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Article

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FINANCIAL ECONOMICS | RESEARCH ARTICLE

The impact of price limit system on the comprehensive quality of the stock market: Research on long-term and short-term effects based on submarkets

Zhuwei Li^{1*}, Xiaoshan Wang² and Chenyang Kang²

Abstract: We construct a difference-in-differences simultaneous equation to study the long-term impact of price limit system on the comprehensive quality of the stock market. Moreover, we use event study method to further test short-term effect. Results show that after the setting of price limit system in China, the quality of total market and the Shenzhen stock market improves to a certain extent. But for the Shanghai stock market, in the long term, the setting of price limit system can reduce liquidity and market efficiency, in the short term, it could cause trading interference effect and price discovery delay effect; nonetheless, it could stabilize volatility and suppress volatility spillover effect.

Subjects: Finance; Public Finance; Investment & Securities

Keywords: price limit system; comprehensive quality of stock market; difference-in-differences simultaneous model; event study method; long-term and short-term effects

JEL classification: G10; G14; G18

1. Introduction

The basic systems of China's stock market¹ are being reformed. According to the operating mechanism of the stock market, basic systems can be divided into issuing systems, trading systems, and delisting systems. The Chinese government and China Securities Regulatory Commission have made vigorous adjustment and reform to delisting system and issuing system.² However, whether the main trading systems, especially price limit system, are still suitable for the status quo of China's stock market operation and development has become the focus among scholars.

In recent years, the call for reform of price limit system has been prominent due to several reasons. First, China's stock market fluctuates frequently and violently, the efficiency of digesting news in the market is low, and the phenomenon of "unilateral market" is obvious. Hence, seeking new trading systems or reform of the trading systems is necessary to improve this phenomenon. Second, since the launch of Shanghai-Hong Kong Stock Connect program in 2014, different trading systems of the A-share

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and H-share markets have caused trading obstacles and unfair systems for investors. Moreover, price limit system is one of the biggest obstacles restricting fairness and smooth transactions. Third, at the beginning of 2016, the failure of exponential circuit breaker mechanism caused the stock market to plummet. The mechanism was halted by the China Securities Regulatory Commission after only 2 days of implementation. Less than 1 month later, the Shanghai composite indicator fell below 2,650 points. Practice shows that circuit breaker system does not apply to the current situation of China's stock market. It can be seen that the combination of deregulation and regulation is the only way to improve the stock market trading systems. Therefore, discussing whether price limit system should be canceled and how to carry out system reforms is urgent.

Throughout the development of China's stock market,³ price limit system has undergone several changes. The Shenzhen Stock Exchange once implemented a maximum price limit of 10% and a minimum price limit of 0.5%, and even canceled price limit system. Moreover, the Shanghai Stock Exchange adjusted the range of price fluctuations several times at the beginning of its establishment, and even abolished price limit altogether. However, the stock market price fluctuated drastically in the years after the cancellation of price limit system; hence, the Shenzhen Stock Exchange and Shanghai Stock Exchange resumed the 10% symmetric price limit system on 26 December 1996, which continues to be implemented to this day.⁴ The changes of price limit system create quasi-natural experimental conditions for the research of this article.

Based on the above background and conditions, this article constructs a difference-in-differences simultaneous model and designs event study to examine the impact of price limit system on the comprehensive quality of the stock market. Unlike previous studies, the main contribution lies in that this article begins from multiple perspectives such as market segmentation and long-term and short-term effects, and combines two methods.⁵ It mainly examines whether changes in price limit system, especially whether price limit exists, have short-term and long-term effects on the comprehensive quality of the stock market, such as liquidity, volatility, and market efficiency, and in addition, judges the rationality and reform of the current system.

Results show that after the setting of price limit system in China, the quality of total market and the Shenzhen stock market improves to a certain extent, but the impact on the quality of the Shanghai stock market has advantages and disadvantages. For example, in the long term, the setting of price limit system can reduce liquidity and market efficiency of the Shanghai stock market. In the short term, it could cause trading interference effect and price discovery delay effect; nonetheless, it could stabilize volatility and suppress volatility spillover effect of the Shanghai stock market. The current price limit system needs to be reformed to a certain extent according to the submarkets.

2. Literature review

2.1. Research on the impact of price limit system on stock market liquidity

Liquidity is one of the important attributes of the stock market that investors, regulators, and researchers pay attention to. According to Amihud and Mendelson (1986), liquidity is the time or cost required to find an ideal price, generally, the higher the market liquidity, the lower the transaction cost and the higher the market quality (Amihud & Mendelson, 1986). Research results on the impact of price limit system on stock market liquidity hold two views. Some scholars believe that price limit system will decrease the liquidity of the stock market. Lin and Chiao (2020) found that the expansion of fluctuation range is not conducive to liquidity, but helpful for price discovery (Lin & Chiao, 2020). Mai and Elgiziry (2017) also found that price limit system reduced liquidity of the stock market, that is, liquidity interference effect was found. Other scholars believe that price limit system has no effect on liquidity (Mai & Elgiziry, 2017). Ayesha and Christo (2018) used the daily data of white corn futures contracts to conduct an empirical study on the effectiveness of price limit system and concluded that price limit system is invalid for white corn futures (Ayesha & Christo, 2018).

2.2. Research on the impact of price limit system on stock market volatility

Volatility is generally defined as price changes, or the frequency and amplitude of price changes. Some scholars found that the price limit system reduced the volatility of the stock market through empirical methods or the construction of artificial stock markets; see Kim et al. (2013), Yeh and Yang (2013), Christopher et al. (1989), and Deb et al. (2016). Some scholars believe that price limit system will increase the volatility of the stock market; see Danişoğlu & Güner, (2018), Zhang et al. (2016), Tao et al. (2017), and Mai and Elgiziry (2017). Moreover, other scholars believe that price limit system has various effects on the volatility of the stock market. Chen et al. (2005) examined the effect of price restrictions on A-shares traded on the Shanghai Stock Exchange and Shenzhen Stock Exchange, and found that when the market atmosphere and investor sentiment are mainly bullish, price limit system can effectively reduce stock volatility when the price is falling, but not when the stock price is rising; the conclusion is opposite in the bear market (Chen et al., 2005). Wang et al. (2014) showed that during the financial crisis, price limit system will increase volatility, whereas in the period of economic stability, price limit system will reduce the volatility when prices move downward (Wang et al., 2014).

2.3. Research on the impact of price limit system on stock market efficiency

Stock market efficiency refers to the reaction efficiency of stock prices to new information in the market. Some scholars believe that price limit system can improve market efficiency. Lim and Brooks (2009) studied the stock market efficiency of mainland China, South Korea, and Taiwan under different price limit systems, and found that compared with the situation without price limit restrictions, the market efficiency was significantly improved during the implementation of price limit system (Lim & Brooks, 2009). Dabbou (2013), Kim et al. (2013), and Lu (2016) also came to similar conclusion. Other scholars believe that price limit system will reduce market efficiency. Farag (2015) used the data of the Egyptian stock market from 1999 to 2010 to study the impact of price limit policy on overreaction and found evidence of abnormal overreaction, and believed that the imperfection of the stock market was due to the implementation of different price limit mechanisms (Farag, 2015). Danişoğlu and Güner (2018), Lien et al. (2019), and Lien et.al. (2020) also came to similar conclusion.

