An Empirical Study on the Price Discovery Function of Share Price Index Futures——Taking CSI 300 Index as an Example

Su Kecheng

Marshall Bussiness School, University of Southern California, Los Angeles, the United States

sukecheng_admit@163.com

Keywords: Stock index futures; Price discovery function; CSI 300; Vector autoregressive model

Abstract: Over the period from 2015 to 2022, China has gradually gave several permissions to stock index futures trading to relax trading restrictions and guided a wide range of institutional investors to participate in the derivatives market. However, the point is whether stock index futures have played a price discovery function during this period. In this paper, the daily time series data of CSI 300 stock index futures from 2020 to 2022 are selected to examine whether stock index futures have a price discovery effect on the spot market after the Covid-19 epidemic. Through empirical research, it is found that the return of the CSI 300 spot price index is the Granger cause of the return of the futures price index, and CSI 300 spot price index returns have a significant positive impact on futures price index returns, which is not a lagged effect but rather a consequent impact at that moment. Moreover, the CSI 300 spot price index returns can well explain the changes in the futures price index returns, but the futures price index returns cannot explain that of the spot, which indicates that the price discovery effect is not significant. It suggests that the CSI 300 index futures do not provide the price discovery function after the Covid-19 epidemic, based on which suggestions would also be put forward in the paper.

1. Introduction

In 2010, the CSI 300 stock index futures came to China's capital market for the first time and became the first publicly issued and traded stock financial derivatives in China. From a theoretical perspective, stock index futures have completed the product structure of the stock market. Compared with China's stock market, stock index futures that allow short selling are helpful in promoting the stability of the capital market and enhancing the transmission efficiency of price information. The definition of price discovery function refers to the ability of the price of a financial product to predict the price of another financial product. Thus, the trading of products with price discovery function is more easily to reflect the market expectation of the underlying price. Since the outbreak of Covid-19 in 2020, China's stock market has endured more than 2 years of severe volatility. The point is whether stock index futures have played a price discovery function during this period. This paper attempts to use a time series model to analyze whether stock index futures prices have a significant impact on spot prices, and to provide strategic recommendations for quantitative investment in the stock index futures market.

2. Literature Review

2.1 Relevant International Literature

Kim et al. (2009) examined the impact of the Korea 200 stock index on the spot market, and found a long-term cointegration relationship between the two [1]. Lien et al. (2010) examined the impact of MIS on the three major stock indices, and found that there is a significant price discovery function in the futures, of which contribution to the S&P 500 is 76.8% [2]. Gupta et al. (2016) [3] investigated the relationship between futures prices and spot prices in the Indian market, and suggested that there is a volatility spillover effect of Indian rubber futures on the spot market. Through an empirical study, Schmidhammer et al. (2016) discovered that stock futures prices are

  DOI: 10.25236/eiemss.2022.004

unable to provide a significant impact on the spot market under extreme market events [4]. Frommberz (2017) studied the relationship between the German stock index and the spot market with the help of high-frequency data, and found that futures prices were reflective of the price discovery principle [5]. Ivanov et al. (2013) investigated the influence of S&P on the ASX200, and concluded that the price discovery function of the index market is stronger than that of the options market [6]. Finjns et al. (2016) explored the link between VIX spot and futures prices, and found a significant two-way Granger causality [7]. A study by Bollen et al. (2016) found that VIX futures have a significant price discovery function [8].

