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Correlation Analysis between the Futures Price and Spot Price of the CSI 300 Stock Index in China

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Abstract. The introduction of stock index futures meets investors' needs for diversified investments and enhances the diversity of China's investment market. With the development of stock index futures, investors are increasingly focusing on the correlation between spot and futures prices. This paper employs a 4-lag VAR model, Granger causality tests, and other methods, utilizing daily data of China's CSI 300 stock index futures and spot prices from January 4, 2002, to June 14, 2024, to analyze their interrelationship. The results indicate a stable long-term relationship between the CSI 300 index futures and spot prices, and confirm that the CSI 300 index futures price possesses a price discovery function.

Keywords: CSI 300 Index; Stock Index Futures; Correlation; Price Discovery.

1. Introduction

Since their inception, stock index futures contracts have gained widespread popularity among investors, who prefer using them for risk hedging. Compared to mature international markets, China's stock index market is still in its nascent stages of development, with relevant laws and regulations under exploration, leading to significant stock price volatility. The primary economic functions of stock index futures are to help investors hedge risks and allocate assets efficiently, thereby filling the gap in short-selling mechanisms within China's securities market. With the rapid development of the financial economy, financial institutions' products and services are widely applied across various industries, but this also accompanies substantial risks, causing significant losses for some investors. Consequently, risk prevention and control naturally become a central focus of financial work. Following the launch of stock index futures in the Chinese market, numerous experts have conducted extensive research. Most findings suggest that CSI 300 stock index futures reduce the volatility of the underlying spot market. However, between June and August 2015, the Shanghai Composite Index recorded its largest decline in seven years, which, to some extent, cast doubt on the volatility-reducing effect of stock index futures. Subsequently, some experts argued that stock index futures exacerbated spot market volatility. Although regulatory authorities have strengthened controls over stock index futures, analyzing the correlation between futures and spot prices remains highly significant.

2. Literature Review

Stock index futures were first introduced in the United States, prompting researchers to explore the relationship between futures and spot markets. They found that, in the short term, futures prices tend to lead spot index movements. Building on this, Granger (1981) first proposed the Co-Integration method, which later became widely used to test for long-run equilibrium relationships between two time series, effectively helping researchers ascertain the link between futures and spot prices. Kawaller et al. (1987) selected trading data from different markets to study price discovery capability. By comparing the responsiveness of S&P 500 futures and spot prices to information, they found that futures prices possess a stronger price discovery capability than spot prices, indicating higher sensitivity to information and lower reaction efficiency in the spot market. Furthermore, Tse (1995), using S&P 500 index market data and combining cointegration and error correction models, further confirmed a long-run cointegrating relationship between futures and spot prices, with the futures market exerting a significant short-term influence on the spot market. Booth et al. (1999) also supported this conclusion, noting that in financial index derivatives, futures price changes typically lead spot price fluctuations, while spot prices also influence futures prices to some extent. Numerous factors affect the price discovery function of stock index futures, including market transaction costs, investor structure, and market liquidity. Bohl (2011), analyzing data from the Warsaw Exchange, found that market investor structure significantly impacts the price discovery function of futures. Specifically, when institutional investors dominate trading, futures prices react more efficiently to information changes, enhancing price discovery; conversely, when retail investors constitute a larger proportion, the reaction efficiency of futures prices to market information decreases significantly. However, some scholars hold contrasting views. For instance, Yang et al. (2012), based on prices since the launch of CSI 300 stock index futures and using a GARCH model, concluded contrary to most preceding studies, suggesting that the futures market's price discovery function is not significant. This indicates ongoing debate regarding the price discovery capability of futures. Chen Rong and Zheng Zhenlong (2008), through an extensive literature review, identified potential misconceptions in futures and spot price research and theoretically discussed their validity. They concluded that the correlation between futures prices and market volatility is weak, making futures prices poor unbiased predictors of future spot prices. Moreover, futures market efficiency depends not solely on a single metric but encompasses various aspects like pricing efficiency and informational efficiency; thus, evaluating futures market efficiency cannot rely simplistically on one test standard. Li Haohua et al. (2018), constructing a Lead-Lag network for stock index futures and spots, found a definite correlation between futures and spot prices, with futures exhibiting significant price discovery functionality. However, in the same year, Mu Hui and Yuan Shengxuan (2018), using daily and 5-minute high-frequency data for the CSI 500 and SSE 50 indices and conducting regression analysis after excluding abnormal spot market fluctuations, found that stock index futures were not the primary driver of stock market volatility. Their GARCH model results showed minimal impact of futures on spot market volatility, suggesting that futures development must account for potential coincidental events. Sun Xinxin (2018), using 5-minute high-frequency trading data for CSI 300 stock index futures and spots to construct jump indicators, found that both markets autonomously adjust to reach equilibrium but found no Granger causality between them. Tian Bing et al. (2019) applied a BEKK-GARCH model to analyze the spillover effects between the "Baidu Index" and CSI 300 stock index futures/stock returns, revealing bidirectional volatility spillovers between futures and spots. Zhou Liang (2019) used a Difference-in-Differences model to examine the impact of stock index futures introduction on spot index volatility, dividing it into long-term and short-term effects: long-term introduction somewhat reduces spot volatility, while short-term effects are insignificant. Other scholars also found strong bidirectional volatility spillovers between CSI 300 futures and spots even around periods of deep discount, with the futures market often dominating this spillover effect (Zhang Xiaofeng and Guo Liyang, 2020). Chen Qi'an et al. (2020), using a GARCH model for empirical analysis, verified the positive role of CSI 300 stock index futures in reducing volatility in the Chinese stock market. Li Yanjun and Lin Xuerui (2021), by setting control and sample groups and employing multiple models, analyzed influencing factors between CSI 300 futures and spots, focusing on micro factors like stock market liquidity and uncertainty, as well as potential extreme events.