In summary, to study the impact of price limit system on the quality of the stock market, most of the existing literature uses parameter tests and single indicators to make a simple before-and-after comparison. However, the research indicators are not comprehensive and lack correlation between indicator variables. These shortcomings are likely to lead to research result errors and mixed and inconsistent results. In addition, the time dimension of the existing literature is relatively single, hence, the conclusions obtained can hardly represent the real effect of China's price limit system after nearly 30 years of implementation. In view of these gaps, this article adopts the method of market division at the research perspective level to investigate the total market and sub-market separately. At the technical level, the difference-in-differences simultaneous model is used to effectively control the ex ante differences and correlations between the research indicator objects and to effectively separate the real results of the policy impact. At the time level, event study method is used to further test the reasons for the short-term effects. Combined with the long-term effects results obtained by using difference-in-differences simultaneous model, this article makes a systematic analysis on the long-term and short-term effects of the change of price limit system on the comprehensive quality of the stock market. These approaches make the research conclusions comprehensive.

3. Indicator setting and model construction

3.1. Sample selection and data sources

According to the quasi-natural experimental conditions provided by the changes of price limit system of China's stock market, and referring to Wu and Qin (2015), difference-in-differences simultaneous model is constructed to study the impact of price limit system on the comprehensive quality of the stock market. Owing to the availability of part of the data and the need to construct reasonable window periods, the period covered by the research data is from 16 April 1991 to 30 November 2019.⁶ These data are obtained from Wind database and RESSET financial database.

3.2. Stock market comprehensive quality indicator setting

Generally, market quality can be measured in terms of liquidity, volatility, efficiency, and transparency.⁷ Given that liquidity, volatility, and efficiency indicators are relatively mature in measurement methods, which are the current standard methods for measuring the quality of the stock market in academia, these three types of indicators are selected as the measurement system of the comprehensive quality of the stock market. Among them, the dual indicator setting method for liquidity and volatility is helpful in verifying the robustness of research conclusions.⁸

3.2.1. Liquidity indicator (LD_{it})

Among liquidity indicators, which including trading volume, trading amount, bid–ask spread, and market depth, refer to Amihud, 2002, we select turnover rate indicator (TR_{it}) and illiquidity indicator (NTR_{it}) to measure the liquidity of the stock market.

Turnover rate is the frequency at which a security changes hands during a specified trading day. The formula is as follows:

$$TR_{it} = \frac{\text{volume}_t^i}{\text{outstanding}_t^i} \times 100, \quad (1)$$

where volume_t^i is the trading volume of stock index i on trading day t , and outstanding_t^i is the number of shares in circulation of stock index i on trading day t .

The illiquidity indicator represents the volatility of stock price caused by the trading volume of each unit, the greater the volatility, the lower the liquidity. The calculation formula is as follows:

$$NTR_{it} = \frac{|\ln P_{ct}^i - \ln P_{ot}^i|}{\text{volume}_t^i}, \quad (2)$$

where P_{ct}^i is the closing price of stock index i on trading day t , and P_{ot}^i is the opening price of stock index i on trading day t .

3.2.2. Volatility indicator (BD_{it})

Using 20-day simple moving-average standard deviation of stock's daily return rate as one of the indicators to measure the volatility of the stock market, the calculation formula of $Sma20_{it}$ is shown in the following formula:

$$Sma20_{it} = \hat{\sigma}_{it+1} = \sqrt{\sum_{t=\tau-T+1}^{\tau} \frac{(r_{it} - \bar{r}_{it})^2}{T-1}}, \quad (3)$$

where r_{it} is the return rate of stock index i at time t , and $\bar{r}_{it}$ is the average return rate from time $(\tau - T + 1)$ to τ , and $T = 20$.

Refer to Barbara & Agata, 2019, the estimated value of GARCH(1,1) is used as the second indicator to measure the volatility of the stock market. The $Garch_{it}$ calculation formula is as follows:

$$h_{it} = \alpha_0 + \alpha_1 r_{it-1}^2 + \beta_1 h_{it-1}, \quad (4)$$

where α_0, α_1 , and β_1 are the parameters to be estimated, h_{it} and h_{it-1} are the conditional variance of the current and previous period.

3.2.3. Market efficiency indicator (XL_{it})

The efficiency of the stock market refers to the efficiency of stock prices in response to new information. If stock prices in the market can respond to all information quickly and accurately, then such a stock market is highly efficient; otherwise the market is inefficient.⁹ The market efficiency coefficient (MEC) proposed by Hasbrouk and Schwartz (1998) is used as the measurement indicator (Hasbrouk & Schwartz, 1998). This indicator is the ratio of variance of stock long-term return to short-term return, which measures the MEC of daytime. The long-term return rate is calculated by 2 days, and short-term return rate is calculated by 1 day. The closer the MEC is to 1, the higher the pricing efficiency. The MEC_{it} calculation formula is

$$MEC_{it} = \frac{Var(R_{it}(2))}{2Var(R_{it}(1))}. \quad (5)$$

Table 1 summarizes the main variables and their meanings.

3.3. Construction of the difference-in-differences simultaneous model

This article uses daily stock market data to conduct empirical research from the perspective of total market and submarkets. It mainly adopts the difference-in-differences simultaneous model and event study method.¹⁰ Total market, which is the Shanghai and Shenzhen stock markets as a whole, changed from having no price limit to 10% price limit on 26 December 1996. Hence, we select 21 May 1992 to 30 November 2019 as the sub-sample period, the total market in mainland China is used as the experimental group, and the Hong Kong stock market is used as the control group. Then, subdivide total market into the Shanghai stock market and the Shenzhen stock market. The Shanghai stock market price limit system changed from having 1% or 5% price limit to no price limit on 21 May 1992. 18 February 1992 to 25 December 1996 is selected as the sub-sample period, the Shanghai stock market is used as the experimental group; whereas the Shenzhen stock market, which has no price limit changes during this period, served as the control group. The Shenzhen stock market price limit system changed from having 0.5% price limit to no price limit on 17 August 1991; hence, the sub-sample period selected is from 16 April 1991 to 17 February 1992, and the Shenzhen stock market is used as the experimental group. The Shanghai stock market, which had no price limit changes during the period, is used as the control group. The Shanghai composite index, Shenzhen composite index, CSI 300 index,¹¹ and Hang Seng index are used as stock market research data. Table 2 shows the experimental design.

When the joint relationship between one or more explanatory variables and the explained variables is determined, a problem of simultaneity will arise. Studies have proven that a mutual influence exists between volatility and liquidity of the stock market.¹² Simultaneous equations can solve the problems of causality and endogeneity caused by variables' simultaneousness, and the difference-in-differences model can effectively eliminate the influence of other factors and events.¹³ Hence, this article refers to the methods of Wang and Yau (2000) and Wu and Qin (2015), then establishes difference-in-differences simultaneous models that includes liquidity (LD_{it}), volatility (BD_{it}), and market efficiency (XL_{it}). See equations (6)–(8):

$$LD_{it} = \alpha_0 + \alpha_1 BD_{it} + \alpha_2 XL_{it} + \alpha_3 LD_{it-1} + \alpha_4 |R_{it}| + \alpha_5 D_t + \alpha_6 D_i + \alpha_7 D_t * D_i + e_{it}^1; \quad (6)$$

$$BD_{it} = \beta_0 + \beta_1 LD_{it} + \beta_2 XL_{it} + \beta_3 BD_{it-1} + \beta_4 P_{it} + \beta_5 D_t + \beta_6 D_i + \beta_7 D_t * D_i + e_{it}^2; \quad (7)$$

$$XL_{it} = \delta_0 + \delta_1 LD_{it} + \delta_2 BD_{it} + \delta_3 XL_{it-1} + \delta_4 R_{it} + \delta_5 D_t + \delta_6 D_i + \delta_7 D_t * D_i + e_{it}^3. \quad (8)$$

Table 1. Description of the main variables

Main variables		Description
Endogenous variables	Liquidity LD_{it}	TR_{it} The liquidity indicator, as shown in formula (1), measures the liquidity of the stock market. The larger the value of this indicator, the better the liquidity of the stock market. Additionally, i represents the stock market, and t represents time, the same below.
		NTR_{it} The illiquidity indicator, as shown in formula (2), measures the illiquidity of the stock market. The larger the value of this indicator, the worse the liquidity of the stock market.
	Volatility BD_{it}	$Sma20_{it}$ This variable measures the 20-day simple moving average standard deviation of stock daily returns, as shown in formula (3). The larger the value of this indicator, the greater the volatility of the stock market; and vice versa.
		$Garch_{it}$ This variable measures the daily volatility calculated by the Garch model, as shown in formula (4). The larger the value of this indicator, the greater the volatility of the stock market, and vice versa.
	Market efficiency XL_{it}	MEC_{it} This variable measures the market efficiency coefficient, as shown in formula (5). The closer the market efficiency coefficient is to 1, the higher the pricing efficiency of the stock market.

