An Empirical Analysis of the Correlation between Spot Price and Futures Price of Silver

Yining Ye[1,*]

[1] *School of Economics, Ocean University of China, Qingdao, 266100, China*
[*] *Corresponding author. Email: yexiahu@nbu.edu.cn*

ABSTRACT

As silver futures appear and are widely traded, it has brought both opportunities and challenges to the market. Many scholars hold the belief that the spot market affects the futures market, and the futures market reacts to the spot market as well. The relationship between them is complex. Taking the silver futures price and spot price from 2015 to 2021 as the research object, this paper explores the relationship between them through the cointegration test, vector error correction model, Granger causality, impulse response model, and other methods. It comes to the conclusion that the spot and futures markets are in long-term equilibrium, and the two markets can modify each other dynamically. What's more, the future price has Granger one-way guiding effect on the spot price, and the Future price can respond to the impact of spot prices faster and absorb the impact of price changes. Taking gold as an example, this paper further explores the effect of other futures on the spot price of silver. Finally, the paper put forward some constructive suggestions.

Keywords: *Silver future, Silver spot, VECM, Granger;*

1.INTRODUCTION

The history of the silver future is more than 5000 years since its initial discovery. It is also one of the most popular precious metal commodities after gold. For centuries, silver has been used as currency, jewelry, and long-term investment options. Nowadays, with the sustaining and ongoing development of the global financial market and the constant improvement of the futures market, a variety of silver-based investment tools are gradually used for trading and investment, such as silver futures, silver options, silver ETF, and so on. The leverage and two-way trading among them have deeply attracted investors all over the world.

Compared with gold, scholars make less research on silver. Therefore, this paper selects the silver future and spot price as the main research object, aiming to explore their impact path and degree of them, so as to help investors make decisions and provide references for relevant departments to improve the market.

With the increase in world silver production, silver futures trading is becoming more and more active. Figure 1 shows the table of trading proportion of main varieties in May 2021 published by Shanghai Futures Exchange. Silver future ranks third, accounting for 10% of the total trading volume, which means that its position and influence in the futures market are also rising day by day.

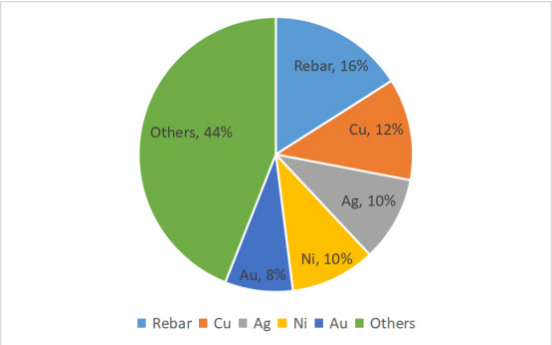

Figure 1 The main types of future in 2021.5 of Shanghai Futures Exchange

The rising market share is accompanied by the rising risk and fluctuating price of silver futures. Figure 2 shows the closing price of silver futures from 2020 to 2021 on the New York Mercantile Exchange. During the two years, the futures price fluctuated greatly, and the market trend was difficult to estimate. Therefore, the relationship between the silver futures price and spot price is very important because it can help investors predict and evaluate the market.

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Figure 2 the Closing Price of Silver Future in 2020--2021 COMEX

All over the world, the research on the relationship between silver futures and the spot is different from each other, and the methods used are also different, as well as the conclusions.