2.2 Relevant Chinese Literature

A study by Zhang (2012) found that there is a significant price discovery relationship in the CSI 300 stock index, of which the impact is more efficient compared to the Xinhua FTSE A50 stock index futures [9]. Huang Yunzhe et al. (2014) investigated the stock index futures in China, and found that there is a stronger price transmission effect compared to the spot market [10]. The research of Liu Ximin (2016) believed that there is a two-way Granger causality between China's CSI 300 stock index futures and the spot market [11]. Song Keyan (2016) suggested in her research that the CSI 300 stock index has a threshold cointegration effect on the spot, of which the positive effect is much more persistent [12]. Yang Lin et al. (2017) argued that the CSI 300 stock index played a role of "falling helper" effect on the spot during the 2015 stock market crash in China [13]. Wei Jianguo et al. (2016) investigated the linkage between stock index futures and spot during the stock market crash in 2015 through a corrected error model, and found that the price discovery function of the SSE 50 was inferior to that of the CSI 500 and the CSI 300 [14]. Li Zheng et al. (2016) examined the impact of SSE 50, CSI 500 and CSI 300 stock index futures on spot prices, and concluded that all three stock index futures could influence spot prices. Chen Xi (2017) compared the impact of several major stock indices in China on spot prices before and after the stock market crash, and found that the impact of the CSI 300 was greater [15].

2.3 Literature Review

In the previous literature, many scholars have used time series analysis techniques, such as vector autoregression, vector error correction model, and Granger causality test, to examine the relationship between stock index futures and spot. Since these studies are more or less dated, this paper attempts to explore the latest data from 2020 to 2022 to examine the price discovery function of stock index futures after the Covid-19 epidemic, and to provide strategic suggestions for quantitative investment in the stock index futures market.

3. Theoretical Analysis

3.1 Arbitrage Mechanism

When an arbitrageur finds a difference in the price of the same underlying in more than one market, the arbitrageur is supposed to buy the undervalued product and sell the overvalued product. As this arbitraging behavior continues, information will also be circulated in the market, causing more bidders to participate and the price difference between the two markets could be gradually eliminated, driving prices in both futures and spot to the same equilibrium price. In other words, when the price of the derivative falls below its theoretical value, the arbitrageur is likely to buy the derivative futures and sell the spot, thereby increasing the price of the derivative and decreasing the spot price.

3.2 Delivery System

From the perspective of futures contracts, the futures contract stipulates that the two parties will carry out the delivery of positions on the expiry date according to certain trading rules under the arrangement of the exchange. The stock index futures exchange asks traders to settle the contract on the third Friday of the expiration month, on which the prices of spot and futures are bound to converge under the influence of the arbitrage mechanism.

4. Empirical Research

4.1 Model Design

The time span studied in this paper is the sample data after the Covid-19 epidemic, so the closing price of the CSI 300 index contract and the daily data of the CSI 300 index from January 1, 2020 to September 9, 2022 are selected. In total, there are 656 observation samples, and the sources are from China Financial Futures Exchange (CFFEX) and Wind database. Then, the cointegration test, Granger causality test, vector autoregression model and other models are used to analyze the influence of CSI 300 spot and futures prices on each other, respectively. The variables in this paper are set as Table 1.

Table 1: Variable Settings

Variable Name	Calculation Method	Code
CSI 300 Spot Price	The logarithmic rate of return on the closing price of the CSI 300 (%)	S
CSI 300 Futures Price	Logarithmic rate of return of the closing price of the CSI 300 stock index futures contract (%)	F

4.2 Descriptive Statistical Analysis

The descriptive statistics of the model are as Table 2, presenting the statistical indicators of the log returns of the CSI 300 spot and futures prices respectively. In perspective of these indicators, the mean of CSI 300 index log return is -0.001 and the median is 0.050, while the mean of CSI 300 futures price is -0.001 and the median is 0.025. On the whole, the median CSI 300 futures return is lower than the average of spot return and there is also significant difference compared to the maximum and minimum values. Obviously, the standard deviation of the futures series (1.409) is higher than that of the spot series (1.317), but the mean of both is close to -0.001, which indicates that the CSI 300 spot and futures prices may converge to a stable level in the long run, but there is a volatility difference in the short term.