(Continued)

Table 1. (Continued)		
Main variables		Description
Dummy variables	System change	D_t This variable represents the dummy variable of system change. The value is 0 before the system change, and the value is 1 after the change.
	Stock market experiment	D_I This variable represents the dummy variable of the stock market experiment. The value is 1 for the experimental group and 0 for the control group.
	Interactive item	$D_t * D_I$ This variable represents the interaction item of dummy variables, and the regression coefficient of the interaction term on the explained variable is the focus.
Prerequisite variables	Lagged endogenous variables	LD_{it-1} This variable represents the first-order lag term of the liquidity indicator.
		BD_{it-1} This variable represents the first-order lag term of the volatility indicator.
		XL_{it-1} This variable represents the first-order lag term of the market efficiency indicator.
	Exogenous variables	$ R_{it} $ This variable represents the absolute value of the daily return rate of the stock market.
		P_{it} This variable indicates the stock index price.
		Rf_t This variable indicates the one-year time deposit benchmark interest rate of the People's Bank of China.

Note: All variables are standardized and outliers are deleted.

Table 2. Experimental design

Test of total market

Market	Quasi-natural experiment	Before the change of price limit system	After the change of price limit system
Total market	Experimental group	No price limit	10%
Hong Kong stock market	Control group	No price limit	No price limit
Test of the Shanghai stock market			
Market	Quasi-natural experiment	Before the change of price limit system	After the change of price limit system
Shanghai stock market	Experimental group	1% or 5%	No price limit
Shenzhen stock market	Control group	No price limit	No price limit
Test of the Shenzhen stock market			
Market	Quasi-natural experiment	Before the change of price limit system	After the change of price limit system
Shenzhen stock market	Experimental group	0.5%	No price limit
Shanghai stock market	Control group	1%	1%

This article focuses on the coefficient of $D_t * D_i$. If the coefficient is significantly positive, it indicates that the changed price limit system has a positive effect on the quality of the stock market; otherwise, it has a negative effect. The rate of return is introduced into the liquidity equation to reflect how the rate of return affects liquidity, the stock index price is introduced into the volatility equation to reflect the impact of price levels on volatility, and the interest rate is introduced into the efficiency equation to reflect the opportunity cost of investors to the market effect on efficiency.

4. Empirical results

This part examines the long-term effect of the price limit system on the comprehensive quality of the total stock market and submarkets.¹⁴

4.1. Impact of price limit system on total market quality

We test total market first. The ADF stationarity test is performed on the data, and the results show that the data are all stable.¹⁵ The Hausman test is performed simultaneously on the liquidity, volatility, and market efficiency equations. The result shows that p -value is greater than 0.1, indicating that the null hypothesis is not rejected, that is, variable endogeneity does not exist in the model.¹⁶ Table 3 shows the regression results of the liquidity, volatility, and market efficiency equations.

The results in Table 3 show that for the regression of liquidity indicator turnover rate TR_{it} , the interaction coefficient is significantly positive under the 1% level; for the regression of illiquidity indicator NTR_{it} , the interaction coefficient is significantly negative at the 1% level. These results indicate that the liquidity of the total market has increased significantly after setting price limit system. For the regression of volatility indicators $Sma20_{it}$ and $Garch_{it}$, the interaction coefficients are significantly negative at the 1% level, indicating that the volatility of the total market has significantly reduced after setting price limit system. For the regression of market efficiency indicator MEC_{it} , the interaction coefficient is significantly positive at the 1% level, that is, the setting of price limit system increases the market efficiency of the total market.

Therefore, after the setting of price limit system, that is, after restricting prices, liquidity of the total market is significantly increased, volatility is significantly reduced, and market efficiency is significantly improved. These results mean that the setting of price limit system is conducive to improving the quality of the total stock market.

Table 3. Regression results of the difference-in-differences simultaneous model of the total market

Liquidity equation			Volatility equation			Market efficiency equation		
Coefficient	TR_{it}	NTR_{it}	Coefficient	$Sma20it$	$Garchit$	Coefficient	MEC_{it}	
Interact item	0.3520*** (15.98)	-0.2612*** (-23.54)	Interact item	-0.8310*** (-32.28)	-0.1102*** (-7.12)	Interact item	0.0112*** (2.67)	
BD_{it}	-12.5175*** (-21.39)	5.5034*** (5.47)	LD_{it}	0.0279e-03*** (32.97)	0.0196e-04*** (4.03)	LD_{it}	0.0068e-04*** (6.56)	
χ_{it}	-0.2712*** (-8.93)	0.1358*** (7.95)	χ_{it}	-0.0078 (-0.27)	-0.1835*** (-9.00)	BD_{it}	-0.1878** (-1.34)	
LD_{it-1}	0.2923e-04*** (37.95)	0.1500e-03*** (49.52)	BD_{it-1}	35.3821*** (90.45)	92.3441*** (86.14)	χ_{it-1}	0.7229*** (25.49)	
$ R_{it} $	-9.6645*** (-31.31)	4.5671*** (67.02)	PI_{it}	0.0069e-04* (1.70)	0.0835e-05 (0.32)	R_{it}	-0.1010** (-1.44)	
Constant	0.1057*** (15.98)	0.1520*** (12.60)	Constant	1.7642*** (17.89)	0.4137*** (11.02)	Constant	0.2636*** (34.30)	
R^2	0.3732	0.3835	R^2	0.5162	0.6828	R^2	0.5257	

Note: ***, **, and * are marked at the significance level of 1%, 5%, and 10%, respectively. “()” is the Z statistic. Some of the indicators have been treated with magnitude. The same in other tables.

4.2. Impact of price limit system on Shanghai stock market quality

After market segmentation, the quality of the Shanghai stock market is regressed according to the difference-in-differences simultaneous model. Table 4 shows the results.

The results in Table 4 show that for the regression of liquidity indicator turnover rate TR_{it} , the interaction coefficient is significantly positive at the 1% level; for the regression of illiquidity indicator NTR_{it} , the interaction coefficient is significantly negative at the 1% level. These results indicate that the cancellation of price limit system has significantly improved the liquidity of the Shanghai stock market. By contrast, the setting of price limit system will reduce the liquidity of the Shanghai stock market.

For the regression of volatility indicators $Sma20_{it}$ and $Garch_{it}$, the interaction coefficients are significantly positive at the level of 1 and 10%, respectively. These results indicate that the cancellation of price limit system has increased the volatility of the Shanghai stock market to a certain extent. By contrast, the setting of price limit system will reduce the volatility of the Shanghai stock market, consistent with the result of Yeh and Yang (2013) and Wang et al. (2014). For the regression of market efficiency indicator MEC_{it} , the interaction coefficient is significantly negative at the 5% level, that is, the cancellation of price limit system reduces the market efficiency of the Shanghai stock market.¹⁷

Therefore, after the cancellation of price limit system, that is, when price restrictions are lifted, the liquidity of the Shanghai stock market significantly improves, market efficiency improves; however, the volatility increases to a certain extent. Conversely, the setting of price limit system will reduce the liquidity, market efficiency, and volatility of the Shanghai stock market. From the perspective of liquidity and market efficiency, the setting of price limit system in Shanghai stock market is detrimental to the quality of the stock market; but from the perspective of volatility, the setting of price limit system in Shanghai stock market is conducive to stabilizing the stock market. Therefore, the setting of price limit system has advantages and disadvantages to the quality of the Shanghai stock market.

