier statistics correspond to a test of the null hypothesis of no ARCH effects from lag orders 1 through *q*. *P*-values are given in brackets; 0.000 indicates less than 0.0005.

Table 4. Quasi maximum likelihood estimation results for GARCH(1,1) models	
	Shenzhen Stock Index
A. GARCH(l,l) full sample estimation results, April 18 1991 to April 1 2011	
$\hat{\omega}$	0.977 (0.387)
$\hat{\alpha}$	0.150 (0.034)
$\hat{\beta}$	0.818 (0.041)
$\hat{\omega}/1-\hat{\alpha}-\hat{\beta}$	30.964 (10.752)
B. GARCH(1,l) estimation results for the sub-samples defined by the structural breaks	
Subsample 1	April 18 1991- May 16 1997
$\hat{\omega}$	38.313 (4.185)
$\hat{\alpha}$	0.000 (0.000)
$\hat{\beta}$	0.000 (0.000)
$\hat{\omega}/1-\hat{\alpha}-\hat{\beta}$	38.313 (4.185)
Subsample 2	May 17 1997- November 10 2006
$\hat{\omega}$	2.578 (0.740)
$\hat{\alpha}$	0.204 (0.056)
$\hat{\beta}$	0.560 (0.091)
$\hat{\omega}/1-\hat{\alpha}-\hat{\beta}$	10.939 (1.479)
Subsample 3	November 11 2006- March 20 2009
$\hat{\omega}$	40.176 (5.391)
$\hat{\alpha}$	0.000 (0.000)
$\hat{\beta}$	0.000 (0.000)
$\hat{\omega}/1-\hat{\alpha}-\hat{\beta}$	40.176 (5.391)
Subsample 4	March 21 2009- April 1 2011
$\hat{\omega}$	12.743(1.544)
$\hat{\alpha}$	0.000 (0.000)
$\hat{\beta}$	0.000 (0.000)
$\hat{\omega}/1-\hat{\alpha}-\hat{\beta}$	12.743 (1.544)
Note: Standard errors are given in parentheses.	

Table 5: Event Description at Each Structure Break Point

Shanghai

Time Period	Duration	Possibly Related Events or Policy Changes	SD	Mean Weekly
Dec. 28, 1990 - Dec. 20, 1996	310 weeks	Publication of the 1996 Regulations	0.0630	-0.0013
Dec. 21, 1996 - Dec. 08, 2006	498 weeks	Most SOEs reached agreement on the compensation	0.0314	0.0029
Dec. 09, 2006 - Mar. 20, 2009	115 weeks	Economic slump/Expansion of capitalization	0.0517	-0.0029
Mar. 21, 2009 - April. 1, 2011	107 weeks		0.0304	-0.0011

Shenzhen

Time Period	Duration	Possibly Related Events or Policy Changes	SD	Mean Weekly
Apr. 18, 1991 - May. 16, 1997	314 weeks	Publication of the 1996 Regulations	0.0626	-0.0006
May. 17, 1997 - Nov. 10, 2006	474 weeks	Most SOEs reached agreement on the compensation	0.0310	0.0022
Nov. 11, 2006 - Mar. 20, 2009	119 weeks	Economic slump/Expansion of capitalization	0.0511	-0.0026
Mar. 21, 2009 - April. 1, 2011	107 weeks		0.0304	-0.0011

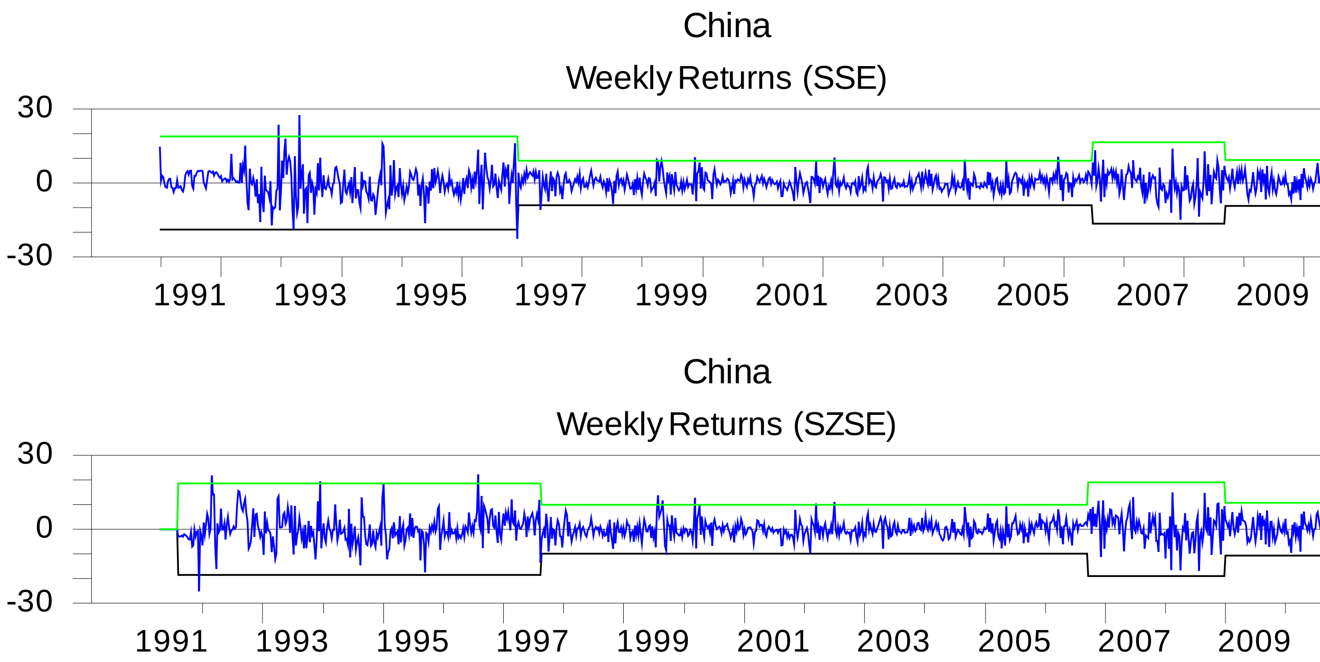

Figure 1: The Structure Break and the Level of Volatility for SSE and SZSE.