Domestic and international literature underscores the significant research value of studying stock index futures. Based on this, this paper takes China's CSI 300 stock index futures and spot prices as its research object, employing methods such as lag-4 VAR model analysis and Granger causality tests for empirical investigation, aiming to provide relevant suggestions for the development of China's stock index futures market and thereby promote the development of its financial markets.

3. Theoretical Analysis

3.1. Conceptual Definition of CSI 300 Stock Index Futures and Spot

Stock Price Index Futures (SPIF), abbreviated as stock index futures, are standardized contracts with a stock market index as the underlying asset. The CSI 300 Index is compiled by comprehensively ranking over 4,000 stocks from the Shanghai and Shenzhen stock exchanges based on average daily turnover and average daily market capitalization, selecting the top 300 stocks as the constituent sample. The total market capitalization of the CSI 300 Index represents approximately half of the combined market cap of the Shanghai and Shenzhen stock exchanges, broadly representing the performance of large-cap stocks. Furthermore, the weight distribution of the CSI 300 Index is relatively dispersed, making it less susceptible to manipulation.

3.2. Primary Functions of Stock Index Futures

The first function of stock index futures is risk hedging.

When investors anticipate a market decline or hold a bearish outlook, they can avoid liquidating their stock holdings by utilizing the hedging function of stock index futures. By taking short positions on the same or similar underlying assets in the futures market, they can lock in current profits and mitigate panic about potential market downturns. This practice addresses the previous absence of short-selling mechanisms in the stock market.

The second function is the potential reduction of stock market volatility. For instance, in the five years preceding the introduction of stock index futures, the average daily amplitude of the CSI 300 Index was 2.51%. In the five years following their introduction, the average daily amplitude decreased to 1.95%. Similarly, the average monthly amplitude also declined from 14.9% to 10.7%. The significant decrease in both metrics suggests, to some extent, that the emergence of stock index futures can curb irrational fluctuations in the stock market, as reflected by changes in the daily and monthly amplitude of the stock index.

The third function is the enrichment of investment strategies. The advent of stock index futures filled the void of short-selling in the stock market, providing investors with risk hedging tools. This not only offers diversified investment choices but also mitigates the phenomenon of singular trading strategies in the stock market.