4.3. Impact of price limit system on Shenzhen stock market quality

The quality of the Shenzhen stock market is regressed according to the difference-in-differences simultaneous model. Table 5 shows the results.

The results in Table 5 show that for the regression of liquidity indicator turnover rate TR_{it} , the interaction coefficient is significantly negative at the 5% level; for the regression of illiquidity indicator NTR_{it} , the interaction coefficient is positive but not significant. These results show that after the abolition of price limit system, the liquidity of the Shenzhen stock market decreases to a certain extent. By contrast, the setting of price limit system is conducive to improving the liquidity of the Shenzhen stock market. For the regression of volatility indicators $Sma20_{it}$ and $Garch_{it}$, the interaction coefficient is significantly positive at the 1% level, indicating that the abolition of price limit system has significantly increased the volatility of the Shenzhen stock market. By contrast, the setting of price limit system is conducive to stabilizing the market. For the regression of market efficiency indicator MEC_{it} , the interaction coefficient is negative but not significant, indicating that the change of price limit system has little effect on the efficiency of the Shenzhen stock market.

Therefore, after the abolition of price limit system, that is, when price limit is lifted, the volatility of the Shenzhen stock market will increase significantly, and the liquidity will decrease to a certain extent. By contrast, the setting of price limit system will help improve the liquidity and reduce the volatility of the Shenzhen stock market. However, the change of price limit system has no significant impact on the efficiency of the Shenzhen stock market, which may be due to the fact that the selected data interval is in the early stage of the development of China's securities market. This period has less data and relatively immature market, which has an impact on the empirical results.

Table 4. Regression results of the difference-in-differences simultaneous model of the Shanghai stock market									
Liquidity equation				Volatility equation			Market efficiency equation		
Coefficient	TR_{it}	NTR_{it}	Coefficient	$Sma20_{it}$	Garchit	Coefficient	Coefficient	MEC_{it}	
Interact item	1.0532*** (13.62)	-1.6374*** (-6.32)	Interact item	0.0047*** (5.35)	0.0011* (1.84)	Interact item		-0.1114** (-2.41)	
BD_{it}	-0.4359* (-1.82)	4.2165** (2.97)	LD_{it}	0.0113e-05*** (32.99)	0.0024*** (4.32)	LD_{it}		-0.0215*** (-2.88)	
XL_{it}	-0.0147 (-1.61)	0.1247 (1.21)	XL_{it}	0.0006* (1.67)	-0.0033*** (-7.38)	BD_{it}		0.9076*** (3.69)	
LD_{it-1}	0.8669*** (87.22)	0.0583e-3*** (5.35)	BD_{it-1}	0.9388*** (201.4)	0.8964*** (96.41)	XL_{it-1}		0.4184*** (22.15)	
$ R_{it} $	2.4870*** (11.89)	23.5011*** (25.72)	P_{it}	0.0352e-05 (0.52)	3.3400e-06* (2.99)	R_{it}		-1.6726*** (-4.45)	
Constant	0.0429 (0.84)	1.6975*** (7.90)	Constant	-0.0036*** (-5.01)	0.0058*** (2.90)	Constant		0.8280*** (16.14)	
R^2	0.4014	0.3846	R^2	0.7609	0.7397	R^2		0.2713	

Table 5. Regression results of the difference-in-differences simultaneous model of the Shenzhen stock market

Liquidity equation			Volatility equation			Market efficiency equation		
Coefficient	TR_{it}	NTR_{it}	Coefficient	$Sma20it$	$Garchit$	Coefficient	MEC_{it}	
Interact item	-2.4746** (-1.57)	1.5764 (3.13)	Interact item	0.0337*** (9.59)	0.0356*** (12.90)	Interact item	-3.9823 (-1.37)	
BD_{it}	-22.7659 (-0.30)	6.3683* (1.03)	LD_{it}	-0.0004e-1* (-1.73)	-0.0014e-2 (-0.76)	LD_{it}	0.0013 (0.06)	
χ_{it}	0.0530e-04 (0.66)	0.2691 (0.31)	χ_{it}	-0.0701e-07 (-1.25)	-0.0328e-07 (-0.74)	BD_{it}	-4.1497 (-0.95)	
LD_{it-1}	0.7851*** (23.26)	0.2670e-4*** (5.02)	BD_{it-1}	0.1128*** (6.57)	-0.0318e-05** (-2.10)	χ_{it-1}	0.3553e-4*** (7.33)	
$ R_{it} $	-94.8312*** (-2.61)	6.3226 (0.52)	P_{it}	0.0001** (2.19)	0.0001*** (3.26)	R_{it}	0.0001 (0.045)	
Constant	1.0680 (0.46)	3.4195*** (6.22)	Constant	-0.0012 (-0.36)	0.0006 (0.23)	Constant	0.2323 (0.17)	
R^2	0.4377	0.3602	R^2	0.6303	0.7032	R^2	0.2989	

To sum up, the setting of price limit system in China's stock market is conducive to the improvement of the quality of total market and the Shenzhen stock market to a certain extent, whereas the impact on the quality of the Shanghai stock market has advantages and disadvantages.

To solve the problem of outdated sub-sample data of the Shanghai and Shenzhen stock markets, and to supplement long-term effect results of the difference-in-differences simultaneous equation model and explore the deep short-term effect causes of the results, event study method is adopted to further test short-term impact of changes in price limit system on the quality of the Shanghai and Shenzhen stock markets.¹⁸

5. Further test results

According to the basic principles of event study method, using market index to reach the price limit or achieve close to it as event trigger point, short-term effects of price limit system on market quality are studied,¹⁹ that is, relevant short-term effects on liquidity, volatility, and market efficiency, such as trading interference effect, volatility spillover effect, and price discovery delay effect are tested.²⁰ On the basis of the criteria for setting window periods and considering the persuasiveness of the data to the market, the period 21 May 1992 to 30 November 2019 is selected as the sample period of the Shanghai stock market, and the period 17 August 1991 to 30 November 2019 is selected as the sample period of the Shenzhen stock market.

5.1. Test for trading interference effect

The Wilcoxon rank-sum test is used to compare the size of the median liquidity²¹ of each group. According to the test principle, if the liquidity of $Stock_{hit}$ group after the event day is significantly greater than that of the other two groups and no significant difference exists between $Stock_{0.9}$ group and $Stock_{0.8}$ group,²² then the existence of trading interference effect is proven. The short-term dynamic window is 10 observation periods before and after the event day.

5.1.1. Test results of the Shanghai stock market

Table 6 shows the test results of trading interference effect before and after the Shanghai stock market sets price limit system. Before the setting of price limit system, the liquidity level of $Stock_{hit}$ group is significantly lower than that of $Stock_{0.9}$ group for two items, and two items of $Stock_{0.9}$ group are significantly higher than that of $Stock_{0.8}$ group (focus on the event day). Hence, no trading interference effect exists. However, after the Shanghai stock market sets price limit system, the liquidity level of $Stock_{hit}$ group is significantly higher than that of $Stock_{0.9}$ group in three items, one is significantly lower than that of $Stock_{0.9}$ group (concentrate on the event day), and only one item of $Stock_{0.9}$ group is significantly higher than that of $Stock_{0.8}$ group. These results suggest a certain degree of trading interference effect.

