

Stock Returns, Volatility, and Trading Volume: Evidence from the Chinese Stock Markets

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ABSTRACT

This paper examines three important issues in Chinese stock markets. First, we examine the behavior of stock returns, volatility, and trading volume in Chinese stock markets. Second, we investigate the contemporaneous and causality relationship among stock returns, volatility, and trading volume at the Shanghai and Shenzhen Stock Exchanges over the period from the beginning of the Shanghai stock market in December 1990 (April 1991 for the Shenzhen stock market) to June 1999. And lastly, we examine the linkage between the Shanghai Stock Exchange and the Shenzhen Stock Exchange. We first find that monthly return volatility and trading volume volatility exhibit strong autocorrelation. However, further empirical tests reject the existence of unit roots. Monthly returns do not exhibit autocorrelation for the Shanghai Stock Exchange Index. With a three variable autoregressive (VAR) model, we then find that return volatility affects stock returns at both Chinese stock markets. There exists a bi-directional causality between return volatility and trading volume volatility. Interestingly, we further find that returns do not cause return volatility directly at both Chinese stock markets, but instead affect trading volume volatility at the Shanghai Stock Exchange. Finally, we find a strong linkage between the Shanghai Stock Exchange and the Shenzhen Stock Exchange in terms of returns, return volatility, and volume volatility.

JEL: G12, G15

Keywords: VAR model; Causality; Linkage in stock markets

I. INTRODUCTION

Previous research has shown that an individual firm's stock return volatility rises after stock prices fall. Two popular explanations of this finding are the leverage effect and time-varying risk premiums. The leverage effect predicts that a decrease in a firm's stock price reduces the value of equity, and therefore, increases the debt ratio of the firm. As a result, the risk associated with the firm increases, causing higher stock return volatility. The time-varying risk premium argues that an expected increase in stock return volatility increases the risk of holding the stock. To compensate for the additional risk, investors require a higher expected risk premium. As a consequence, we should observe an immediate stock price decline.

If price and quantity are two fundamentals in a financial demand and supply system, then the importance of trading volume and its information content should not be ignored when we study the financial market interactions. Unfortunately most research has focused on the behavior and relationship between returns and return volatility, while less study has been done on trading volume volatility. The relationship among returns, return volatility, and trading volume volatility has received far less attention.

This paper examines three important issues related to the relationship among stock returns, volatility, and trading volume in Chinese stock markets. First, we examine the behavior of stock returns, volatility, and trading volume. Second, we investigate the contemporaneous and causality relationship among stock returns, volatility, and trading volume at the Shanghai and Shenzhen Stock Exchanges over the period from the beginning of these markets (from December 1990 for the Shanghai Stock Exchange and from April 1991 for the Shenzhen Stock Exchange) to June 1999. Lastly, we examine the linkage between the Shanghai Stock Exchange and the Shenzhen Stock Exchange. We first find that monthly return volatility and trading volume volatility exhibit strong autocorrelation. However, further empirical tests reject the existence of unit roots. Monthly returns do not exhibit autocorrelation for the Shanghai Stock Exchange Index. In contrast with the previous findings with the U.S. data, we find a strongly positive contemporaneous relationship between returns and volatility for both Chinese stock markets. With a three variable VAR model, we further discover that return volatility affects stock returns at both Chinese stock markets. There exists a bi-directional causality between return volatility and volume volatility. Interestingly, we also find that returns do not cause return volatility directly at both Chinese stock markets, but instead affect trading volume volatility at the Shanghai Stock Exchange. Finally, we find a strong linkage between the Shanghai Stock Exchange and the Shenzhen Stock Exchange in terms of returns, return volatility, and volume volatility.

The remainder of the paper is organized as follows. Section 2 briefly reviews the literature. Section 3 describes the data set. The methodology and hypotheses are discussed in Section 4. Section 5 provides the empirical results, along with discussions of their implications and Section 6 concludes the paper.

II. LITERATURE REVIEW

Black (1976) is the first to examine the relationship between stock returns and volatility by using a sample of 30 industrial stocks in the period of 1962-75. He estimated the following model for stock i between months t and $t+1$:

$$\frac{\sigma_{i,t+1} - \sigma_{i,t}}{\sigma_{i,t}} = \alpha_0 + \lambda_0 r_{i,t} + \varepsilon_{0,t+1} \quad (1)$$

where $\sigma_{i,t}$ and $\sigma_{i,t+1}$ are the monthly standard deviations of stock i 's returns in time t and $t+1$ respectively, estimated by using the daily stock returns within the month, $r_{i,t}$ is the stock i 's return in month t , α_0 and λ_0 are regression coefficients, and $\varepsilon_{0,t+1}$ is an error term. He found that the coefficient λ_0 was always negative and usually less than -1.

Christie (1982) used a similar approach to examine this problem using quarterly data in 1962-78. With a larger sample size of 379 firms, he found that the average coefficient of λ_0 was negative and around -0.23. In addition, Christie also considered the leverage effect and found that a firm's debt equity ratio was an important determinant in causing negative λ_0 . Nelson (1991), Cheung and Ng (1992) considered several nonlinear models and found that over 95% of firms under consideration exhibited a negative relationship between stock returns and volatility.

Duffee (1995) examined the problem from a slightly different angle. He noticed that regression (1) is equivalent to the following regression:

$$\log\left(\frac{\sigma_{i,t+1}}{\sigma_{i,t}}\right) = \alpha_0 + \lambda_0 r_{i,t} + \varepsilon_{0,t+1} \quad (2)$$

where \log is the natural logarithm. Note that regression (2) can be further decomposed into two separate regressions as follows:

$$\log(\sigma_{i,t}) = \alpha_1 + \lambda_1 r_{i,t} + \varepsilon_{1,t} \quad (3)$$

$$\log(\sigma_{i,t+1}) = \alpha_2 + \lambda_2 r_{i,t} + \varepsilon_{2,t+1}, \quad (4)$$

and the coefficient interested in (2), λ_0 , is the difference between the regression coefficients of λ_2 and λ_1 in (4) and (3).