3.3. Factors Influencing Stock Index Futures and Spot Prices

The stock index reflects the overall movement of stock prices. Determining stock pricing is complex because a company's intrinsic value and operational status are often unknown and difficult for investors to ascertain precisely. Investors optimistic about a company or the market will buy stocks, while pessimistic investors will sell. When buying volume exceeds selling volume, stock prices rise; conversely, when selling volume exceeds buying volume, prices fall. Therefore, stock prices generally fluctuate in line with their intrinsic value, but discrepancies can occur. Investors typically seek stocks whose intrinsic value exceeds their market price (undervalued stocks) for investment, aiming to obtain certain investment returns.

Macroeconomic conditions are another influencing factor. Under favorable macroeconomic conditions, most market participants tend to exhibit optimism. Consequently, the stock price index often shows an upward trend. Conversely, when macroeconomic conditions deteriorate, the stock price index tends to decline. Additionally, the stock price index to some extent reflects the production and operating conditions of enterprises, which in turn are closely related to the stock index. Improving corporate performance typically boosts corporate profits and elevates the stock price index. Conversely, deteriorating corporate performance reduces profits and restrains the rise of the stock price index. This aligns with the stock market's function as an "economic barometer."

Generally, interest rates and stock prices exhibit an inverse relationship. When interest rates fall, the returns on deposits and bonds decrease, prompting investors to shift towards higher-yielding assets like stocks. This increases capital inflows into the stock market, enhances market liquidity, and naturally pushes the stock price index upward.

Monetary policy is another cause of stock price index fluctuations. To adjust industrial structure or advance market-oriented economic reforms, governments often implement policies targeting specific industries or regions, such as adjusting interest rates or lowering reserve requirement ratios. These policies can impact the overall macroeconomy or specific economic sectors, thereby influencing the trends of constituent stocks of the CSI 300 Index or other individual stocks.

4. Empirical Analysis of CSI 300 Futures and Spot Prices

4.1. Model Specification and Data Selection

The trading hours for CSI 300 stock index futures are 9:30–11:30 and 13:00–15:00. Literature review indicates that higher frequency data sampling can amplify market microstructure noise (Zhang L et al., 2005). Simultaneously, to ensure sufficient sample size and estimation accuracy, using daily frequency data for CSI 300 index futures and spot prices is a reasonable choice. Therefore, this study selects daily data for China's CSI 300 index futures and spot prices from January 4, 2002, to June 14, 2024, totaling 5,445 observations. Data is sourced from the Wind database. The model is specified as $Y_t = \alpha + \beta_1 X1_t + \varepsilon_t$. Table 1 defines the main variables, and Table 2 presents descriptive statistics for the two variables: CSI 300 index futures (lnhsqh) and spot prices (lnhsxp).

Table 1. Variable Definitions

Variable	Definition
Y_t	Dependent variable, lnhsxp, natural log of CSI 300 spot closing price
$X1_t$	Core explanatory variable, lnhsqp, natural log of CSI 300 futures closing price

Table 2. Descriptive Statistics

Variable	N	Mean	p50	SD	Min	Max
lnhsxp	2344	8.261	8.252	0.153	7.770	8.667
lnhsqp	2344	8.258	8.248	0.154	7.775	8.666

4.2. Stationarity Test

Often, two time series exhibit similar trends without a genuine economic relationship. Regressing such series might yield a good fit, misleadingly suggesting a high correlation, a phenomenon known as "spurious regression." To avoid this, stationarity tests are conducted on the time series before model building to determine if a long-run equilibrium relationship truly exists. This paper employs the Augmented Dickey-Fuller (ADF) test, a unit root test, on the natural logarithm series of the CSI 300 index, lnhsqh and lnhsxp. Specific test results are shown in Table 3.

Table 3. Stationarity Test Results (ADF Test p-values)

Variable	ADF Test (p-value)
lnhsxp	0.0126
lnhsqp	0.0093

The ADF test p-values are both less than 0.05, rejecting the null hypothesis of a unit root at the 95% significance level. This indicates that the variables are stationary, containing no unit root. Therefore, the data used are integrated of the same order, permitting further empirical analysis.

4.3. Ranger Causality Test

The Granger causality test results for the daily CSI 300 index futures and spot price data from January 4, 2002, to June 14, 2024, are shown in Table 4. The p-values for both directions are less than 0.01, indicating that CSI 300 index futures and spot prices are Granger causes of each other.