5.1.2. Test results of the Shenzhen stock market

Table 7 shows the test results of trading interference effect before and after the setting of price limit system in the Shenzhen stock market. Before the setting of price limit system, the liquidity level of $Stock_{hit}$ group is significantly higher than that of $Stock_{0.9}$ group for two items (concentrate on the event day), and one of $Stock_{0.9}$ group's liquidity level is significantly higher than that of $Stock_{0.8}$ group. Therefore, a certain degree of trading interference effect exists. However, after the Shenzhen stock market sets price limit system, one of the liquidity level of $Stock_{hit}$ group is significantly higher than that of $Stock_{0.9}$ group, one is significantly lower than that of $Stock_{0.9}$ group, and two of $Stock_{0.9}$ group are significantly higher than $Stock_{0.8}$ group. Therefore, no trading interference effect exists.

We can see the setting of price limit system has a certain degree of trading interference effect on the short-term liquidity of the Shanghai stock market, but it is conducive to suppressing the trading interference effect for the Shenzhen stock market. This conclusion is consistent with the

Table 6. Test results of trading interference effect on the Shanghai stock market before and after the change of price limit system

Window	Before setting price limit system				Window	After setting price limit system			
	$Stock_{hit}$	$Stock_{0,9}$	$Stock_{0,8}$			$Stock_{hit}$	$Stock_{0,9}$	$Stock_{0,8}$	
-10	-0.0358	0.1445	0.1525		-10	-0.2125	0.0972		
-9	0.0513	-0.4633	-0.0775		-9	0.0578	0.0412	>	
-8	-0.0791	-0.0159	-0.0493		-8	0.1505	-0.0502		
-7	0.0190	0.0534	-0.0844		-7	-0.1190	-0.0600		
-6	-0.0897	-0.0381	-0.0882		-6	-0.0560	-0.0233		
-5	-0.1393	0.3473	-0.0221	>>	-5	-0.0682	-0.0163		
-4	-0.0138	0.2555	0.0156		-4	-0.0487	0.1305		
-3	0.0088	-0.3620	-0.0714		-3	0.1013	0.0321		
-2	-0.0964	0.5502	0.0742	>>	-2	0.2477	-0.0473		
-1	0.0122	0.3351	-0.0964	>>	-1	0.3693	0.0542		
0	0.4208	0.1266	-0.0629		0	0.7631	0.1340	>	
1	-0.0229	-0.0614	-0.2055	>	1	-0.0917	-0.0099	>	
2	-0.2835	-0.1556	-0.3343		2	-0.5372	0.0473	>>	
3	-0.1084	-0.2369	-0.1911		3	-0.1226	-0.0866		
4	-0.2761	-0.0387	-0.0629		4	0.4393	-0.0445		
5	-0.1322	-0.0222	-0.0380		5	-0.0765	-0.0310		
6	-0.0172	-0.0741	-0.1322		6	-0.2502	-0.0029		
7	-0.1446	-0.2161	-0.0024		7	-0.0685	0.0679	>>	
8	-0.0614	-0.1324	-0.0594		8	-0.1142	-0.0809		
9	-0.1398	-0.0491	-0.2212		9	-0.0954	-0.0383		
10	-0.0614	0.0852	-0.0714		10	-0.0955	0.0541		

Note: ">>" indicates that the data on the left are significantly larger than the data on the right at the 1% significance level; ">" indicates that the data on the left are significantly greater than the data on the right at the 5% significance level. By contrast, "<<" means that the data on the left are significantly smaller than the data on the right at the 1% significance level, and "<" means that the data on the left are significantly smaller than the data on the right at the 5% significance level. The same in other tables.

Table 7. Test results of trading interference effect on the Shenzhen stock market before and after the change of price limit system

Window	Before setting price limit system				Window	After setting price limit system			
	$Stock_{hit}$	$Stock_{0,9}$	$Stock_{0,8}$			$Stock_{hit}$	$Stock_{0,9}$	$Stock_{0,8}$	
-10	-0.1955	0.0696	0.0599		-10	-0.0468	-0.0359		
-9	0.0164	-0.1073	-0.1710		-9	0.1512	-0.0594		
-8	0.0255	0.2624	0.0420		-8	0.1144	0.1716		
-7	0.0521	0.0357	0.3357		-7	0.1175	0.0147		
-6	0.1049	0.1079	0.5884		-6	-0.0733	-0.0232		
-5	0.4278	0.1705	0.1265		-5	-0.1172	-0.0157		
-4	0.0652	0.1092	0.1813		-4	0.1753	-0.0458		
-3	-0.0774	0.3308	0.5670		-3	-0.1259	0.2679	<	>
-2	0.3952	0.6638	0.3095		-2	0.2635	-0.1255		
-1	5.3299	0.5072	0.1043	>>	-1	0.3317	0.0851		
0	0.9240	0.0483	0.2077		0	1.0358	0.3446	>	
1	0.5558	-0.0661	0.2693		1	-0.1467	0.1453		
2	-0.3273	-0.0558	-0.0314		2	-0.1258	-0.1279		
3	-0.2504	-0.0763	-0.1215		3	-0.0493	-0.0987		
4	0.2189	0.0343	-0.0596		4	-0.0386	0.2502	>	
5	-0.2141	-0.0633	0.0326		5	-0.1322	0.0204		
6	0.0590	0.0906	0.0119		6	-0.0346	0.0028		
7	0.0526	-0.1485	0.2814		7	0.1334	-0.0804		
8	-0.0226	0.0364	0.2179		8	-0.0823	-0.0204		
9	0.0362	0.0434	0.1438		9	0.0418	-0.0133		
10	-0.1866	0.0364	-0.0640		10	-0.1445	0.0963		

long-term effect of price limit system on the liquidity of the two markets according to the difference-in-differences model.

5.2. Tests for volatility spillover effect

5.2.1. Test results of the Shanghai stock market

The Wilcoxon rank-sum test is used to compare the size of the median volatility²³ of each group. The test principles and the setting of dynamic windows are the same as above.

Table 8 shows the test results of volatility spillover effect before and after the Shanghai stock market sets price limit system. Before the setting of price limit system, the volatility level of *Stock_{hit}* group is significantly higher than that of *Stock_{0.9}* group in three items. Three items in *Stock_{0.9}* group are significantly higher than *Stock_{0.8}* group, and one item is significantly lower than *Stock_{0.8}* group (concentrate on the event day). Therefore, a certain degree of volatility spillover effect exists. After setting price limit system, *Stock_{hit}* group's volatility level has three items significantly higher than *Stock_{0.9}* group and one item significantly lower than *Stock_{0.9}* group (focus on the event day). Two items in *Stock_{0.9}* group are significantly higher than *Stock_{0.8}* group and one item is significantly lower than *Stock_{0.8}* group, and the significance level has declined. These results indicate that the volatility spillover effect has weakened.

5.2.2. Test results of the Shenzhen stock market

Table 9 shows the test results of volatility spillover effect before and after the setting of price limit system in the Shenzhen stock market. Before the setting of price limit system, the volatility level of *Stock_{hit}* group is significantly higher than that of *Stock_{0.9}* group in two items, and one item of *Stock_{0.9}* group is significantly higher than *Stock_{0.8}* group. Hence, weak volatility spillover effect exists. After setting price limit system, the volatility level of *Stock_{hit}* group is significantly higher than that of *Stock_{0.9}* group in one item, one item in *Stock_{0.9}* group is significantly higher than *Stock_{0.8}* group, and one item is significantly lower than *Stock_{0.8}* group, indicating that the volatility spillover effect is further weakened and almost non-existent.

We can see the setting of price limit system has a good effect of restraining volatility spillover on the Shanghai and Shenzhen stock markets, and it is conducive to stabilizing the market. This conclusion is consistent with long-term effect of price limit system on the volatility of the two markets according to the difference-in-differences model.