Table 2: Descriptive statistical analysis

	S	F
Mean	-0.001	-0.001
Median	0.050	0.025
Maximum	5.513	7.158
Minimum	-8.209	-10.636
Std. Dev.	1.317	1.409
Skewness	-0.649	-0.760
Kurtosis	6.440	9.965

Figure 1 presents the trend of CSI 300 stock index futures and spot prices. It can be seen that the two trends are very close, showing nearly the same trend in 2020-2022. It indicates that CSI 300 stock index futures may have a strong predictive ability for the spot price. Meanwhile, the correlation coefficient analysis demonstrates that the two logarithmic returns have a strong correlation, with the correlation coefficient of 0.952, as shown in Figure 2.

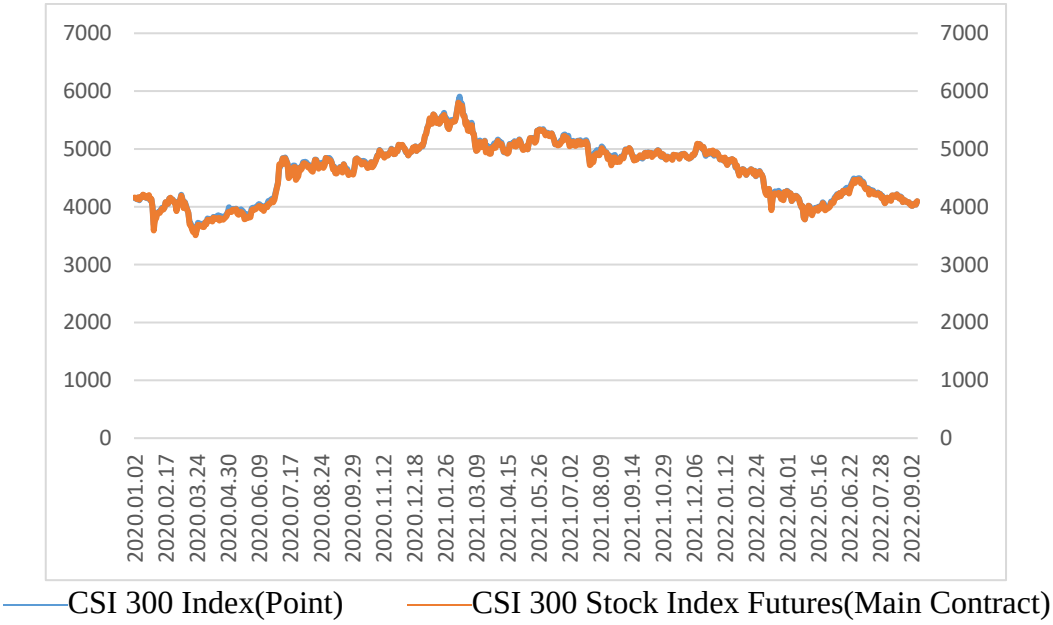

Figure 1: CSI 300 Futures and Spot Prices

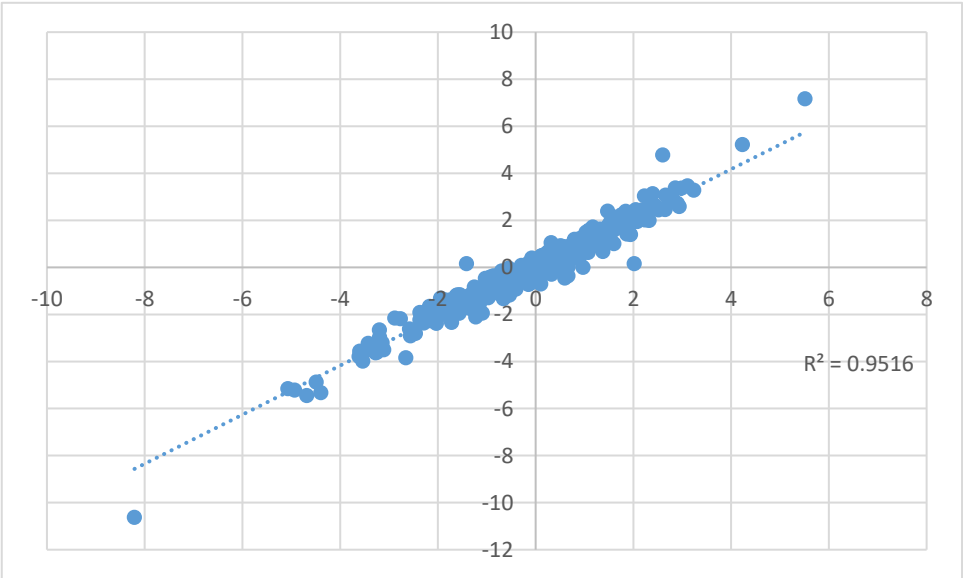

Figure 2: Correlation coefficient between CSI 300 futures and spot

4.3 Stationarity Analysis

In the next step, the ADF test is used to further examine whether there is a unit root in the CSI 300 spot and futures prices, which is the major approach to prevent spurious regressions. Therefore, both series are obtained as smooth series by the unit root test, indicating that the log returns of CSI 300 spot and futures prices can be analyzed directly in time series. Specific results can be seen in Table 3 and Table 4.

Table 3: ADF test of CSI 300 spot price

Augmented Dickey-Fuller test statistic	t-Statistic	Prob.*
Test critical values:	-25.413	0.000
1% level	-3.440	
5% level	-2.866	
10% level	-2.569	

Table 4: ADF test of CSI 300 futures prices

Augmented Dickey-Fuller test statistic Test critical values:	t-Statistic	Prob.*
	-26.169	0.000
1% level	-3.440	
5% level	-2.866	
10% level	-2.569	

4.4 Vector Autoregression Analysis

4.4.1 Optimal Lag Order Test

In the test of the stock index futures price discovery model, the first step is to identify the lag order P. The optimal order model ensures that the error of the model can be reduced, which can refer to the statistical test of the Akaike Information Criterion (AIC). By comparing AIC statistics of each lag order model, it can be