ISSN 2616-5902 Vol. 6, Issue 9: 97-104, DOI: 10.25236/AJBM.2024.060914

Study on the Dynamic Relationship between PVC Futures and Spot Prices Based on Vector Autoregression Model

Aihua Wang[1,a,*], Qian Zhang[1], Zhaoxuan Mao[2], Hongyan Zhuang[3]

[1]*College of Business and Economics, Shanghai Business School, Shanghai, China*
[2]*Shenzhen Diankuan Network Technology Co., Ltd., Shenzhen, China*
[3]*Hanshan Normal University, Chaozhou, China*
[a]*wah79127@163.com*
[*]*Corresponding author*

Abstract: *This study employs the Vector Autoregression (VAR) model to explore the dynamic relationship between Polyvinyl Chloride (PVC) futures and spot prices, aiming to reveal the characteristics of price volatility and the mechanism of information transmission between the futures and spot markets. The findings demonstrate a long-term equilibrium relationship between PVC futures and spot prices, with a bidirectional guiding influence. Notably, PVC futures prices exhibit a significant leading effect on the spot market, while the response of spot prices to futures market fluctuations is relatively slower. Finally, combining these findings, the study offers decision support recommendations for market participants, underscoring the importance of accurately understanding the interplay between futures and spot markets in effective market monitoring and risk control.*

Keywords: *Futures Prices, Price Discovery, Price Correlation, Spot Prices*

1. Introduction

In the global economic system, Polyvinyl Chloride (PVC), as an extremely important plastic raw material, plays an indispensable role in several key industries. Due to PVC's unique properties, it is widely used in manufacturing, particularly in fields such as construction, packaging, medical devices, and the automotive industry. Consequently, fluctuations in PVC prices directly affect the stability of the global supply chain and manufacturing costs, thereby having a profound impact on the overall economy. Therefore, a deep understanding of c dynamics between PVC futures and spot prices is crucial for predicting market trends, devising effective business strategies, and making rational resource allocations. Against this backdrop, this study utilizes the Vector Autoregression (VAR) model, aiming to provide a systematic analytical framework to more accurately interpret and predict the interactions and impacts between these two markets.

2. Literature Review

2.1. Research on the Dynamic Relationship between Futures and Spot Prices Research

Ma Zhengwei and Ma Yiqun (2021) [1] investigated the correlation between crude oil futures and polyvinyl chloride futures prices, concluding that there is not only a linear relationship but also a nonlinear relationship between crude oil futures and polyvinyl chloride futures prices. Chen Wenchao and Zhong Hao (2021) [2] studied the impact mechanism of stock index futures on the stock market, concluding that the price discovery function of the CSI 300 stock index futures is directly related to the extent of restrictions in the stock market.

Liu Junfeng (2004)[3] used cointegration theory to analyze the long-term equilibrium relationship between Chinese commodity futures markets and spot markets, using copper and hard wheat as examples, and found a cointegrative relationship between commodity futures market prices and spot market prices. Wang Keshan and Yu Jianbin (2008)[4] analyzed the transmissibility between U.S. soybean futures prices and spot prices, showing a significant long-term equilibrium relationship between the U.S. soybean futures market and spot market. Lu Ying (2013)[5] employed quantitative methods to analyze the

ISSN 2616-5902 Vol. 6, Issue 9: 97-104, DOI: 10.25236/AJBM.2024.060914

relationship between white sugar futures prices and spot prices, finding that white sugar futures prices influence spot prices, although the guidance of spot prices on futures prices is weak."

3. Data Processing and Model Selection

3.1. Data Processing

This paper selects historical data of polyvinyl chloride (PVC) from May 25, 2009, to September 1, 2023, as the study period. After removing data for non-trading days, there were still missing values in the current prices, which were filled using the average of the adjacent trading days' values, resulting in a total of 3,396 data points. For ease of subsequent analysis, the data were log-transformed. In this paper, PVC is used as the symbol for polyvinyl chloride, with 'lnpv' representing the logarithmic value of the spot prices, and 'lnpvc' representing the logarithmic value of the futures prices.