Table 4. Grang er Causality Test Results

Equation	Excluded	chi2	df	Prob>chi2
lnhsxp	lnhsqp	42.223	4	0.000
lnhsxp	ALL	42.223	4	0.000
lnhsqp	lnhsxp	51.58	4	0.000
lnhsqp	ALL	51.58	4	0.000

4.4. Empirical Regression Results

Regression was performed on the time series data, with results shown in Table 5.

Table 5. Regression Results

	(1)
VARIABLES	lnhsxp
lnhsqp	0.989***
	(847.59)
Constant	0.097***
	(10.08)
Observations	2,344
R-squared	0.997

From the regression results, the model is highly significant at the 99% confidence level: the R-squared is approximately 0.997, indicating an excellent fit and accurately reflecting the explanatory variable's influence on the dependent variable. Thus, the final model is:

$$Y_t = 0.097 + 0.989X1_t$$

The coefficient for the core explanatory variable (lnhsqp) is 0.989, indicating that a one-unit increase in lnhsqp leads to a 0.989 unit increase in lnhsxp. This coefficient is very close to 1, suggesting a very strong positive correlation between spot and futures prices. The t-statistic is 847.59, and the p-value is less than 0.01, indicating the coefficient is statistically highly significant. The R-squared value of 0.997 shows that the model has extremely high explanatory power, accounting for 99.7% of the variation in the spot price. This implies the model fits the data exceptionally well, and changes in spot prices are almost entirely explainable by changes in futures prices.

Based on the regression results, futures prices (lnhsqp) have a strong explanatory power over spot prices (lnhsxp), indicating that the futures market plays a crucial role in the price discovery process of the spot market. The near-complete explanation of spot price changes by futures price changes suggests high efficiency in information transmission within the futures market, enabling it to quickly reflect market information and expectations.

Based on the above analysis, the following policy recommendations are proposed to further enhance the price discovery function of the spot market: Promote the development of the futures market: Enhance market liquidity and trading activity by introducing more market participants and diversifying trading products, thereby increasing the depth and breadth of the futures market Strengthen information transparency: Improve market information transparency, ensuring all participants have equal access to information through stringent disclosure requirements and enhanced supervision; Improve regulatory mechanisms: Regulatory bodies should strengthen oversight against market manipulation, ensuring market fairness and transparency, and protecting investor interests Enhance financial market infrastructure: Upgrade the technological infrastructure of trading and settlement systems to increase transaction speed and efficiency, reducing technical risks; Investor education and training: Intensify education and training for investors to improve their understanding and operational capabilities regarding futures and spot markets, thereby reducing irrational market fluctuations.

Through these policy measures, the guiding role of the futures market over the spot market can be further enhanced, strengthening the price discovery function of the spot market and promoting the healthy and stable development of financial markets.

4.5. Error Correction Model

As shown in the table, for Y (Δlnhsxp), when short-term deviations from equilibrium occur, the system corrects the disequilibrium back towards the long-run relationship with an adjustment coefficient of -0.2 per period. This indicates that while Y might experience short-term deviations due to various factors, a stable long-run equilibrium relationship exists, and the adjustment strength is relatively strong.

Table 6. Error Correction Model

	(1)
VARIABLES	D.lnhsxp
D.lnhsqp	0.828***
	(134.97)
L.e	-0.200***
	(-17.83)
Constant	0.000
	(0.33)
Observations	2,343
R-squared	0.887

4.6. VAR Model Construction

After the stationarity test, the optimal final order of the VAR model is determined. According to the information criterion, that is, when AIC and HQIC take the minimum value, the corresponding order is the optimal order. Then, based on the LR likelihood ratio test for comprehensive comparison and consideration, the order of the variable lag is determined to be the 4th order. Therefore, the VAR (4) model is established.