After studying the relationship between return and volatility for the stocks traded in NYSE/AMEX, Duffee (1995) found that λ_1 is strongly positive and significant in (3). The sign of λ_2 in regression (4) is ambiguous. In addition,

λ_1 always exceeds λ_2 , which makes λ_0 negative. These results indicate that a positive contemporaneous relation between firm stock returns and return volatility in (3) causes the negative relation between the change in volatility and stock returns in (2). Furthermore, he confirmed that at the aggregate level based on a stock market index, λ_1 turns out to be negative. That raises the question of why the relationship between stock returns and volatility behaves so differently at the aggregate level than the individual firm level, which partially motivates this study.

III. DATA

The data used in this study includes monthly time series of stock index returns, return volatility, and trading volume volatility. The daily stock indices and trading volume of the Shanghai Stock Exchange and the Shenzhen Stock Exchange are obtained from the *Securities Times*. In order to construct monthly time series, we hand-collect the daily data for the entire sample period, starting from the beginning of the Shanghai Stock Exchange in December 1990 and the Shenzhen Stock Exchange in April 1991 to June 1999.

For the monthly returns, we use $(P_t - P_{t-1}) / P_{t-1}$, where P_t is the index price at the end of month t while P_{t-1} is the index price at the end of month $t-1$.¹ For the market return volatility, we calculate the mean-adjusted monthly standard deviation based on the daily index returns.² The daily index returns are calculated in the same way as the monthly returns. The advantage of using the mean-adjusted monthly standard deviation as a proxy for the market return volatility is that it is capable of truly reflecting the dispersion of the daily index returns from its monthly average. The volume volatility is defined as the monthly mean-adjusted standard deviation of the logarithm of daily trading volume.

IV. METHODOLOGY

We first examine the stationarity of monthly return volatility and volume volatility for both Shanghai and Shenzhen stock markets.³ We perform the ARMA process, along with the Dickey-Fuller unit root test in order to ensure that the regression results obtained later are robust. The seasonal behavior for the Shanghai and Shenzhen stock index returns are also analyzed and identified.

After checking the stationarity of return volatility and volume volatility, we then extend Dufee's (1995) approach to examine the contemporaneous relationship among market returns, return volatility, and volume volatility. We estimate the regression of

$$\ln \left(\frac{\sigma_t}{\sigma_{t-1}} \right) = \alpha_0 + \alpha_1 R_{t-1} + \alpha_2 \ln \left(\frac{v_t}{v_{t-1}} \right) + \mu_{1,t}, \quad (5)$$

which can be further decomposed into the following two regressions:

$$\ln(\sigma_t) = \beta_0 + \beta_1 R_{t-1} + \beta_2 \ln(v_t) + \mu_{2,t}, \quad (6)$$

$$\ln(\sigma_{t-1}) = \lambda_0 + \lambda_1 R_{t-1} + \lambda_2 \ln(v_{t-1}) + \mu_{3,t}, \quad (7)$$

where σ_t and σ_{t-1} are return volatility in months t and $t-1$, R_{t-1} is the market index return in month $t-1$, v_t and v_{t-1} are volume volatility in months t and $t-1$, and $\mu_{i,t}$ are the error terms. The coefficients in regression (5) can be obtained from regressions (6) and (7) under the constraint that $\beta_2 = \lambda_2$. The results from regressions (6) and (7) will provide empirical evidence regarding the contemporaneous relationship among returns, volatility, and trading volume for both Chinese stock markets.

In order to examine the causality relationship among stock returns, return volatility, and trading volume volatility we further propose a three variable VAR model. We follow Granger's definition (1969) of causality: x 'causes' y if and only if y is better predicted using the past history of x , together with the past history of y itself, rather than using just the past history of the y variable. Generally, the unidirectional Granger causality test is carried out by using an F-test on the coefficients of the lagged values of x 's in the regression of y on its past values and the past values of x .

Let x_t be $\ln\left(\frac{\sigma_t}{\sigma_{t-1}}\right)$ and y_t be $\ln\left(\frac{v_t}{v_{t-1}}\right)$.⁴ The VAR model takes the form of

$$x_t = c_1 + \sum_{i=1}^{m_1} \beta_{1i} x_{t-i} + \sum_{i=1}^{n_1} \delta_{1i} y_{t-i} + \sum_{i=1}^{p_1} \gamma_{1i} R_{t-i} + \varepsilon_{1,t} \quad (8)$$

$$y_t = c_2 + \sum_{i=1}^{m_2} \beta_{2i} y_{t-i} + \sum_{i=1}^{n_2} \delta_{2i} x_{t-i} + \sum_{i=1}^{p_2} \gamma_{2i} R_{t-i} + \varepsilon_{2,t} \quad (9)$$

$$R_t = c_3 + \sum_{i=1}^{m_3} \beta_{3i} R_{t-i} + \sum_{i=1}^{n_3} \delta_{3i} x_{t-i} + \sum_{i=1}^{p_3} \gamma_{3i} y_{t-i} + \varepsilon_{3,t}, \quad (10)$$