3.2. Model Selection

To analyze the dynamic relationships among various variables in detail, this paper selects the Vector Autoregression (VAR) model. The mathematical formula for the VAR model [6] is as follows.

$$\begin{pmatrix} y_{1t} \\ y_{2t} \\ \cdots \\ y_{kt} \end{pmatrix} = A1 \begin{pmatrix} y_{1\,t-1} \\ y_{2\,t-1} \\ \cdots \\ y_{k\,t-1} \end{pmatrix} + A2 \begin{pmatrix} y_{1\,t-2} \\ y_{2\,t-2} \\ \cdots \\ y_{k\,t-2} \end{pmatrix} + \cdots + B \begin{pmatrix} x_{1\,t} \\ X_{2\,t} \\ \cdots \\ x_{k\,t} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1\,t} \\ \varepsilon_{2\,t} \\ \cdots \\ \varepsilon_{k\,t} \end{pmatrix} \quad (1)$$

In the model, y_t is a vector of k endogenous variables, x_t is a vector of d exogenous variables, and ε is k-dimensional disturbance vector. These variables can be contemporaneously correlated with each other but are not correlated with their own lagged values.

4. Empirical Analysis of the Dynamic Relationship Between PVC Futures and Spot Prices

4.1. Stationarity Test

Table 1: ADF Unit Root Test Results for Futures Prices and Spot Prices.

		critical value			
sequence	ADF test statistic	1%	5%	10%	P value
lnpv	-2.818	-3.432	-2.862	-2.567	0.056
lnpvc	-2.393	-3.432	-2.862	-2.567	0.144
△lnpv	-20.092	-2.566	-1.941	-1.617	0.000
△lnpvc	-57.447	-2.566	-1.941	-1.617	0.000

In this paper, the ADF unit root test is employed to determine the stationarity of the series. Initially, the series are tested under three conditions: with a time trend and an intercept, with only an intercept, and without either. Based on the minimum criteria of AIC, SC, and HQ information criteria, the scenario with only an intercept is ultimately selected.

As shown in Table 1, the ADF test results indicate that after logarithmic transformation, the p-values of the data exceed 5%, leading to the acceptance of the null hypothesis that the series have a unit root, indicating non-stationarity. The series are then differenced once, and based on the minimum criteria of AIC, SC, and HQ information criteria, the condition without a trend and intercept is finally chosen. The results demonstrate that the first differences of the two series are stationary.

4.2. Construction of a VAR Model

The ADF unit root test results indicate that all original series are non-stationary. However, after first differencing, the p-values are 0, suggesting that all series are integrated of order one. The modeling and analysis are then conducted using the first-differenced series.

4.2.1. Determining the Lag Order

According to Table 2 and Table 3, the lag order of the VAR model is determined through the minimum criteria of AIC, SC, and HQ information criteria. The results indicate that the highest number of asterisks

ISSN 2616-5902 Vol. 6, Issue 9: 97-104, DOI: 10.25236/AJBM.2024.060914

occurs at lag 5, leading to the establishment of a VAR(5) model.

Table 2: VAR model lag order.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	21723.76	NA	9.22E-09	-12.82655	-12.82293	-12.82526
1	22118.5	788.781	7.32E-09	-13.05728	-13.04642	-13.0534
2	22153.73	70.34191	7.18E-09	-13.07572	-13.05763	-13.06925
3	22184.69	61.80264	7.07E-09	-13.09164	-13.06631	-13.08259
4	22202.62	35.762	7.01E-09	-13.09986	-13.06730*	-13.08822
5	22213.86	22.41299	6.98e-09*	-13.10414*	-13.06434	-13.08991*
6	22214.67	1.613021	7.00E-09	-13.10226	-13.05522	-13.08544
7	22219.76	10.12790*	6.99E-09	-13.1029	-13.04862	-13.0835
8	22223.3	7.053551	6.99E-09	-13.10263	-13.04112	-13.08064

Table 3: Empirical Results.