Shah and Prem were committed to exploring the relationship between spot prices and futures prices of different commodities. They used ADF test and kpss to test the stability of the data. Their Johansen cointegration test revealed that there were at least five cointegration pairs in the six cointegration pairs, except the crude oil. In addition, the result of Granger causality showed that there was only a one-way connection between spot and futures [1]. A. K. Sarkar and Shailesh Rastogi used GARCH (1,1) model to evaluate the impact of the introduction of derivatives on the metal spot and concluded that gold and silver future contributed to the increase of market depth and price discovery in the spot market [2]. NARENDER Kumar and Sunita Arora explored the relationship between silver spot closing price and futures contract in five and a half years and found that there was a significant correlation between spot and futures prices. The two original price series were non-stationary, but they were stable after the first-order difference, which meant that spot return and Futures return were stable. At the same time, they found that the price series was cointegrated, and there was a one-way causal relationship from futures return to spot return [3]. Khan ferojuddin M. A. and Ramani L. found that spot silver and futures silver prices were cointegrated through the cointegration test and Granger causality test, and there was no Granger cause between them [4]. Wang Ying found that there is a stable and placid equilibrium on a long-term scale between China's silver futures and spot price through the cointegration test and error correction model as well as granger causality. The imbalance in the short term could be adjusted in time. However, the change in silver spot price led to the change of futures price in one direction, which showed that the price discovery function of silver futures didn't make a significant difference[5]. Weiwei Cai found that the interaction between silver futures and the spot market was stronger on different time scales by using wavelet decomposition and wavelet multiple analysis. Therefore, in the lower frequency, 4-6 months, and in the high frequency of one week, the integration was very high. Yuhan Wu used the cointegration test, ECM model, Granger causality test, and other relevant methods to find that there was a long-term equilibrium relationship between spot and futures prices, and a strong function of short-term dynamic correction. Silverspot price and future price are Granger causes for each other, and in terms of mutual guidance and impact effect, silver futures prices are stronger than spot prices [6].

Existing studies all believe that there is a certain relationship between the spot and futures price of silver, but there is no clear conclusion on the direction and mode of this relationship. This paper focuses on the influence mode and degree between the two, so as to provide guidance for investors' decision-making.

The paper is mainly divided into five parts. The first part is the data introduction. The source of time series data and the scientificity of data selection are introduced in detail. The second part introduces the principle of each model and the corresponding data processing results. In this part, this paper first tests the stability of the spot and futures prices of silver. After obtaining the stationary series through first-order difference, it could be seen whether it passes the Johanson cointegration test. Then, the vector error correction model is constructed to analyze the interaction between the spot price and its corresponding lag, as well as the futures price and its corresponding lag. Further, the Granger causality model is used to analyze whether the spot price and futures price are two-way impacts, one-way impacts, or no impact. Finally, the impulse response model is used to explore the response direction and degree of one variable when the other variable is impacted. And further, carry out variance decomposition to explore the contribution of spot and futures price structure shocks. The third part is the objective conclusion of empirical analysis. The fourth part is the discussion of the research conclusion. The fifth part is the constructive suggestions based on the research results.

2.DATA

There are mainly 11 indicators in this paper, and their abbreviations are shown in Table 1.

Table1. Indicators and their letter code

Indicator	Code
SP	The spot price of silver future
FP	Future price of silver future
SP_t	Spot price of silver future at time t
FP_t	Future price of silver future at time t

SP_{t-n}	Spot price of silver future lagging n phase
FP_{t-n}	Future price of silver future lagging n phase
$\Delta(SP_t)$	Spot price of silver after first-order difference
$\Delta(FP_t)$	Future price of silver after first-order difference
$AuFP_t$	Future price of gold future at time t
$\Delta(AuFP_t)$	Future price of gold after first-order difference
$AuFP_{t-n}$	Future price of gold future lagging n phase

This paper selects the daily frequency data of the national silver spot price and the silver future price of the Shanghai Futures Exchange from January 3, 2017 to December 31, 2021 as the research object. After excluding non-trading days, 1215 groups of sample data are obtained. At the same time, in order to reduce the impact of the approaching delivery date on price continuity, the futures price data choose the closing price. Table 2 manifests the descriptive statistics of the collected data.

Table 2. Descriptive statistics of the data

	SP	FP
Mean	4260.71	4266.95
Max	6708.33	6575.00
Min	2942.67	2930.00
Standard Deviation	725.23	728.88
Skewness	0.85	0.84
Kurtosis	2.62	2.57
J-B	155.23	152.82
P	0.00	0.00

It can be seen that the skewness of SP and FP is greater than 0, the sequence shows a right tail-flick distribution. The J-B statistics are significant, indicating that they all show a non-normal distribution. The linear distribution of the two is shown in Figure 3. The overall trend between the two is similar.