obtained that the AIC statistic with a lag of 6 orders is 3.671, reaching the minimum. What's more, most of the other reference statistical indicators also reach a minimum at the lag of 6 orders, indicating that the VAR (6) model of CSI 300 futures price and spot price can be formulated. Final results can be seen in Table 5.

Table 5: Optimal lag order test

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-1228.276	NA	0.167	3.887	3.901	3.893
1	-1178.139	99.798	0.145	3.741	3.784*	3.758
2	-1165.626	24.828	0.141	3.714	3.785	3.742
3	-1160.430	10.277	0.140	3.711	3.809	3.749
4	-1153.947	12.782	0.139	3.703	3.829	3.752
5	-1142.974	21.565	0.136	3.681	3.835	3.741*
6	-1135.785	14.083*	0.135*	3.671*	3.854	3.742
7	-1134.836	1.853	0.136	3.680	3.891	3.762
8	-1133.532	2.537	0.137	3.689	3.928	3.782
9	-1129.074	8.649	0.137	3.687	3.955	3.791
10	-1126.394	5.183	0.138	3.692	3.987	3.806

4.4.2 Vector Autoregressive Model Analysis

Table 6 presents the output results of VAR(6) model between CSI 300 futures and spot prices. In this paper, the impact relationship is visualized through impulse response plots in the latter part according to the analytical approach of previous scholars. In the inverse AR root test, as shown in Figure 3, all vector dots are within the unit circle, reflecting the stability of the model residuals. In the CSI 300 spot price model, the coefficient of the 5-period futures price lag is 0.535, passing the 1% significance level, but the other coefficients are not significant, which suggests that the information presented by the CSI 300 futures price is ahead of the spot market by 5 trading days. To a certain extent, this also indicates that the CSI 300 futures price can impact the spot price change in the same direction. In addition, in the model in which the dependent variable is CSI 300 futures, the coefficient of the spot price lag 1 period is 0.469, which passes the 5% significance level, indicating that the CSI 300 spot price also has an impact on the futures price, which reflects that there may be a mutual influence relationship between the two.