Table 7. Lag Order Selection Criteria

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	8850.65				1.80E-06	-7.56295	-7.56115	-7.55803
1	15579.9	13458	4	0	5.70E-09	-13.311	-13.3056	-13.2962
2	15611.9	64.031	4	0	5.50E-09	-13.335	-13.326	-13.3103
3	15631.2	38.658	4	0	5.50E-09	-13.3481	-13.3355	-13.3136
4	15711.8	161.13*	4	0	5.1e-09*	-13.4135*	-13.3974*	-13.3692*

Subsequently, the stability of the estimated VAR (4) model is tested, typically by examining the inverse roots of the associated characteristic autoregressive (AR) polynomial. The determination of VAR model stability requires assessing whether the moduli of all inverse roots are less than one. If all inverse root moduli are less than one, meaning all points lie within the unit circle in the corresponding graph, the model is considered stable. Conversely, if any inverse root modulus exceeds one, indicating points lie outside the unit circle, the model is unstable. As illustrated in the figure, all points are located inside the unit circle, confirming that all inverse root moduli are less than one. Therefore, the VAR model is stable, indicating a long-run stable relationship exists between the selected time series variables Y and X, thus permitting further analysis.

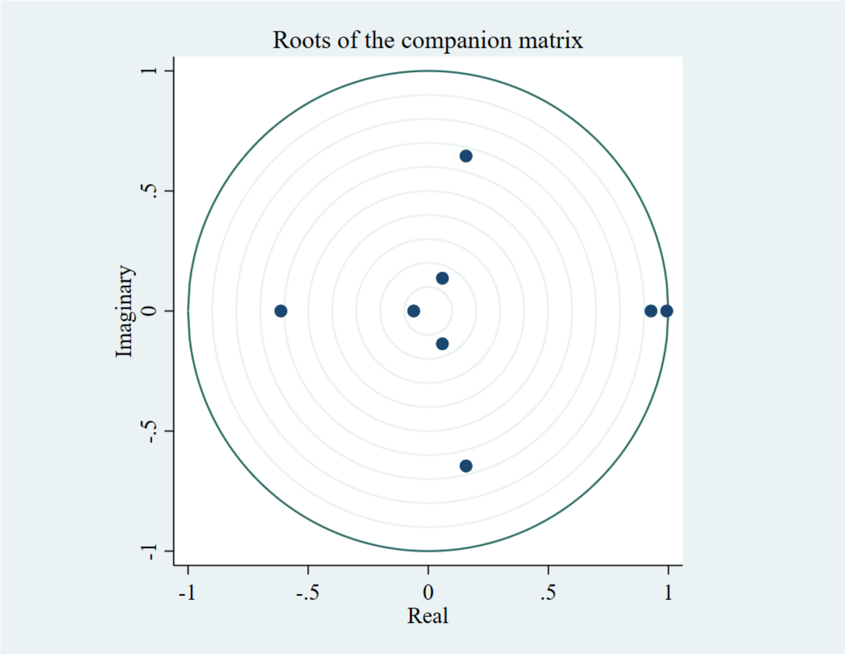

Figure 1. VAR model

4.7. Analysis of impulse response function

A detailed analysis of the impulse response functions for the CSI 300 spot and futures markets was conducted to explore the role of the futures market in the price discovery function of the spot market. By analyzing impulse responses over different time horizons, the dynamic relationship between spot and futures prices was examined, leading to a series of policy recommendations aimed at further strengthening the value discovery function of the futures market relative to the spot market.

As evidenced by the results presented in the figure, when the spot price experiences an autonomous shock, its response value peaks at period 0 (0.013888) and subsequently demonstrates a gradual decay, while persistently maintaining levels above 0.013 throughout the observed horizon. This pattern indicates strong persistence in the spot price's response to its own innovations, with the shock effect exhibiting progressive attenuation over time while remaining statistically significant.

The response of the spot price to futures price shocks reaches its maximum at period 0 (0.014837), followed by a systematic decline to 0.013924 by period 10. This suggests that futures price shocks exert an immediate and substantial influence on spot prices, with this impact gradually diminishing yet maintaining economic significance across the time horizon. Conversely, the response of futures prices to spot price innovations registers zero at period 0, then manifests a steady increase, attaining 0.001990 by period 10. Although the magnitude remains relatively modest, this progressively strengthening trajectory indicates that the futures market exerts a measurable influence on the spot market, with this effect becoming increasingly evident over time.