where R_t is the return in month t , $\varepsilon_{1,t}$, $\varepsilon_{2,t}$ and $\varepsilon_{3,t}$ are the residuals in the VAR model which can be correlated with each other, and m , n , and p are the numbers of lags in the VAR model. Our test procedure works as follows: First, we estimate equation (8) using ordinary least squares (OLS) by treating the VAR model as a system of seemingly unrelated regression equations (SURE). By setting $n_1 = p_1 = 0$ in (8), we use the Akaike's Information Criterion, the Akaike's Final Prediction Error (FPE), as the criterion to choose the optimal lag of m_1 in order to minimize FPE:

$$FPE(m_1) = \left(\frac{T+k}{T-k}\right) \left(\frac{SSR(m_1)}{T}\right) \quad (11)$$

where T is the sample size, $k = m1+1$ (the number of coefficients estimated, including the constant), while $SSR(m1)$ is the sum of the squared residuals given the lag of $m1$.⁵ By fixing $m1$ at its optimal lag $m1^*$, we further search for the optimal $n1$ in (8) and test if volume volatility causes return volatility by examining the following null hypothesis:⁶ $H_0: \delta 1_i = 0$, for $i = 1$ to $n1$.

In testing H_0 , the standard F-test is used. It is defined as:

$$F = \frac{\frac{SSR_R - SSR_U}{n1}}{\frac{SSR_U}{T - (n1 + m1^*)}}, \quad (12)$$

where $m1^*$ is the optimal lag found in the previous step. If the null hypothesis is rejected it suggests that trading volume causes return volatility. Finally, by fixing the optimal lags of $m1^*$ and $n1^*$ in (8), we further examine whether or not returns cause return volatility by testing the null hypothesis: $\gamma 1_i = 0$ for $i = 1$ to $p1^*$, using the traditional F-test described in (12).⁷ We repeat the same procedure in (9) to test if volatility and returns cause volume volatility, and again in (10) to examine whether return volatility and volume volatility cause returns. To make sure that the results obtained are valid from SURE, we check the regression residuals from (8), (9) and (10) to see if they are correlated. If uncorrelated, equations (8), (9), and (10) can be estimated either separately or jointly. The results should not be significantly different. If the residuals are found correlated, then we have to re-estimate the VAR model jointly with the optimal lags found in the previous procedure along with the adjustment for correlation in residuals.

Finally, we check for the linkage between stock returns, return volatility, and trading volume volatility at the Shanghai Stock Exchange and the Shenzhen Stock Exchange by running the regression of

$$S_t = \alpha + \beta z_t + \varepsilon_t, \quad (13)$$

where S_t can be the index return, return volatility, or trading volume volatility at the Shanghai Stock Exchange, while z_t is the corresponding variables at the Shenzhen Stock Exchange. If the two markets are closely correlated, we expect that the estimated coefficient β should be significant and close to 1.

V. EMPIRICAL RESULTS AND IMPLICATIONS

Figure 1 shows the monthly Shanghai Stock Exchange index return volatility in terms of the mean-adjusted standard deviation using the daily index returns over the period of December 1990 to June 1999. It shows that the return volatility was high when the Exchange was first introduced in December 1990, and then began stabilizing after late 1995. Figure 2 shows the monthly Shenzhen Stock Exchange

index return volatility over the period of April 1991 to June 1999. It indicates that the market return volatility is not stable over time as it shifts with significant events, which is confirmed by a more detailed visual picture about the behavior of market returns month by month at the Shanghai Stock Exchange (Figure 3) and the Shenzhen Stock Exchange (Figure 4). Figures 5 and 6 show the monthly volatility of trading volume at the Shanghai Stock Exchange and the Shenzhen Stock Exchange, respectively.