Table 6: Vector Autoregressive Tests

Variable	Dependent variable: CSI 300 Spot (S)			Dependent variable: CSI 300 Futures (F)		
	Coefficient	Standard deviation	t-statistic	Coefficient	Standard deviation	t-statistic
S(-1)	-0.067	0.203	-0.332	0.469	0.217	2.160
S(-2)	-0.039	0.222	-0.176	0.302	0.238	1.270
S(-3)	-0.233	0.226	-1.030	0.015	0.242	0.063
S(-4)	-0.289	0.226	-1.281	-0.048	0.242	-0.200
S(-5)	-0.563	0.221	-2.544	-0.360	0.237	-1.520
S(-6)	-0.204	0.201	-1.019	-0.070	0.214	-0.328
F(-1)	0.070	0.190	0.369	-0.458	0.203	-2.253
F(-2)	0.030	0.211	0.144	-0.307	0.225	-1.362
F(-3)	0.222	0.215	1.032	-0.025	0.230	-0.109
F(-4)	0.255	0.215	1.186	0.016	0.230	0.071
F(-5)	0.535	0.211	2.543	0.342	0.225	1.521
F(-6)	0.190	0.190	1.000	0.073	0.203	0.361
C	0.010	0.052	0.186	0.010	0.056	0.183
R-squared	0.412			0.416		
Adj. R-squared	0.307			0.302		
Sum sq. resids	1089.390			1245.664		
S.E. equation	1.317			1.408		
F-statistic	2.654			2.878		
Log likelihood	-1079.515			-1122.478		
Akaike AIC	3.409			3.543		
Schwarz SC	3.499			3.633		
Mean dependent	0.011			0.011		
S.D. dependent	1.313			1.407		

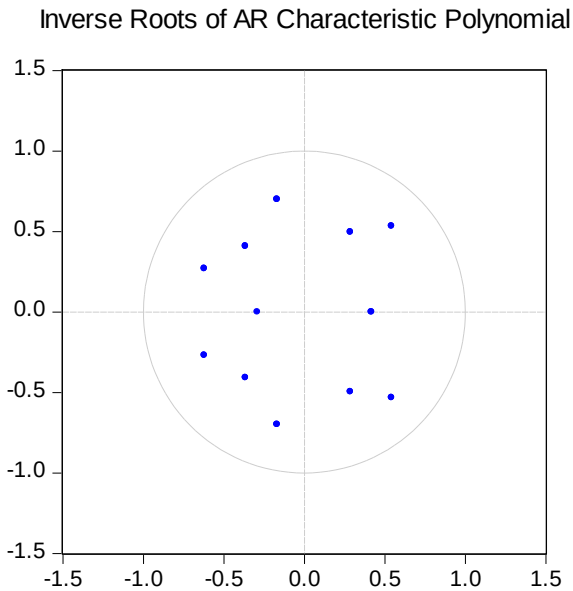

Figure 3: Inverse AR root test

4.4.3 Granger Causality Test

The Granger causality test model helps to test whether the two groups of time series have statistical sequential correlation, that is, the ability of the two groups to explain each other. As shown in Table 7, in the hypothesis test, the P value of the original hypothesis "CSI 300 futures

price is not the Granger cause of the spot price" is 0.755, which fails the 10% significance level and negates the price discovery effect of CSI 300. The reason is that the historical futures price changes do not contribute to the interpretation of spot price changes. In contrast, the original hypothesis "the CSI 300 spot price is not the Granger reason for the futures price" has a P value of 0.035, passing the 5% significance level, which indicates that the CSI 300 spot price can guide the changes in the futures price index. Therefore, the results show that there is a one-way Granger causality between the CSI 300 futures price and the spot price.