5.3. Tests for price discovery delay effect

The research method is to calculate the inertial probability and reversal probability of stock price trend, focusing on the probability of inertia. If price discovery delay effect exists, then the existence of price limit system will hinder the process of price discovery and the stock price will continue to move closer to the equilibrium price on the trading days after the event day. That is, the inertia probability of the price trend of *Stock_{hit}* group will be significantly greater than the other two groups. Conversely, if price discovery delay effect does not exist, then the market is efficient in the short term.

5.3.1. Test results of the Shanghai stock market

Table 10 shows the test results of price discovery delay effect before and after the Shanghai stock market sets price limit system. Before the setting of price limit system, the inertial probability of stock market price of *Stock_{hit}* group in upward trend and downward trend is less than that of *Stock_{0.9}* group, such as $0.73 < 0.80$ and $0.50 < 1.00$, respectively. These results indicate that price discovery delay effect does not exist. However, after the setting of price limit system, the inertial probability of stock market price of *Stock_{hit}* group in upward and downward trends is significantly greater than that of the other two groups, such as $0.80 > 0.50 > 0.00$ and $1.00 > 0.71 > 0.38$, respectively. Therefore, the setting of price limit system hinders the process of price discovery in

Table 8. Test results of volatility spillover effects on the Shanghai stock market before and after the change of price limit system

Window	Before setting price limit system				Window	After setting price limit system			
	$Stock_{hit}$	$Stock_{0,9}$	$Stock_{0,8}$			$Stock_{hit}$		$Stock_{0,9}$	$Stock_{0,8}$
-10	0.0025				-10	0.0003		0.0012	0.0003
-9	0.0028				-9	0.0003		0.0006	0.0005
-8	0.0014		>>		-8	0.0006	>	0.0002	0.0005
-7	0.0025	>>			-7	0.0004		0.0002	0.0004
-6	0.0018				-6	0.0001		0.0005	0.0005
-5	0.0025				-5	0.0004		0.0008	0.0008
-4	0.0036				-4	0.0003		0.0007	0.0008
-3	0.0016		>>		-3	0.0010		0.0003	0.0009
-2	0.0049	>>			-2	0.0003		0.0003	0.0007
-1	0.0017		>>		-1	0.0009		0.0004	0.0016
0	0.0100				0	0.0006	>	0.0049	0.0025
1	0.0040		<<		1	0.0001	>>	0.0011	0.0013
2	0.0059				2	0.0001	<	0.0017	0.0012
3	0.0024				3	0.0010		0.0006	0.0007
4	0.0028				4	0.0008		0.0003	0.0007
5	0.0025				5	0.0001		0.0001	0.0008
6	0.0020				6	0.0006		0.0003	0.0011
7	0.0030	>			7	0.0005		0.0004	0.0008
8	0.0014				8	0.0004		0.0002	0.0004
9	0.0013				9	0.0002		0.0004	0.0008
10	0.0011				10	0.0004		0.0005	0.0005

Table 9. Test results of volatility spillover effect on the Shenzhen stock market before and after the change of price limit system

Window	Before setting price limit system				Window	After setting price limit system			
	$Stock_{hit}$	$Stock_{0,9}$	$Stock_{0,8}$			$Stock_{hit}$	$Stock_{0,9}$	$Stock_{0,8}$	
-10	0.0003	0.0005	0.0015		-10	0.0008	0.0003		$Stock_{0,8}$
-9	0.0004	0.0004	0.0017		-9	0.0008	0.0003		0.0009
-8	0.0004	0.0002	0.0011		-8	0.0006	0.0017		0.0009
-7	0.0005	0.0005	0.0011		-7	0.0003	0.0002	<	0.0015
-6	0.0002	0.0007	0.0205		-6	0.0012	0.0005		0.0012
-5	0.0012	0.0010	0.0002		-5	0.0005	0.0005		0.0017
-4	0.0018	0.0010	0.0057		-4	0.0016	0.0008		0.0017
-3	0.0021	0.0064	0.0021		-3	0.0003	0.0018		0.0016
-2	0.0037	0.0027	0.0026		-2	0.0012	0.0019		0.0015
-1	0.0173	0.0090	0.0012	>	-1	0.0022	0.0010		0.0019
0	0.0088	>>	0.0059		0	0.0090	0.0071	>>	0.0055
1	0.0050	0.0045	0.0041		1	0.0010	0.0014		0.0015
2	0.0094	0.0027	0.0033		2	0.0013	0.0011		0.0013
3	0.0007	0.0031	0.00037		3	0.0016	0.0012		0.0018
4	0.0026	0.0021	0.0009		4	0.0015	0.0014		0.0013
5	0.0021	>	0.0006		5	0.0008	0.0014		0.0007
6	0.0031	0.0005	0.0015		6	0.0010	0.0009		0.0012
7	0.0006	0.0009	0.0008		7	0.0015	0.0013		0.0006
8	0.0009	0.0010	0.0016		8	0.0004	0.0004		0.0007
9	0.0011	0.0004	0.0015		9	0.0003	0.0011		0.0009
10	0.0010	0.0005	0.0008		10	0.0008	0.0005		0.0005

Table 10. Test results of price discovery delay effect on the Shanghai stock market before and after the change of price limit system

Before setting price limit system				After setting price limit system			
Stock market uptrend	$Stock_{hit}$	$Stock_{0.9}$	$Stock_{0.8}$	Stock market uptrend	$Stock_{hit}$	$Stock_{0.9}$	$Stock_{0.8}$
Inertial probability	0.73	0.80	0.71	Inertial probability	0.80	0.50	0.00
Reversal probability	0.27	0.20	0.29	Reversal probability	0.20	0.50	1.00
Stock market downtrend	$Stock_{hit}$	$Stock_{0.9}$	$Stock_{0.8}$	Stock market uptrend	$Stock_{hit}$	$Stock_{0.9}$	$Stock_{0.8}$
Inertial probability	0.50	1.00	0.40	Inertial probability	1.00	0.71	0.38
Reversal probability	0.50	0.00	0.60	Reversal probability	0.00	0.29	0.63

the Shanghai stock market. As a result, the stock price continues to move closer to the equilibrium price in the trading after the event day, and short-term efficiency of the market decreases.

In addition, after setting price limit system, the inertia probability of $Stock_{hit}$ group in the downtrend is greater than that of $Stock_{hit}$ group in the uptrend, such as $1.00 > 0.80$. This result indicates that when the stock price rises, investors in the Shanghai stock market tend to sell stocks to obtain price gains, which inhibits further prices rise; when stock price falls, investors in the Shanghai stock market tend to hold stocks to prevent losses, that is, “disposition effect” exists, or quickly sell stocks to stop losses and repurchase them at a lower price, leading prices to further drop, that is, “killing down” phenomenon exists, prospect theory proves that the result is caused by investors’ different risk preferences for price increases and drops.

5.3.2. Test results of the Shenzhen stock market

Table 11 shows the test results of price discovery delay effect before and after the setting of price limit system in the Shenzhen stock market. Before the setting of price limit system, the inertia probability of stock market price of $Stock_{hit}$ group in the uptrend is less than that of the other two groups, such as $0.42 < 0.50 < 0.67$, and less than $Stock_{0.8}$ group in the downtrend, such as $0.33 < 0.40$. These results indicate that price discovery delay effect does not exist. After setting price limit system, the inertial probability of stock market price of $Stock_{hit}$ group is equal to that of $Stock_{0.9}$ group and greater than that of $Stock_{0.8}$ group in the uptrend, such as $1.00 = 1.00 > 0.71$, and in the downtrend, it is less than that of $Stock_{0.9}$ group, such as $0.80 < 1.00$. Therefore, no price discovery delay effect exists. Moreover, after setting price limit system, the inertia probability of $Stock_{hit}$ group in the uptrend is greater than that of $Stock_{hit}$ group in the downtrend, such as $1.00 > 0.80$. This result indicates that when the stock price rises, investors in the Shenzhen stock market tend to buy stocks to further raise price, that is, “chasing up” effect exists; when stock price falls, investors in the Shenzhen stock market tend to buy stocks to balance costs and keep stock price from falling further.