Figure 1

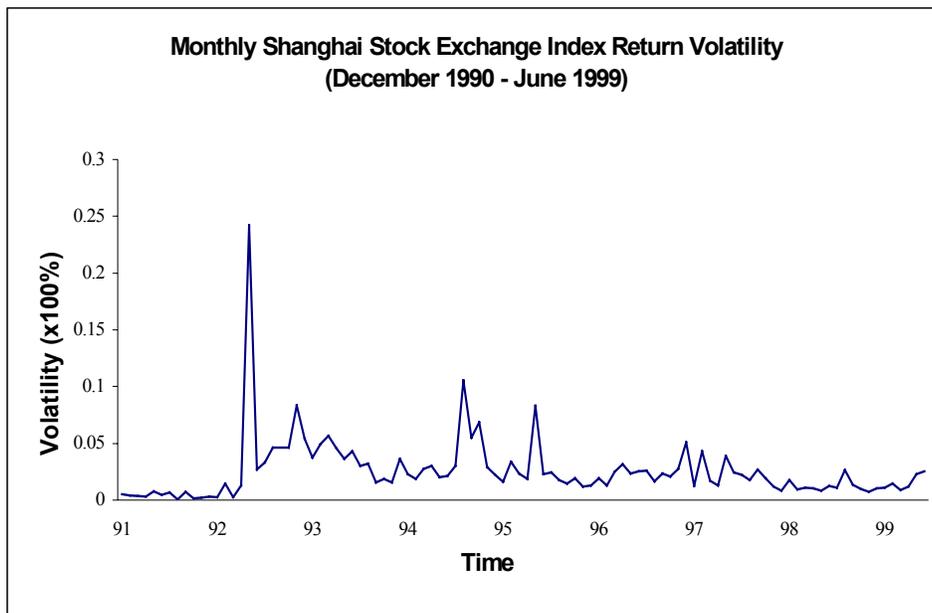


Figure 2

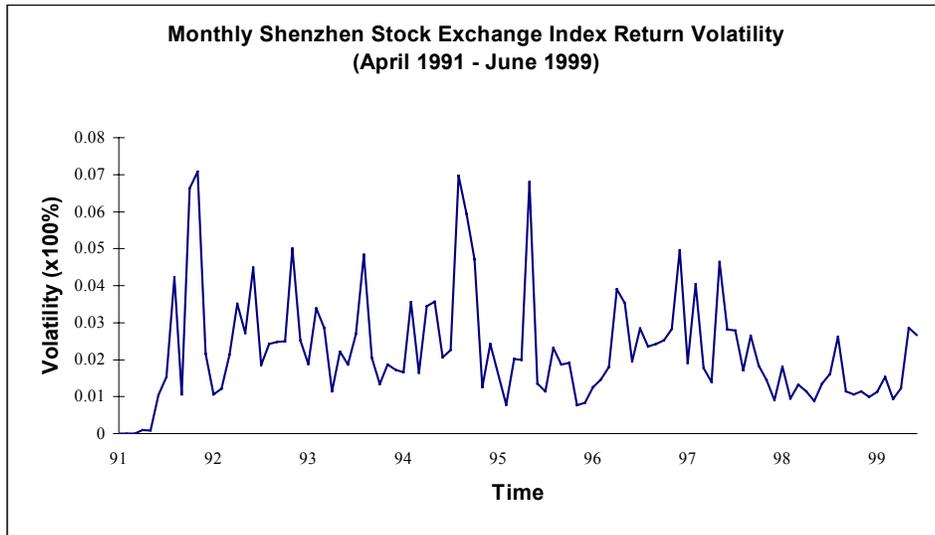


Figure 3

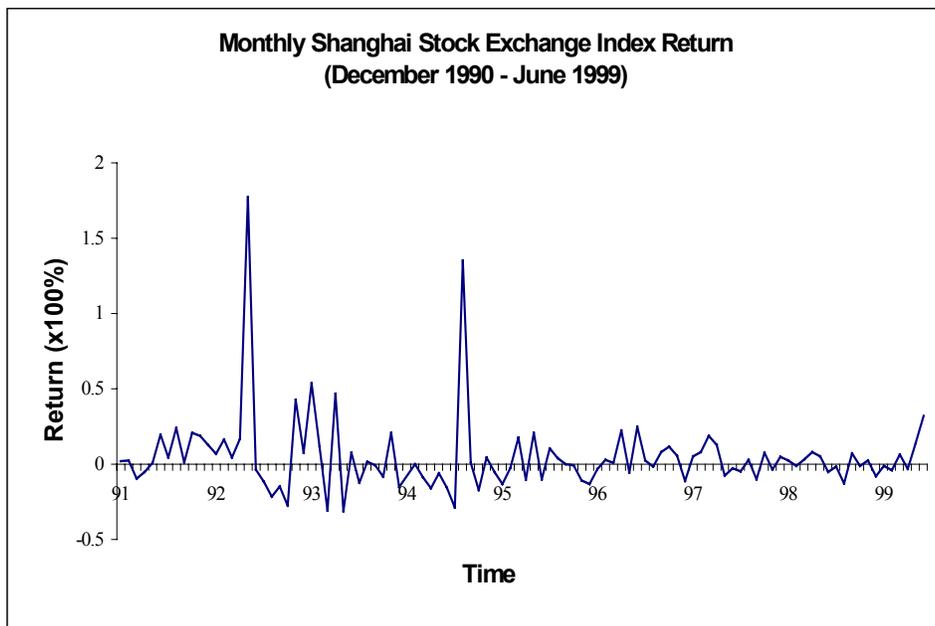


Figure 4

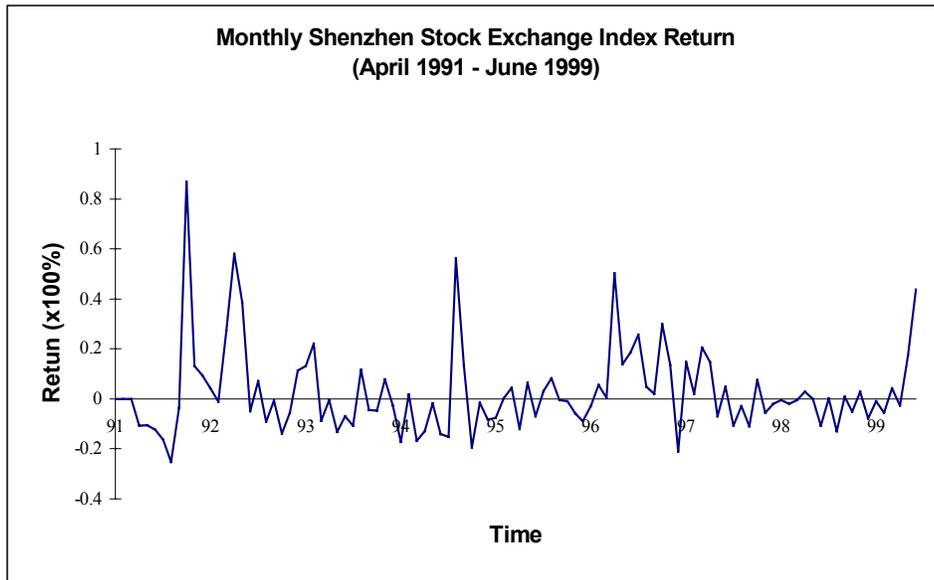


Figure 5

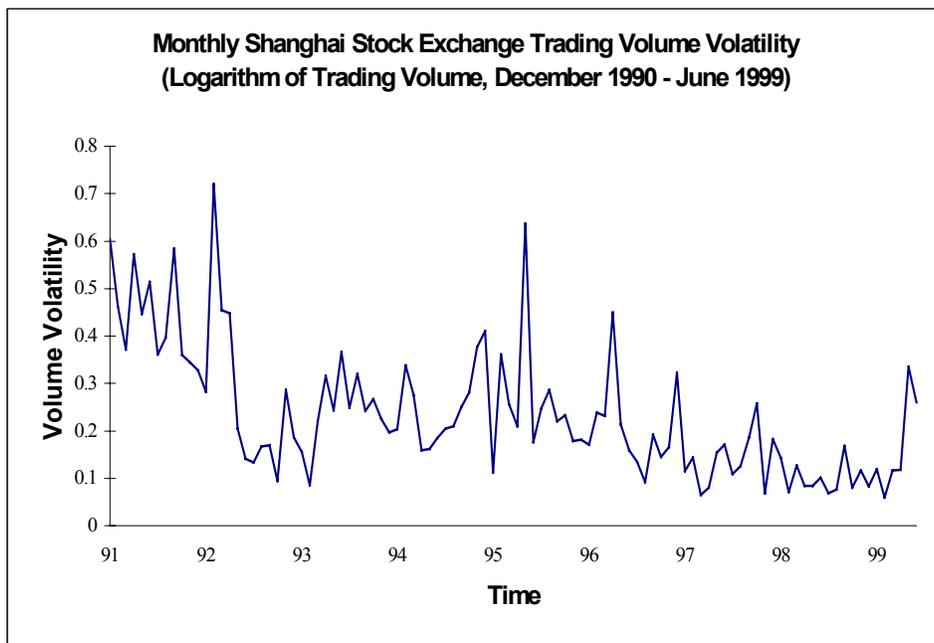


Figure 6

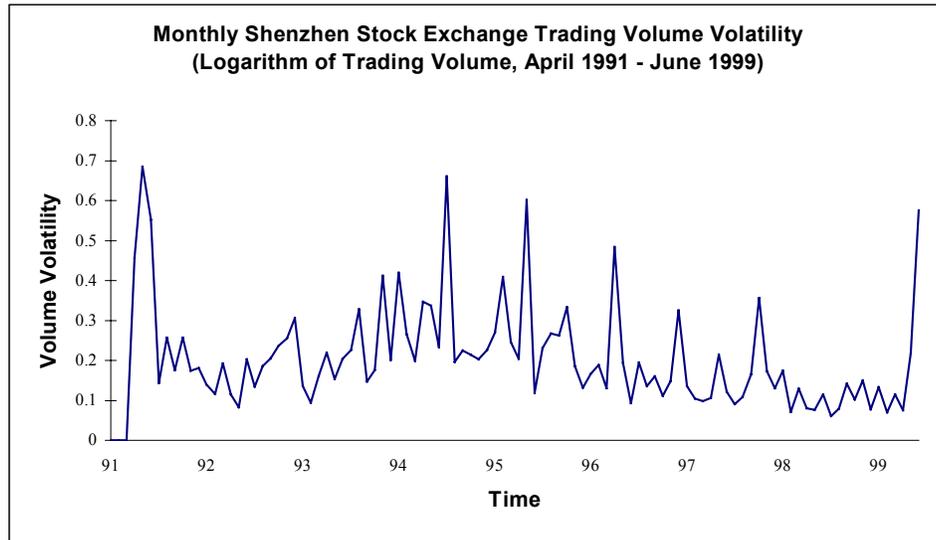


Table 1 presents the summary statistics of stock returns, return volatility, and trading volume volatility for the two stock markets in China. The average monthly return volatility are 2.57% and 2.35% over the sample periods at the Shanghai Stock Exchange and the Shenzhen Stock Exchange, while the average monthly stock returns are 4.989% and 2.788%, respectively. Thus, for the performance in terms of the risk-adjusted returns, the Shanghai Stock Exchange outperforms that of the Shenzhen Stock Exchange. We also find that over the two sub-periods, the average monthly return on the Shanghai Stock Exchange drops from 7.169% to 2.491%, accompanied by a decline in return volatility. On the other hand, the average monthly return on Shenzhen Stock Exchange increases from 1.818% to 3.818%, along with an increase in return volatility.

Table 2 shows the correlations among stock returns, return volatility, and trading volume volatility for the entire sample period and the two sub-periods. The statistics in Table 2 indicate that the correlation between monthly returns, return volatilities, and trading volume volatilities in the two Exchanges are 0.552, 0.377, and 0.502 respectively over the entire sample period. The correlation of returns and volatility at the Shanghai Stock Exchange is 0.638, and 0.375 at the Shenzhen Stock Exchange. We also notice that returns at one exchange are correlated to the volatility of another exchange. Similarly, return volatility at one exchange is correlated to the volume volatility at another exchange. Looking at the two sub-periods, we find that the correlation between returns in two markets

increases to 0.822 in the second sub-period, which strongly indicates that the two markets tend to move together in recent years. The correlation between returns and return volatility is very strong in the first sub-period for both Exchanges, but becomes weaker in the second sub-period. On the other hand, the correlation between returns and volume volatility in both Exchanges increases over the second sub-period, indicating that the volume volatility has played a more important role in recent years.