	DLNPV	DLPVC
DLNPV (-1)	0.145256	0.134555
DLNPV (-2)	-0.04202	0.011944
DLNPV (-3)	-0.025326	-0.073573
DLNPV (-4)	0.05035	0.105376
DLNPV (-5)	0.062716	0.072631
DLPVC (-1)	0.191331	-0.024933
DLPVC (-2)	0.09789	-0.004713
DLPVC (-3)	0.081102	0.011933
DLPVC (-4)	0.032965	0.003844
DLPVC (-5)	-0.00113	-0.051426
C	4.01E-06	-1.13E-05

4.2.2. Exogeneity Test

Dependent variable: DLPVC

Excluded	Chi-sq	df	Prob.
DLNPV	40.25521	5	0.0000
All	40.25521	5	0.0000

Dependent variable: DLNPV

Excluded	Chi-sq	df	Prob.
DLPVC	347.7471	5	0.0000
All	347.7471	5	0.0000

Figure 1: Exogeneity Test Results.

The Figure 1 results show that all p-values are less than 0.05, leading to the rejection of the null hypothesis. This indicates that futures prices have predictive power over spot prices and vice versa, implying that PVC futures prices and spot prices are endogenous variables to each other. Therefore, the VAR model is meaningful to implement.

4.2.3. Model Stability Assessment

The Table 4 results indicate that the highest unit root coefficient is 0.728075, which is less than 1, and all unit roots fall within the unit circle. This demonstrates that the model constructed for futures market prices and spot market prices is stable.

ISSN 2616-5902 Vol. 6, Issue 9: 97-104, DOI: 10.25236/AJBM.2024.060914

Table 4: AR Root Test.

Root	Modulus
0.728075	0.728075
0.167717 - 0.560124i	0.584695
0.167717 + 0.560124i	0.584695
0.396069 - 0.397883i	0.56141
0.396069 + 0.397883i	0.56141
-0.552757	0.552757
-0.184426 - 0.506277i	0.538822
-0.184426 + 0.506277i	0.538822
-0.406858 - 0.290043i	0.499658
-0.406858 + 0.290043i	0.499658

4.3. Cointegration Test

Following Figure 2 and Figure 3 shows the unit root tests and the process of constructing the VAR model, it was found that the PVC futures and spot price series are both integrated of order one, and the optimal lag order for the VAR model is 5, which meets the requirements for a cointegration test. To verify whether the two market prices have a long-term equilibrium relationship, this study employs the Johansen method to conduct a cointegration test on the futures and spot prices.

Based on the results, under the 'None' scenario, both the trace test and maximum eigenvalue test statistics exceed the critical values at the 5% significance level, and the p-values are less than 0.05. This leads to the rejection of the null hypotheses that no cointegration relationships exist. Therefore, it is concluded that there is a cointegration relationship between the logarithms of PVC futures prices (lnpv) and spot prices (lnpvc), indicating two cointegration relationships. This suggests a long-term equilibrium relationship exists between PVC futures and spot prices.

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.007812	33.39348	15.49471	0.0000
At most 1 *	0.002003	6.798533	3.841466	0.0091

Trace test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Figure 2: Trace Test Results.

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.007812	26.59495	14.26460	0.0004
At most 1 *	0.002003	6.798533	3.841466	0.0091

Max-eigenvalue test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Figure 3: Maximum Eigenvalue Test Results.

4.4. Establishing an Error Correction Model

Given the various random factors that may cause deviations from equilibrium in the short term, the ECM often makes continuous adjustments based on the direction and magnitude of the deviations to bring the variables back to equilibrium. Therefore, to establish an ECM for PVC futures prices and spot prices, the residuals can be used as the equilibrium error term, effectively linking the short-term and long-

ISSN 2616-5902 Vol. 6, Issue 9: 97-104, DOI: 10.25236/AJBM.2024.060914

term states of PVC futures and spot prices.