Table 7: Granger Causality Test

Null hypothesis	Obs	F-Statistic	Prob.
The CSI 300 futures price is not the Granger cause of the spot price	649	0.281	0.755
The CSI 300 spot price is not the Granger reason for the futures price		3.373	0.035

4.4.4 Impulse Response Graph Analysis

Impulse response graphs can depict how a change in one variable in a time series model will be followed by a change in another variable over time. In the following graph, the blue line represents the mean effect, and the red dashed lines represent the upper and lower bounds of the mean effect at the 95% confidence interval. Figure 4 shows that when there is an external shock of 1 unit in the logarithmic return of CSI 300 futures, there is no obvious shock effect within 1-5 trading days, but there is a significant impact on the 6th trading day. Afterwards, the impact effect stabilizes over time and makes no further growth, which indicates that the price change of CSI 300 futures will have an impact on the spot price with a lag of 5-6 periods, but this impact will not be significant until the 6th trading day.

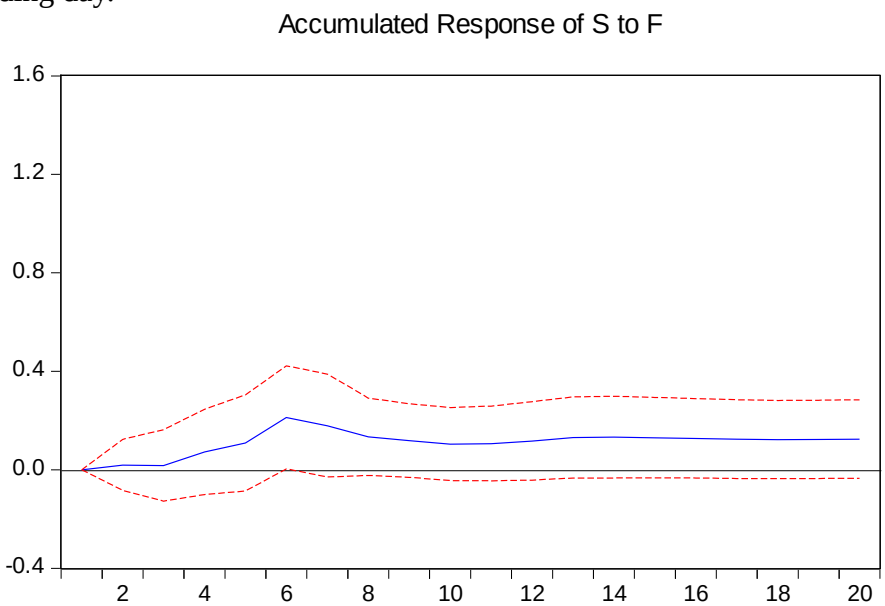

Figure 4: Impact Curve of Futures Price to Spot Price

In the impact curve of spot price to futures price, as shown in Figure 5, a more stable impact relationship can be noted. Because there is an obvious same-trend feedback in futures prices returns in Period 1, with an effect of about 1.38 units. This impact effect does not expand over time, but contracts slightly to the zero area,which means that the spot price in the CSI 300 market has an impact on the futures market, and the price information generated by spot trading may be ahead of the futures market.