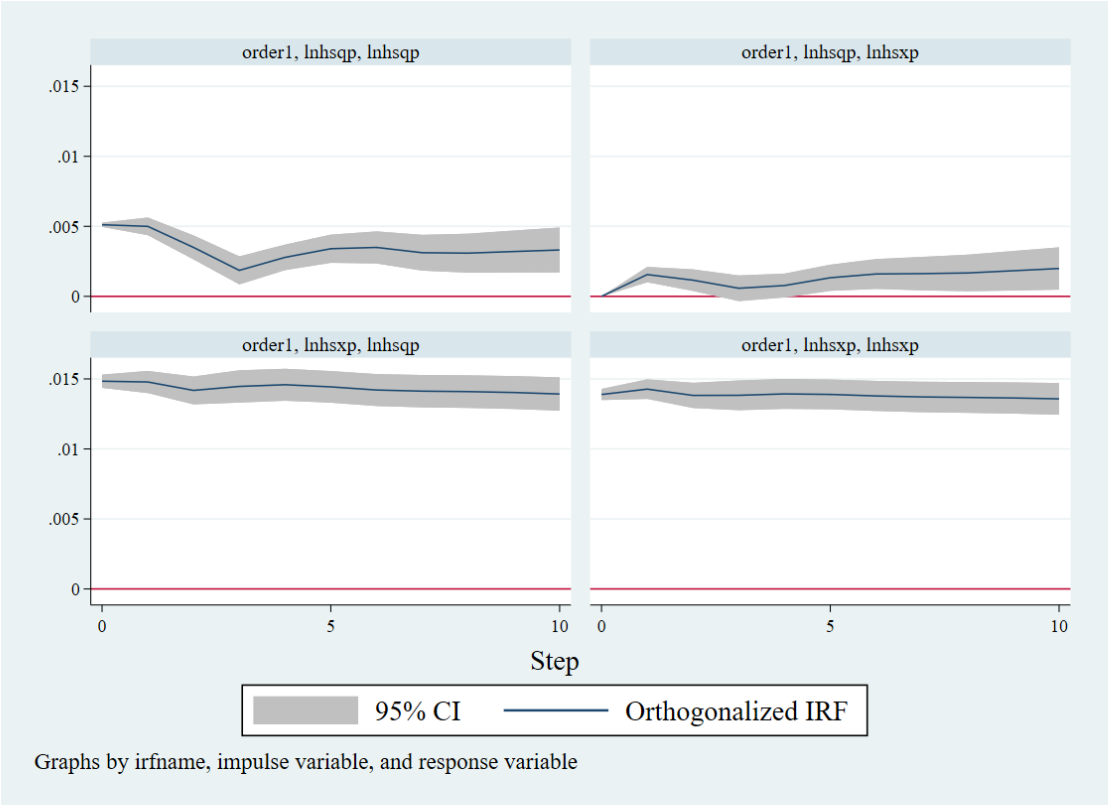

Figure 2. Impulse response function

The response of futures prices to their own shocks maximizes at period 0 (0.005115) and subsequently experiences consistent attenuation, declining to 0.003312 by period 10. This pattern reveals comparatively weaker persistence in futures price responses to autonomous innovations, with the shock effect demonstrating progressive dissipation throughout the time horizon. The pronounced and highly persistent response of spot prices to endogenous shocks suggests that price fluctuations in the spot market are predominantly driven by internal market mechanisms. These intrinsic factors potentially encompass market sentiment dynamics and supply-demand fundamentals. The substantial responsiveness of spot prices to futures market innovations indicates efficient information transmission and price signal propagation from futures to spot markets. As a sophisticated financial derivatives market, the futures market demonstrates enhanced price discovery capabilities, effectively incorporating market expectations and forward-looking price trends, thereby providing crucial reference value for spot market pricing. The initially limited but progressively strengthening response of futures prices to spot market shocks implies that the futures market's influence on spot prices remains constrained in the short term but becomes increasingly manifest over extended horizons. This phenomenon may be attributed to the futures market's heightened sensitivity to information flows, coupled with temporal requirements for complete information transmission to the spot market. The significant yet less persistent response of futures prices to their own innovations indicates that futures price volatility is substantially influenced by market-specific factors, though such influences demonstrate progressive decay over time.