Table 3 reports the test results of unit roots for returns, return volatility, and trading volume volatility at both Exchanges. We find that returns at both Exchanges are stationary. Even though we observe strong autocorrelation for return volatility and volume volatility at both financial markets in China, the empirical results show that there is no unit root for return volatility and volume volatility.⁸

Table 1
Summary statistics of stock return, volatility, and trading volume
for Chinese stock markets

The Shanghai Stock Exchange (December 90 – June 1999)			
	(12.90 – 06.99)	(12.90 – 06.95)	(07.95 – 06.99)
Average daily return	0.195%	0.257%	0.122%
Standard deviation of daily return	3.83%	4.86%	2.06%
Coefficient of variation	19.64	18.91	16.88
Average monthly return	4.989%	7.169%	2.491%
Standard deviation of monthly return	26.14%	34.66%	9.53%
Coefficient of variation	5.24	4.83	3.83
Average monthly return volatility	2.57%	3.18%	1.87%
Average daily trading volume	2.41	0.84	4.25
The Shenzhen Stock Exchange (April 1991 – June 1999)			
	(04.91 – 06.99)	(04.91 – 06.95)	(07.95 – 06.99)
Average daily return	0.115%	.058%	0.179%
Standard deviation of daily return	2.836%	3.28%	2.23%
Coefficient of variation	24.66	56.55	12.46
Average monthly return	2.788%	1.818%	3.818%
Standard deviation of monthly return	17.64%	20.81%	13.64%
Coefficient of variation	6.33	11.45	3.57
Average monthly return volatility	2.35%	2.70%	1.98%
Average daily trading volume	2.48	0.52	4.69

Table 2

Correlations among stock return, volatility, and trading volume
for Chinese stock markets (April 1991 – June 1999)

	RET1	RET2	VOLA1	VOLA2	VOLUME1	VOLUME2
RET1	1.000					
RET2	0.552	1.000				
VOLA1	0.638	0.190	1.000			
VOLA2	0.249	0.375	0.377	1.000		
VOLUME1	0.131	0.093	0.108	0.175	1.000	
VOLUME2	-0.037	-0.021	0.033	0.160	0.502	1.000

Correlations among stock return, volatility, and trading volume
for Chinese stock markets (April 1991 – June 1995)

	RET1	RET2	VOLA1	VOLA2	VOLUME1	VOLUME2
RET1	1.000					
RET2	0.551	1.000				
VOLA1	0.676	0.242	1.000			
VOLA2	0.271	0.469	0.271	1.000		
VOLUME1	0.077	0.053	-0.234	-0.639	1.000	
VOLUME2	-0.163	-0.228	-0.146	-0.050	0.262	1.000

Correlations among stock return, volatility, and trading volume
for Chinese stock markets (July 1995 – June 1999)

	RET1	RET2	VOLA1	VOLA2	VOLUME1	VOLUME2
RET1	1.000					
RET2	0.822	1.000				
VOLA1	0.054	0.111	1.000			
VOLA2	0.044	0.219	0.906	1.000		
VOLUME1	0.289	0.382	0.495	0.462	1.000	
VOLUME2	0.379	0.486	0.398	0.414	0.787	1.000

RET1 is the monthly index return on the Shanghai Stock Exchange;
RET2 is the monthly index return on the Shenzhen Stock Exchange;
VOLA1 is the monthly index return volatility on the Shanghai Stock Exchange;
VOLA2 is the monthly index return volatility on the Shenzhen Stock Exchange;
VOLUME1 is the monthly trading volume volatility (Standard deviation of the logarithm of daily trading volume) on the Shanghai Stock Exchange;
VOLUME2 is the monthly trading volume volatility (Standard deviation of the logarithm of daily trading volume) on the Shenzhen Stock Exchange.

Table 3

We perform the unit root test on the stock index returns, stock return volatility, and trading volume volatility for the Shanghai and Shenzhen Stock Exchanges in China respectively, using the Dickey-Fuller test procedure:

$$\Delta y_t = c + \alpha t + \beta y_{t-1} + \varepsilon_t,$$

where c is a drift term, t is a time trend, and Δy_t is the first order difference of the series y_t .

The null hypothesis for the test of the existence of a unit root is $H_0: \beta = 0$ versus the alternative $H_a: \beta < 0$. The T-values are in parentheses.

Shanghai Stock Exchange (December 1990 – June 1999)			
	Monthly return	Monthly return volatility	Monthly volume volatility
β	-1.066 (-10.57*)	-0.791 (-8.07*)	-0.458 (-5.71*)
R^2	0.53	0.40	0.25

Shenzhen Stock Exchange (April 1991 – June 1999)			
	Monthly return	Monthly return volatility	Monthly volume volatility
β	-0.751 (-7.36*)	-0.717 (-7.38*)	-0.736 (-7.71*)
R^2	0.36	0.37	0.39

*Significant at the 5% level.

We report the contemporaneous relationship among stock returns, volatility, and trading volume for both Chinese stock markets in Table 4. In contrast with the previous findings with the U.S. data at the aggregate level, we find a strongly positive contemporaneous relationship between stock returns and return volatility. This result is consistent with the Duffee's findings (1995) at the individual firm's level. The evidence may characterize the emerging market behavior where higher returns are accompanied by higher return volatility. Interestingly, the lagged returns are also positively related to return volatility at the Shenzhen Stock Exchange. In addition, we find that volume volatility and return volatility are positively correlated. The positive relationship is even stronger for the Shanghai Stock Exchange. This finding is consistent with our expectation that high volume volatility usually indicates high return volatility.

Table 4

We run the following regressions to investigate the contemporaneous relationship among stock returns, return volatility, and trading volume volatility for the Shanghai Stock Exchange and Shenzhen Stock Exchange:

$$\ln(\sigma_t) = \beta_0 + \beta_1 R_{t-1} + \beta_2 \ln(v_t) + \mu_{2,t}, \quad (6)$$

$$\ln(\sigma_{t-1}) = \lambda_0 + \lambda_1 R_{t-1} + \lambda_2 \ln(v_{t-1}) + \mu_{3,t}, \quad (7)$$

where σ_t is the monthly return volatility measured by the standard deviation of daily returns within the month t , v_t is the monthly volume volatility measured by the standard deviation of the logarithm of daily trading volumes in the month t , R_t is the index return in time t , and $\mu_{2,t}$ and $\mu_{3,t}$ are error terms. The T-values are in parentheses.