Table 5: Error Correction Model Test Results.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DLNPV	0.698527	0.024094	28.99171	0.0000
E(-1)	-0.025642	0.004264	-6.012859	0.0000

DLNPVC = 0.698527*DLNPV - 0.025642*E(-1)

$$R^2 = 0.199517 \qquad D.W = 2.251034$$

In the model, the dependent variable is the first-differenced futures price (DLNPVC), while the independent variables are the first-differenced spot price (DLNPV) and the lagged one-period residual term e(-1). The obtained p-value is 0, leading to the rejection of the null hypothesis, which indicates a significant linear relationship between futures prices and spot prices.

Specifically, this result suggests that changes in futures prices are closely related to changes in spot prices. Even when controlling for changes in spot prices, changes in futures prices still have predictive power, indicating that market participants' expectations of futures prices are influenced by spot prices. Additionally, the significance of the lagged one-period residual term suggests that the previous period's residuals (i.e., the unexplained part) have a significant impact on the current period's futures prices.

The above Table 5 test results show that the equation has an R of 0.199517, and the Durbin-Watson (D.W) value also indicates that there is no autocorrelation in the residual terms. The ECM error correction term coefficient is -0.025642, which aligns with the expected correction mechanism.

4.5. Granger Causality Test

Table 6: Granger causality test.

	Obs	F-Statistic	Prob.
DLNPV does not Granger Cause DLPVC	3390	8.0510	0.0000
DLPVC does not Granger Cause DLNPV		69.5494	0.0000

The Table 6 results indicate that when the null hypotheses are "Δlnpv is not a Granger cause of Δlnpvc" and "Δlnpvc is not a Granger cause of Δlnpv," the p-values are both less than 0.05. Thus, both null hypotheses are rejected, suggesting that PVC futures prices and spot prices have a bidirectional guidance relationship

4.6. Impulse Response

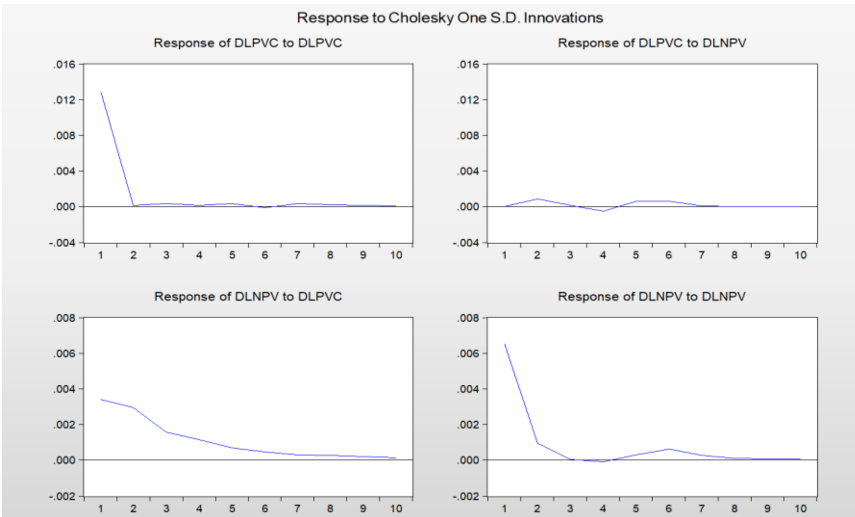

Figure 4: Impulse Effect Graph.