Therefore, the setting of price limit system has played a role in hindering price discovery to a certain extent on the short-term market efficiency of the Shanghai stock market. However, no price discovery delay effect exists in the Shenzhen stock market. This conclusion is consistent with the long-term effect of price limit system on the efficiency of the two markets according to the difference-in-differences model.

Table 11. Test results of price discovery delay effect on the Shenzhen stock market before and after the change of price limit system

Before setting price limit system				After setting price limit system			
Stock market uptrend	$Stock_{hit}$	$Stock_{0.9}$	$Stock_{0.8}$	Stock market uptrend	$Stock_{hit}$	$Stock_{0.9}$	$Stock_{0.8}$
Inertial probability	0.42	0.67	0.50	Inertial probability	1.00	1.00	0.71
Reversal probability	0.33	0.33	0.50	Reversal probability	0.00	0.00	0.29
Stock market downtrend	$Stock_{hit}$	$Stock_{0.9}$	$Stock_{0.8}$	Stock market downtrend	$Stock_{hit}$	$Stock_{0.9}$	$Stock_{0.8}$
Inertial probability	0.33	0.25	0.40	Inertial probability	0.80	1.00	0.57
Reversal probability	0.33	0.50	0.20	Reversal probability	0.20	0.00	0.43

To sum up, the setting of price limit system in China's stock market causes trading interference effect and price discovery delay effect in the Shanghai stock market in the short term. Nonetheless, it will suppress volatility spillover effect, which has advantages and disadvantages to the quality of the Shanghai stock market. In the Shenzhen stock market, no trading interference effect and price discovery delay effect have been tested, and the setting of price limit system will suppress the volatility spillover effect, which is conducive to the improvement of the quality of the Shenzhen stock market.

6. Conclusion

In the long run, the implementation of price limit system to restrict prices can improve the liquidity of total market, reduce volatility, improve market efficiency, and is conducive to improving the quality of the market. After market segmentation, in the long term, the setting of price limit system can reduce the liquidity and market efficiency of the Shanghai stock market, but can stabilize the volatility of the Shanghai stock market. In the short term, it can cause trading interference effect and price discovery delay effect, but restrain volatility spillover effect, that is, it has advantages and disadvantages to the quality of the Shanghai stock market. In the long run, it has nonsignificant effect on the market efficiency of the Shenzhen stock market, the remaining performance is similar to that of the total market, that is, the setting of price limit system can improve the liquidity of the Shenzhen stock market, reduce volatility, and suppress short-term volatility spillover effect, and it is conducive to the improvement of the quality of the Shenzhen stock market. In addition, investors in the Shanghai and Shenzhen stock markets have irrational behaviors such as "chasing ups and killing downs" and "disposition effects".

Based on the conclusions, this article proposes the some reform suggestions: Given that the price limit will hinder price discovery process and cause interference to trading, the price limit can possibly be relaxed gradually. Moreover, given that investors' reactions are asymmetrical, an asymmetric price limit system can be set to ensure high quality and high efficiency of stock trading while keeping the system in line with international standards. The 20% symmetrical price limit system proposed by the science and technology innovation board has become a test field for the reform of the trading system. However, due to the short operating time, the overall science and technology innovation board market fluctuates greatly. At this stage, the effect of this system can not be judged, but it can provide an experimental path and experimental area for the reform of price limit system. If the experiment is successful, then price limit system of the stock main board market can be reformed through reasonable design.

Furthermore, referring to Narayan (2021) and other existing literature, we believe that COVID-19 pandemic is an important factor affecting the stock market. In future research, we can consider the impact of the COVID-19 on the comprehensive quality of the stock market, and also consider whether the behavior of stock market traders has changed and whether the system needs to be improved under the normalization of the COVID-19 epidemic.

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Notes

1. The Chinese mainland stock market, including Shanghai Stock Exchange and Shenzhen Stock Exchange, has relatively strict trading system. But Hong Kong Stock Exchange (in Hong Kong, China) is a stock market in line with international standards of trading systems. The target market of this article is the main-board market of Shanghai and Shenzhen, rather than GEM and New OTC Market, because the main board market is suitable for the majority of investors and there is no minimum capital restriction, but there are some restrictions in other markets, for example, the GEM requires that the average daily assets should not be less than 500,000 YUAN.
2. On 17 October 2014, the "Several Opinions on Reforming, Improving and Strictly Implementing the Delisting System of Listed Companies" was formally issued and achieved obvious results. On 21 December 2015, the "Decision on authorizing the State Council to adjust the application of relevant provisions of the Securities Law in the implementation of the reform of the registration system for stock issuance (draft)" was submitted to the 18th meeting of the Standing Committee of the 12th National People's Congress for deliberation and approval.
3. The China's stock market in this article refers to the mainland stock market, such as the total market (including Shanghai and Shenzhen stock markets), Shanghai market, and Shenzhen market.
4. The system stipulates that, except for the first day of listing, the trading price of stocks (including A-shares and B-shares) and fund securities within a trading day shall not rise or fall by more than 10% relative to the closing price of the previous trading day. Orders that exceed the price limit are considered invalid. On 13 June 2019, China's Science and Technology Innovation Board officially opened. Although the trading system, including the price limit, has been reformed, it has become a 20% price limit. However, due to the short operating time, the overall market fluctuates greatly and does not show a stable system effect.
5. Two methods are DID model and event study. DID model is the main study based on the data of the full sample period, which can reflect of the long-term effects of the three market quality indicators, such as liquidity, volatility, and market efficiency. Event study is a further supplement based on window period data and can reflect the three corresponding short-term effects, such as trading interference effect, volatility spillover effect, and price discovery delay effect.
6. In order to avoid market turmoil interference to the data results, the market data for the first quarter of Shanghai and Shenzhen stock markets were excluded. In addition, on 4 December 2015, Shanghai Stock Exchange, Shenzhen Stock Exchange, and China Financial Futures Exchange officially issued relevant regulations on indicator circuit breakers. The standard circuit breaker index is CSI 300 index, with two thresholds of 5 and 7%. It was officially implemented on 1 January 2016, and suspended on 8 January 2016. The circuit breaker mechanism is a kind of price stabilization mechanism; in order to avoid its impact on the test results, the market data of the month after 1 January 2016 is excluded. Furthermore, to avoid the impact of the COVID-19 from the late of 2019 to 2021 on the data results, the data of the corresponding time period is not considered.
7. Referring to the existing research (Amihud, 2002; Barbara & Agata, 2019; Hasbrouck & Schwartz, 1998; Wang & Yau, 2000; Wu & Qin, 2015) and the measurement methods mentioned in the stock market quality report issued by Shanghai Stock Exchange, we set the index system from the three aspects of stock market quality to measure the stock market quality systematically and comprehensively. These three aspects are liquidity, volatility, and market efficiency.
8. The market efficiency indicator is very classic and difficult to replace, so we did not perform variable replacement.