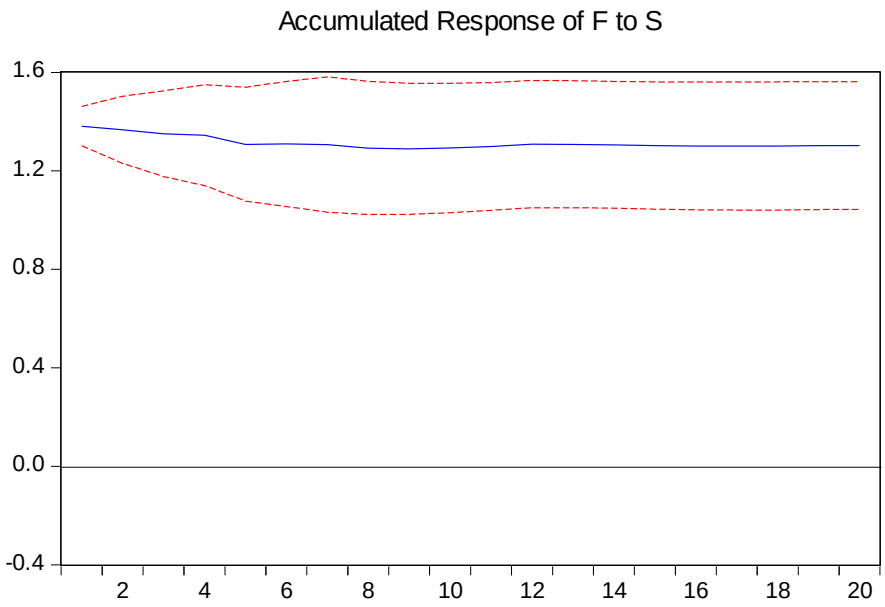

Figure 5: Impact Curve of Spot Price to Futures Price

4.4.5 Variance Decomposition

Next, by further examining the contribution levels of the historical CSI 300 spot and futures prices to each other's series respectively, it is not difficult to find from Table 8 that the CSI 300 spot yield is more explained by its own historical data, and the futures index explains no more than 1.088%, indicating that the changes in the CSI 300 spot price are hardly contributed by the futures price information. In contrast, when the dependent variable is CSI 300 futures, the historical data of CSI 300 futures makes no significant contribution, and the contribution level of spot prices is consistently higher than 94%, which further shows that China's CSI 300 spot price determines the futures price changes, and the price discovery function of futures is not obvious.

Table 8: Variance Decomposition of CSI 300 Spot Price Model

Period	Dependent variable: CSI 300 Spot (S)			Dependent variable: CSI 300 Futures (F)		
	S.E.	LOG(S)	LOG(F)	S.E.	LOG(S)	LOG(F)
1	1.317	100.000	0.000	1.408	96.219	3.781
2	1.317	99.979	0.021	1.414	95.463	4.537
3	1.317	99.979	0.021	1.414	95.449	4.551
4	1.318	99.804	0.196	1.415	95.354	4.646
5	1.319	99.727	0.273	1.416	95.341	4.659
6	1.323	99.116	0.884	1.419	94.840	5.160
7	1.324	99.053	0.947	1.419	94.814	5.186
8	1.325	98.936	1.064	1.420	94.790	5.210
9	1.325	98.923	1.077	1.420	94.767	5.233
10	1.325	98.912	1.088	1.420	94.757	5.243

5. Conclusions and Suggestions

5.1 Research Conclusions

In this paper, the daily time series data of CSI 300 stock index futures from 2020-2022 are selected to examine whether stock index futures have a price discovery effect on the spot market after the Covid-19 epidemic. Through the empirical research, it is found that the return of the CSI 300 spot price index is the Granger cause of the return of the futures price index, and CSI 300 spot price index returns have a significant positive impact on futures price index returns, on which the

impact does not have a lagged effect but immediate shock. In addition, the CSI 300 spot price index returns can explain the changes in the futures price index returns well, but the futures price index returns cannot explain the spot, which also suggests that the price discovery effect is not significant. The possible reason for such result is that there are not many participants in China's stock index futures market, in which the market influence of trading capital scale is far less than that of the spot market, and the volatility of stock index futures prices is also greater. Therefore, the spot market traders would not refer to the stock index futures price of CSI 300, and the stock index futures trading price would rather follow the spot market price and adjust.

On the other hand, this may also be accounted for by the fact that the market mechanism of China's stock market is still imperfect, and there are a large number of irrational retail investors, resulting in market chaos such as speculation, opportunism and follow suit. When the spot market price is regulated, the spot market fluctuations are also constrained, and the mechanism of futures market information transmission to the spot market cannot be fully played.