Shanghai Stock Exchange

(December 1990 – June 1999)

β_0	β_1	β_2	R^2
-3.662 (-19.86*)	-0.009 (-0.02)	1.633 (2.47*)	0.06
λ_0	λ_1	λ_2	
-3.660 (-20.53*)	0.799 (2.30*)	1.784 (2.71*)	0.10

Shenzhen Stock Exchange

(April 1991 – June 1999)

β_0	β_1	β_2	R^2
-3.977 (-34.29*)	1.131 (3.30*)	0.451 (0.91)	0.10
λ_0	λ_1	λ_2	
-4.049 (-34.31*)	1.292 (3.63*)	0.506 (1.05)	0.12

*Significant at the 5% level.

Table 5

We estimate a three variable VAR model using the "SURE" procedure. Let x_t be $\ln\left(\frac{\sigma_t}{\sigma_{t-1}}\right)$ and y_t be $\ln\left(\frac{v_t}{v_{t-1}}\right)$. The VAR model takes the form of

$$x_t = c_1 + \sum_{i=1}^{m_1} \beta_{1i} x_{t-i} + \sum_{i=1}^{n_1} \delta_{1i} y_{t-i} + \sum_{i=1}^{p_1} \gamma_{1i} R_{t-i} + \varepsilon_{1,t} \quad (8)$$

$$y_t = c_2 + \sum_{i=1}^{m_2} \beta_{2i} y_{t-i} + \sum_{i=1}^{n_2} \delta_{2i} x_{t-i} + \sum_{i=1}^{p_2} \gamma_{2i} R_{t-i} + \varepsilon_{2,t} \quad (9)$$

$$R_t = c_3 + \sum_{i=1}^{m_3} \beta_{3i} R_{t-i} + \sum_{i=1}^{n_3} \delta_{3i} x_{t-i} + \sum_{i=1}^{p_3} \gamma_{3i} y_{t-i} + \varepsilon_{3,t}, \quad (10)$$

where σ_t is the monthly return volatility measured by the standard deviation of daily returns within the month t , v_t is the monthly volume volatility measured by the standard deviation of the logarithm of daily trading volumes in month t , R_t is the index return in time t , and $\varepsilon_{i,t}$ ($i = 1, 2, 3$) is an error term. With the Akaike's Final Prediction Error approach, we find that the optimal lags for n_1 and p_1 in (8), n_2 and p_2 in (9), and n_3 and p_3 in (10) are all equal to 1. We perform the causality test using the traditional F-test.

The Shanghai Stock Exchange

(December 1990 – June 1999)

	δ_{11}	γ_{11}	δ_{21}	γ_{21}	δ_{31}	γ_{31}
	0.270	0.223	0.108	-0.348	0.078	-0.040
F-value	(4.13*)	(0.56)	(6.07*)	(4.35*)	(4.98*)	(0.57)

(December 1990 – June 1995)

	δ_{11}	γ_{11}	δ_{21}	γ_{21}	δ_{31}	γ_{31}
	0.274	0.215	0.058	-0.340	0.090	-0.042
F-value	(1.01)	(0.27)	(2.17)	(3.83)	(3.04)	(0.16)

(July 1995 – June 1999)

	δ_{11}	γ_{11}	δ_{21}	γ_{21}	δ_{31}	γ_{31}
	0.319	1.003	0.364	-1.437	0.055	-0.045
F-value	(5.15*)	(1.88)	(7.06*)	(3.72)	(2.58)	(2.39)

The Shenzhen Stock Exchange

(April 1991 – June 1999)

	δ_{11}	γ_{11}	δ_{21}	γ_{21}	δ_{31}	γ_{31}
	0.297	0.307	0.213	-0.357	0.050	0.038
F-value	(7.60*)	(0.80)	(6.97*)	(1.60)	(4.09*)	(1.48)

Table 5 (Continued)

(April 1991 – June 1995)						
	δ_{11}	γ_{11}	δ_{21}	γ_{21}	δ_{31}	γ_{31}
	0.236	0.037	0.106	-0.480	0.081	0.086
F-value	(1.52)	(0.01)	(1.62)	(2.21)	(4.23*)	(2.37)
(July 1995 – June 1999)						
	δ_{11}	γ_{11}	δ_{21}	γ_{21}	δ_{31}	γ_{31}
	0.357	1.121	0.468	-0.521	0.071	-0.095
F-value	(10.22*)	(5.85*)	(8.55*)	(0.77)	(3.23)	(2.12)

*Significant at the 5% level.

Table 5 presents empirical evidence of the causality relationship among returns, return volatility, and trading volume volatility.⁹ We first find that the optimal lags for return volatility and volume volatility in (8) and (9) are 2 (i.e., $m1^*=m2^*=2$) and the optimal lags for the remaining variables in the three variable VAR model are 1 (i.e., $m3^*=n1^*=p1^*=1$, $i=1,2,3$) for both Chinese stock markets over the entire period and two sub-periods. We then find that volume volatility causes return volatility because most of the estimated coefficients associated with the lagged volume volatility, δ_{11} , are significant. Higher volume volatility causes higher return volatility since all the estimated coefficients are positive. This result seems to indicate that higher volume volatility over this period increases the risk in the stock market, causing higher stock return volatility next period. Stock returns do not seem to affect return volatility directly as five out of six estimated coefficients, γ_{11} s are insignificant.

Symmetrically, we find that return volatility causes volume volatility as well. Four out of six estimated coefficients associated with the lagged return volatility, δ_{21} , are significant. As expected, higher return volatility causes higher volume volatility because all the estimated coefficients are positive. This result further suggests that there exist a bi-directional causality between return volatility and volume volatility.