9. The efficiency of the stock market includes the efficiency of information transmission, the speed of response to new information, and the efficiency of pricing. Pricing efficiency, also known as information efficiency, refers to the ability of securities prices to reflect information, or the speed and accuracy with which prices reflect all relevant information.
10. The event study method is detailed in the introduction of the further test.
11. The CSI 300 index components and compilation method are used to extrapolate the full sample period, representing the total market data.
12. Some scholars studied the relationship between trading volume, bid-ask spread, and price volatility of four types of futures, and the results show a positive correlation between trading volume and price volatility (Wang and Yau, 2000). Barbara and Agata (2018) found a two-way causal relationship between liquidity and volatility (Barbara & Agata, 2019). The liquidity-volatility causal relationship is common and is often asymmetric.
13. The sample data passes the endogeneity test, and then we use the two-stage least-squares method to regress. After using the difference-in-difference model, the control variables of other factors including financial crisis, securities margin trading, and stamp duty are not significant or significantly decrease, indicating that the interference from other events and factors can be eliminated.
14. In the long-term test part, we use dual indicators to establish liquidity and volatility, thus can verify the robustness of the results.
15. ADF stationarity test results show that the p -value of the variables is 0, which means the data are all stable.
16. The pre inspection results of sub markets are the same, like ADF stationarity test and the Hausman test. ADF stationarity test results show that the p -value of the variables is 0, which means the data are all stable. Limited to space, the pre inspection contents in the following are omitted, and the descriptive statistical results can be seen in Appendix.
17. First of all, the products of the Shanghai and Shenzhen stock market are different. Shanghai stock market only has the main board, while Shenzhen stock market not only has the main board, but also SME board and GEM board; Secondly, the two markets are different in the application of units, Shanghai stock market requires the minimum application of 1,000 shares, while Shenzhen stock market is 500 shares; Finally, there are differences in the types of investors in both markets. So the performance of the Shanghai stock market is different.
18. The study finds that the performance of the total market is similar to that of the Shenzhen stock market. Therefore, the test results based on the event study method only show the analysis of the Shanghai and Shenzhen stock markets; analysis will not be repeated for the total market.
19. The long-term effect results of the difference-in-differences simultaneous model are supplemented and explore the reasons for short-term effects.
20. In the short-term test part, we also replace the index to test robustness, but limited to space, the results are omitted.
21. Take the TR_{it} indicator as an example. The conclusions of other liquidity indicators are the same, and will not be repeated one by one. The same below.
22. $Stock_{hit}$ group, $Stock_{0.9}$ group, and $Stock_{0.8}$ group refer to stock portfolios whose prices touch the 10%, 9%, and 8% price limit, respectively.
23. Take the $Garch_{it}$ indicator as an example. The conclusions of other volatility indicators are the same.

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Appendix

Table A1 shows the descriptive statistical results of the total market and Hong Kong market. For the two markets, the difference between the maximum and minimum value of the indicators is large, indicating that the indicators change greatly during the selected period (e.g. the minimum value of TR_{it} of total market is 0.0053, while the maximum value is 7.3329). The average of indicators of the total market in Chinese Mainland is all higher than those of the Hong Kong market, meaning that the liquidity, volatility and market efficiency of total market is higher than that of Hong Kong market.

After conducting market segmentation, **Table A2** shows the descriptive statistical results of the Shanghai and Shenzhen stock market. For the two markets, the difference between the maximum and minimum value of the indicators is relatively large, indicating that the indicators change greatly during the selected period (e.g. the minimum value of TR_{it} of the Shanghai stock market is 0.0120, while the maximum value is 1.3759). The average of volatility and market efficiency indicators of the Shanghai stock market is higher than that of the Shenzhen stock market (e.g. the average of $Sma20_{it}$ of the Shanghai stock market is 0.0395, while the value is 0.0291 for the Shenzhen market). However, for the Shanghai stock market, the average of TR_{it} is 0.6566 and the average of NTR_{it} is 0.7711, while for the Shenzhen stock market, the average of TR_{it} is 0.7881 and the average of NTR_{it} is 0.6655, which shows that the liquidity of the two markets is difficult to distinguish between high and low.

Table A3 shows the descriptive statistical results of the Shenzhen and Shanghai stock market. For the two markets, the difference between the maximum and minimum value of the indicators is relatively large, indicating that the indicators change greatly during the selected period (e.g. the minimum value of TR_{it} of the Shenzhen stock market is 0.0015, while the maximum value is 1.1618). The average of liquidity and market efficiency indicators of the Shenzhen stock market is higher than that of the Shanghai stock market (e.g. the average of TR_{it} of the Shenzhen stock market is 0.2871, while the value is 0.2143 for the Shanghai stock market). For the Shenzhen stock market, the average of $Sma20_{it}$ is 0.0303 and the average of $Garch_{it}$ is 0.0305, while for the Shanghai stock market, the average of $Sma20_{it}$ is 0.0182 and the average of $Garch_{it}$ is 0.0375, which shows that the volatility of the two markets is difficult to distinguish between high and low.

Table A1. Descriptive statistical results of the total market

	Indicator	Variable	Number of observations	Average	Standard deviation	Minimum value	Maximum value
Total market (experimental group)	Liquidity	TRit	6553	0.0361	1.0102	0.0053	7.3329
		NTRit	6553	0.1711	1.4076	0.0001	8.0211
	Volatility	Sma20it	6553	0.0204	0.0262	0.0026	0.9885
		Garchit	6553	0.0232	0.0224	0.0059	0.5766
Hong Kong market (control group)	Market efficiency	MECit	6553	0.9800	0.2390	0.0171	1.0000
		TRit	6550	0.0251	0.0980	0.0007	5.6121
	Volatility	NTRit	6468	0.1392	1.9231	0.0006	15.8952
		Sma20it	6551	0.0150	0.0223	0.0004	1.5170
	Market efficiency	Garchit	6450	0.0157	0.0072	0.0017	0.0901
		MECit	6450	0.9321	0.2743	0.0358	1.0000

Note: As the result of the NTR indicator calculation is relatively small, for the convenience of comparison, we multiply it by 10⁹. The same in other tables.

Table A2. Descriptive statistical results of the Shanghai stock market

	Indicator	Variable	Number of observations	Average	Standard deviation	Minimum value	Maximum value
Shanghai stock market (experimental group)	Liquidity	TRit	1183	0.6566	0.8034	0.0120	1.3759
		NTRit	1181	0.7711	0.2265	0.1094	4.1728
	Volatility	Sma20it	1183	0.0395	0.0414	0.0051	0.5504
		Garchit	1183	0.0374	0.0301	0.0043	0.2591
	Market efficiency	MECit	1183	0.9234	0.5043	0.2931	1.0000
		TRit	1182	0.7881	0.8749	0.0000	4.8080
Shenzhen stock market (control group)	Liquidity	NTRit	1181	0.6655	1.0460	0.0000	12.3477
		Sma20it	1183	0.0291	0.0131	0.0104	0.0856
	Volatility	Garchit	1183	0.0288	0.0143	0.0000	0.1065
		MECit	1183	0.9213	0.4890	0.2878	1.0000
	Market efficiency						

Table A3. Descriptive statistical results of the Shenzhen stock market							
	Indicator	Variable	Number of observations	Average	Standard deviation	Minimum value	Maximum value
Shenzhen stock market (experimental group)	Liquidity	TRit	228	0.2871	0.2722	0.0015	1.1618
		NTRit	228	0.5733	0.2230	0.0001	2.0900
	Volatility	Sma20it	228	0.0303	0.0229	0.0040	0.0832
		Garchit	228	0.0305	0.0228	0.0091	0.0995
Shanghai stock market (control group)	Market efficiency	MECit	228	0.9641	0.4240	0.4641	1.0000
	Liquidity	TRit	229	0.2143	0.2822	0.0006	1.3041
		NTRit	228	0.5350	0.8670	0.1070	1.9340
	Volatility	Sma20it	229	0.0182	0.1325	0.0051	0.1809
		Garchit	229	0.0375	0.0511	0.0063	0.0696
	Market efficiency	MECit	229	0.9375	0.5074	0.6916	1.0000



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