The above Figure 4 reveals that PVC futures prices impact themselves, with Δlnpvc generating an effect of 0.013 in the first lagged period, decreasing to zero in the second lagged period, followed by slight oscillations, and finally converging to zero by the eighth period. The impact of PVC futures prices on spot prices is zero in the first lagged period, increases in the second lagged period, and then tends to

ISSN 2616-5902 Vol. 6, Issue 9: 97-104, DOI: 10.25236/AJBM.2024.060914

converge after slight oscillations. The spot prices of PVC influence futures prices with an impact of approximately 0.004 in the first impulse period, with the effect gradually diminishing and stabilizing by the tenth period. Spot PVC prices also impact themselves, generating an impact greater than 0.006 in the first lagged period, decreasing thereafter, turning negative in the fourth lagged period, and finally converging to zero with slight oscillations by the eighth period.

4.7. Variance Decomposition

Table 7: Variance Decomposition of PVC Futures Prices.

Period	S.E.	DLPVC	DLNPV
1	0.0128	100.0000	0.0000
2	0.0128	99.5357	0.4643
3	0.0128	99.5159	0.4841
4	0.0129	99.3820	0.6180
5	0.0129	99.1470	0.8530
6	0.0129	98.9325	1.0675
7	0.0129	98.9279	1.0721
8	0.0129	98.9281	1.0719
9	0.0129	98.9276	1.0724
10	0.0129	98.9263	1.0737

Table 8: Variance Decomposition of PVC Spot Prices.

Period	S.E.	DLPVC	DLNPV
1	0.0073	21.6032	78.3968
2	0.0080	32.0176	67.9824
3	0.0081	34.5423	65.4577
4	0.0082	35.8061	64.1939
5	0.0082	36.2173	63.7827
6	0.0083	36.2291	63.7710
7	0.0083	36.2772	63.7228
8	0.0083	36.3303	63.6697
9	0.0083	36.3626	63.6374
10	0.0083	36.3801	63.6199

The Table 7 and Table 8 results show that as the number of periods increases, the variance contribution from the self-fluctuations of PVC futures prices gradually decreases, although the decline is slight, dropping from 100% to 98.93%. Conversely, the variance contribution from changes in spot prices gradually increases, but the magnitude of change is also small, rising from 0% to 1.075%.

For PVC spot prices, the variance contribution from their own changes shows a decreasing trend, with the contribution rate declining from 78.40% to 63.62%. In contrast, the contribution from changes in futures prices shows an increasing trend, with the contribution rate rising from 21.60% to 36.38%. These findings highlight how, over time, the interdependencies between futures and spot prices of PVC evolve, reflecting an increasing influence of futures price movements on spot price variations.

5. Empirical Results

First, the ADF unit root test showed that the first differences of the series are stationary. Subsequently, the VAR model was applied, and results indicated that a VAR (5) model was most suitable under a 5-lag order. The exogeneity test results demonstrated that futures and spot prices are endogenous variables, thus validating the use of the VAR model.

Second, the cointegration test revealed two cointegration relationships, suggesting a long-term equilibrium relationship between PVC futures and spot prices. An error correction model was established accordingly. The Granger causality test indicated a bidirectional guidance relationship between futures and spot prices.

Lastly, impulse response and variance decomposition analyses were conducted. The impulse response function tests showed that a standard deviation positive shock to spot PVC prices led to an initial impact of approximately 0.004 on futures prices, with the effect diminishing and stabilizing by the tenth period.

ISSN 2616-5902 Vol. 6, Issue 9: 97-104, DOI: 10.25236/AJBM.2024.060914

The shock results indicate that spot PVC prices in China have a positive guiding effect on futures prices. When spot PVC prices are impacted by external information, futures prices are positively influenced, quickly reaching a peak before gradually declining and stabilizing. The variance decomposition results reveal that PVC futures prices themselves play a dominant role in their formation, with a gradually decreasing contribution rate. The contribution of spot PVC prices to futures prices shows some lag, becoming apparent in the second period and gradually increasing thereafter.