Interestingly, we further find that returns affect trading volume volatility at the Shanghai Stock Exchange, but not at the Shenzhen Stock Exchange. All the estimated coefficients, γ_{21} , are negative. This seems to indicate that higher returns tend to lower trading volume volatility. Significant news and events in China usually cause volume volatility. High return periods are usually characterized by good news, causing less fluctuation in trading volume.

Finally, we find that stock returns are directly affected by return volatility, but not volume volatility. Higher return volatility causes higher stock returns as the

estimated coefficients associated with the lagged return volatility, δ_{31} s, are all positive and generally significant. This finding is consistent with the time-varying risk premium hypothesis that higher volatility increases the risk of holding stocks. Therefore, prices should fall and returns should rise.

In order to make sure that the results in Table 5 are valid, we check the correlation among the residuals from the VAR model. We find that the correlation coefficients range from -0.10 to 0.18 , which is not significant at the 5% significant level.¹⁰

We report the linkage between stock returns, return volatility, and trading volume volatility at the Shanghai Stock Exchange and the Shenzhen Stock Exchange in Table 6. We find that the estimated coefficient between returns is 0.831 , which is a very high level. This indicates that returns in the two markets are highly correlated. The estimated coefficient between return volatility is 0.725 . It also indicates a strong linkage between return volatility at the two Exchanges. Surprisingly, the trading volume volatility at the two Exchanges is highly correlated as well, for the estimated coefficient is 0.481 . Therefore, we conclude that there exists a strong linkage between the Shanghai Stock Exchange and the Shenzhen Stock Exchange in terms of returns, return volatility, and volume volatility.

VI. CONCLUSIONS

This paper examines three important issues related to the relationship among stock returns, volatility, and trading volume using the most recent Chinese stock market data. First, we examine the behavior of stock returns, volatility, and trading volume volatility. Second, we investigate the contemporaneous and causality relationship among stock returns, volatility, and trading volume at the Shanghai and Shenzhen Stock Exchanges over the period from the beginning of the stock markets in December 1990 (April 1991) to June 1999. Finally, we examine the linkage between the Shanghai Stock Exchange and the Shenzhen Stock Exchange.

We find that monthly return volatility and trading volume volatility exhibit strong autocorrelation. However, further empirical tests reject the existence of unit roots. Monthly returns do not exhibit autocorrelation for the Shanghai Stock Exchange Index. In contrast with the previous findings with the U.S. data at the aggregate level, we find a strongly positive contemporaneous relationship between returns and volatility for both Chinese stock markets, which is consistent with the previous findings at the individual firm's level. The simultaneous relationship between return volatility and volume volatility is also positive.

Table 6

To check for linkage between two time series, S_t and z_t , we run a regression of z_t on S_t and check if the estimated coefficient, β , is significant. To be more exact, we run the following regression of

$$S_t = \alpha + \beta z_t + \varepsilon_t, \quad (13)$$

and test if β is significant. In this study, we check the linkage between stock index returns in the Shanghai and Shenzhen Stock Exchanges in China. The same relationship is examined between return volatility and volume volatility for the two Exchanges. T-values are in parentheses.

**Monthly Returns between Shanghai and Shenzhen Stock Exchanges
(April 1991 – June 1999)**

β	0.831 (6.53*)
R^2	0.31

**Monthly Returns Volatility between Shanghai and Shenzhen Stock
Exchanges (April 1991 – June 1999)**

β	0.725 (3.90*)
R^2	0.14

**Monthly Volume Volatility between Shanghai and Shenzhen Stock
Exchanges (April 1991 – June 1999)**

β	0.481 (5.32*)
R^2	0.23

*Significant at the 5% level.

With a three variable VAR model, we further find that return volatility causes stock returns at both Chinese stock markets. Higher return volatility tends to cause higher returns, which is consistent with the time-varying risk premium hypothesis. There exists a bi-directional causality between return volatility and volume volatility. Higher return volatility increases volume volatility and vice versa. Interestingly, we also find that returns do not cause return volatility directly at both Chinese stock markets, but instead affects trading volume volatility at the

Shanghai Stock Exchange. Finally, we find a strong linkage between the Shanghai Stock Exchange and the Shenzhen Stock Exchange in terms of returns, return volatility, and volume volatility.

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NOTES

1. Chinese stock markets were established between late 1990 and early 1991. These emerging markets were very volatile. Monthly returns, on one occasion, exceeded 170% while the monthly volatility was as high as 25%. Therefore, the traditional approximation using the logarithm of relatives for index returns is not appropriate in this case.
2. Most of previous studies use different methods to estimate the market volatility. For example, Duffee (1995) uses the square root of the sum of squared daily returns within the month, while French, Schwert, and Stambaugh (1987) consider additional first-order autocorrelation in daily returns. Chen, Cuny, and Haugen (1995) use implied volatility estimated from S&P 500 index options.
3. Most research has shown that return volatility and volume volatility are autocorrelated. Therefore, checking for stationarity is a necessary step to start the analysis. See Duffee (1995), for example.
4. Since return volatility and trading volume volatility are both strongly autocorrelated the log relative transformation is appropriate.
5. This procedure is similar to a pre-whitening process. Any effect thereafter should be caused by other factors.
6. In determining the optimal lag of $n1^*$ (later $p1^*$), we still use FPE, the Akaike's information criterion similar to (11) by adjusting the parameter k . For more detailed discussion on this technique, see Zhou (1997).
7. You need to adjust the degrees of freedom.
8. Since returns, return volatility, and volume volatility for both Exchanges are stationary, we don't need to examine the cointegration among these variables.
9. We only report the coefficients that are associated with causality tests. The full set of the estimated coefficients in regressions (7) – (9) is available from the authors.
10. The squared correlation coefficient multiplied by the number of observations is approximately a Chi-Square distribution with one degree of freedom. The critical value is 3.831.

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