5.2 Research Suggestions

At present, the CSI 300 stock index futures in China still have no significant price discovery effect, and the price fluctuations are more easily influenced by the spot market, so the CSI 300 stock index futures may either follow the spot market sentiment and sell short or bearish, without leading market information itself, which is why the CSI 300 stock index futures cannot be used as the basis for theoretical price judgment in the spot market.

In other words, it reflects that the stock index derivatives market in China is still not mature enough for individual investors to participate in derivatives trading. It is still necessary to develop more index derivatives in the market planning, and can develop new derivatives corresponding to different industry indices, such as American options and odd options contracts, so as to boost the capital scale of the futures market and enable the futures market to influence the spot market.

References

[1] Kim S, Joon Kim I, Oh Nam S. The Lead-Lag Relationship Between Stock Index Options and The Stock Index Market[J]. International Journal of Managerial Finance, 2009, 5(3):311-332.

[2] Lien D, Shrestha K. A New Information Share Measure[J]. The journal of futures markets, 2009, 29(4):377-395.

[3] Gupta A, Varma P. Impact of Futures Trading on Spot Markets: An Empirical Analysis of Rubber in India[J]. Eastern Economic Journal, 2016, 42(3):373-386.

[4] Christoph, Schmidhammer, Sebastian, et al. The Day The Index Rose 11 %: A Clinical Study on Price Discovery Reversal[J]. Review of Quantitative Finance&Accounting, 2016.

[5] Frijns B, Tourani-Rad A, Webb R I. On the Intraday Relation Between the VIX and its Futures[J]. Journal of Futures Markets, 2015:171-187.

[6] Ivanov S I, Jones F J, Zaima J K. Analysis of DJIA, S&P 500, S&P 400, NASDAQ 100 and Russell 2000 ETFs and their influence on price discovery[J]. Global Finance Journal, 2013, 24(3):171-187.

[7] O'Neill, Michael, J, et al. Tail Wags Dog: Intraday Price Discovery in VIX Markets[J]. The journal of futures markets, 2017.

[8] Zhang Xiaobin, Chu Kairong. A Comparative Study on the Price Discovery Efficiency of CSI 300 Index and FTSE A50 Index [J]. Price Theory and Practice, 2012(9):70-71.

[9] Tao Libin, Pan Wanbin, Huang Junzhe. Changes in CSI 300 Stock Index Futures Price Discovery Ability and Its Determinants [J]. Financial Research, 2014(4):128-142.

[10] Liu Ximin. Research on the Price Discovery Function of Stock Index Futures under Abnormal Stock Market Volatility[J]. China Economic and Trade Tribune, 2016(35).

[11] Song Keyan. Research on the Guiding Relationship between China's Stock Index Futures and Index Spot Prices—Analysis Based on Asymmetric Threshold Cointegration Model [J]. Research on Financial Issues (9): 57-63.

[12] Yang Lin, Yang Yaru. Are Stock Index Futures The "Behind The Scenes" of The Stock Market Crash--Empirical Analysis based on High-Frequency Data of CSI 300 Stock Index Futures during the Stock Market Crash in 2015 [J]. Financial Theory and Practice, 2017(3).

[13] Wei Jianguo, Li Xiaoxue. A Comparative Study on the Price Discovery Function of China's Three Major Stock Index Futures based on the VECM-PT-IS model [J]. Journal of Wuhan University of Technology (Social Science Edition), 2016, 29(3):354- 360.

[14] Li Zheng, Bu Lin, Hao Yi. Re-discussion on the Price Discovery Function of China's Stock Index Futures: Empirical Evidence from Three Listed Varieties [J]. Finance and Trade Economics (7th issue): 79-93.

[15] Chen Qian. Research on the Price Discovery Function of China's Stock Index Futures [D]. China Economic and Trade Tribune, 2017, 18, 69-85.