6. Recommendations

6.1. Optimization and Improvement of Market Mechanisms

Regulatory bodies and market administrators should consider further optimizing market mechanisms based on the discovered cointegration relationships and Granger causality, to better reflect the impact of spot prices on the futures market. Specific measures include:

Policy support and subsidies: Given the bidirectional guidance relationship, governments or regulatory bodies could implement more flexible policy support measures, such as adjusting policies in response to spot price changes or providing temporary subsidies.

Flexible market intervention measures: Regulatory bodies could flexibly manage and intervene in the market, timely adjusting market rules or providing necessary guidance to maintain market stability.

Risk warning mechanisms: Establish mechanisms to promptly publish risk warnings and alerts, reminding market participants to be aware of market risk changes.

Stakeholder dialogue platforms: Create platforms for dialogue between governments, regulatory bodies, and market participants to strengthen communication, consider different stakeholders' opinions and suggestions, and jointly optimize market mechanisms.

6.2. Risk Management Tools and Product Innovation

Based on the relationship between futures and spot prices, more diversified and effective risk management tools could be developed to assist producers and investors in managing risks during market fluctuations. Additionally, more varied futures contracts could be introduced to meet the needs of different investors and producers.

6.3. Policy Support and Industry Standards

Policymakers could consider enacting policies that support the development of futures and spot markets. Establishing and adhering to industry standards can also help increase market transparency and stability. Specific measures include:

Standardization of information disclosure: Implement unified standards for disclosing key indicators such as prices, inventory, and trading volume by participants in both spot and futures markets. This standardization can enhance market transparency, reduce information asymmetry, and help better understand market supply and demand dynamics, reducing uncertainty for investors and producers.

Market regulation and standardization: Strengthen market supervision to ensure the legality and fairness of market transactions. Policy makers should establish strict systems and regulatory mechanisms to prevent market price manipulation or improper disclosure of information, maintaining market order and boosting confidence among investors and producers.

Promotion of technological innovation: Policy support for technological innovation, especially in the areas of trading, settlement, and risk management in spot and futures markets. Policy encourages research and development of new trading platforms or financial instruments to enhance market efficiency and operability.

7. Conclusion

This study uses a Vector Autoregression (VAR) model to analyze the dynamic relationship between PVC futures and spot prices from May 2009 to September 2023, focusing on price volatility and information transmission. Results indicate a long-term equilibrium and bidirectional guidance between

ISSN 2616-5902 Vol. 6, Issue 9: 97-104, DOI: 10.25236/AJBM.2024.060914

futures and spot prices, with futures prices leading and spot prices reacting more slowly. Impulse response analysis and variance decomposition reveal the underlying mechanisms of these interactions, underscoring the futures market's crucial role in price discovery. Based on these findings, the study offers decision support, emphasizing the importance of understanding futures and spot market interactions for effective market monitoring and risk management.

References

[1] Ma Zhengwei, Ma Yiqun. Study on the Correlation between Chinese Crude Oil Futures and Polyvinyl Chloride Futures Prices. [J]. Petroleum Science Bulletin, 2021(3).*

[2] Chen Wenchao, Zhong Hao. The Impact Mechanism of Stock Index Futures on the Stock Market and Empirical Analysis. [J]. China Collective Economy, 2021(10)

[3] Liu Junfeng. Study on the Long-term Equilibrium Relationship between Chinese Commodity Futures Market and Spot Market Based on Cointegration Theory [D]. Tianjin: Tianjin University, 2004.

[4] Wang Keshan, Yu Jianbin. Study on the Price Transmission Relationship between U.S. Soybean Futures Market and Spot Market [J]. China Circulation Economy, 2008 (09).

[5] Lu Ying. Study on the Price Relationship between China's White Sugar Futures Market and Spot Market [D]. Anhui: Anhui Agricultural University, 2013

[6] Ma Zhengwei, Ma Yiqun. Study on the Correlation between Crude Oil Futures and PVC Futures Prices in China [J]. Petroleum Science Bulletin, 2021(3).