Through rigorous analysis of impulse response functions for CSI 300 spot and futures markets, it becomes evident that the futures market contributes meaningfully to the price discovery mechanism in the spot market. The substantial responsiveness of spot prices to futures market innovations confirms the efficient transmission of information and price signals from futures to spot markets. However, the initially constrained but progressively intensifying response of futures prices to spot market shocks suggests that the futures market's influence, while potentially limited in immediate terms, becomes increasingly pronounced over extended periods. To further enhance the price discovery functionality of futures markets, implementation of comprehensive policy measures appears warranted to foster sustainable development and stability in financial markets.

4.8. Variance Decomposition

Variance decomposition analyzes the proportion of the forecast error variance for a variable attributable to shocks from itself and other variables at different time steps. Here, we analyze the decomposition for lnhsxp, considering shocks from itself (lnhsxp) and from lnhsqp.

Table 8. Variance Decomposition for lnhsxp

	(1)	(2)
Step	fevd	fevd
1	1	0
2	0.993929	0.006071
3	0.993637	0.006363
4	0.994767	0.005233
5	0.995195	0.004805
6	0.994486	0.005514
7	0.993393	0.006607
8	0.992507	0.007493
9	0.991722	0.008278
10	0.990806	0.009194

Short-term Analysis: At step 1, the spot price (lnhsxp) accounts for 100% of its own forecast error variance, with no contribution from futures prices. This indicates that initially, spot price fluctuations are entirely determined by its own shocks, with no immediate discernible impact from futures prices.

Medium-term Analysis: From step 2 onwards, the contribution of futures prices (lnhsqp) to the forecast error variance of spot prices begins to emerge, albeit small, and shows a gradual increase. For instance, at step 2, the contribution is 0.61%, rising to 0.66% by step 7. This increasing trend suggests that the influence of futures prices on spot prices becomes more apparent over time.

Long-term Analysis: As the time horizon extends, the contribution of futures prices to the forecast error variance of spot prices gradually increases, rising from 0.61% at step 2 to approximately 0.92% at step 10. Although the influence of futures prices grows, the vast majority of spot price variation (99.08% at step 10) is still explained by its own shocks, indicating that spot price movements remain predominantly driven by internal market factors.

The variance decomposition results indicate that the futures market has a limited impact on the spot market in the very short term, but this influence strengthens over a longer horizon. This suggests that the futures market possesses a certain degree of price discovery functionality, reflecting and transmitting partial market information, thereby exerting a guiding influence on price formation in the spot market. Through its price signals, the futures market reflects expectations about future prices and influences spot market price adjustments via information transmission mechanisms.

5. Summary

The empirical analysis demonstrates that the CSI 300 futures market plays a significant role in the price discovery process of the spot market. The futures market reflects market expectations regarding future price trends, rapidly incorporating information and transmitting it to the spot market. The spot market, in turn, adjusts its prices to reflect information from the futures market, thereby enhancing price discovery efficiency.

Volatility in the futures market also transmits to the spot market. Due to higher leverage and liquidity, futures prices can exhibit more pronounced fluctuations. When significant volatility occurs in the futures market, the spot market reacts swiftly, adjusting prices to incorporate the new information. This volatility transmission mechanism contributes to the market's overall price discovery function.

Information flow is a key factor in the interaction between futures and spot markets. The futures market typically reacts more quickly to macroeconomic data, policy changes, and international market movements. Through futures price changes, investors can access information earlier and make corresponding trading decisions in the spot market. This information flow mechanism further strengthens the guiding role of the futures market over the spot market.

Through empirical analysis of the relationship between the CSI 300 futures and spot markets, this paper finds that the futures market significantly promotes the price discovery process in the spot market. The futures market not only reflects expectations of future prices but also, through price signals and volatility transmission mechanisms, guides price adjustments in the spot market. Future research could further explore the effects of other factors, such as policy changes and international market influences, on the futures-spot relationship to gain a more comprehensive understanding of the role of futures markets in financial markets.

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