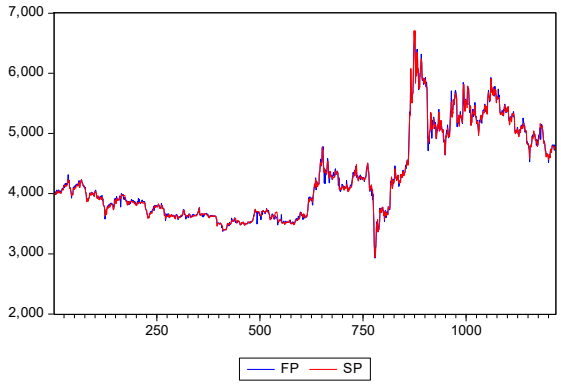

Figure 3 The trend of FP and SP

3. MODELS AND RESULTS

3.1.the Unit Root Test

3.1.1.Model Introduction

Many researchers choose the unit root test to test the stationarity of time series. ADF unit root test is always used to check if a unit root exists in the sequence. If there is, it means that the time series is non-stationary.

The ADF test has three main models:

$$\Delta X_t = \delta X_{t-1} + \sum_{t=1}^{m} \beta_t \Delta X_{t-1} + \varepsilon_t \quad (1)$$

$$\Delta X_t = \alpha + \delta X_{t-1} + \sum_{t=1}^{m} \beta_t \Delta X_{t-1} + \varepsilon_t \quad (2)$$

$$\Delta X_t = \alpha + \gamma + \delta X_{t-1} + \sum_{t=1}^{m} \beta_t \Delta X_{t-1} + \varepsilon_t \quad (3)$$

Each Greek letter in the model represents: ε_t refers to residual, γ refers to time trend, α is a constant term, and m is the lag order. The original hypothesis of ADF is $H_0: \delta = 0$, which means, that rejecting the original hypothesis, it indicates that there is no unit root in this time series, so this time series is a stable time series. When accepting the original hypothesis and rejecting the alternative hypothesis, it indicates that this time series has a unit root and is a non-stationary time series. The lag order of the time series must be determined after that [7].

3.1.2.Model Results

The test result shows that both silver futures price and spot price are non-stationary series, so regression analysis cannot be carried out. In this paper, the unit root test is also carried out for the first-order difference sequence of spot price and futures price. The result is shown in Table 3. Both P values are 0. Therefore, it can be explained that the sequence after the first-order difference is stable, so it can be used for the next analysis.

Table 3. The ADF Results of SP and FP

	F-statistic	Prob
SP	-19.37	0.00
FP	-33.67	0.00

3.2. Johanson Cointegration Test

3.2.1.Model Introduction

Johanson cointegration test is a test based on regression coefficient, and its premise is to determine the optimal lag order through the VAR model. There are many meanings of co-integration. In this paper, it is mainly used to test whether the causal relationship described by the regression equation is pseudo regression, that is, to test whether there is a stable connection between variables. Therefore, for a non-stationary sequence, the method of causality test is generally a cointegration test.

Of course, there may also be cases where the co-integration relationship is not established in non-stationary sequences. In this case, the VAR model can be established. Under the condition of satisfying the same order and single integration, the granger causality test is carried out by using variable difference. If there is a cointegration relationship between variables, an error correction model is established for short-term causality analysis.

3.2.2.Model Results

This paper uses a cointegration test to judge whether there is a cointegration relationship between the silver futures price and spot price. Firstly, the optimal lag order, in theory, is determined by the VAR model. The VAR model in this paper is:

$$\begin{bmatrix} SP_t \\ FP_t \end{bmatrix} = \alpha_0 + A_1 \begin{bmatrix} SP_{t-1} \\ FP_{t-1} \end{bmatrix} + \ldots\ldots + A_n \begin{bmatrix} SP_{t-n} \\ FP_{t-n} \end{bmatrix} + \begin{bmatrix} \varepsilon_{sp} \\ \varepsilon_{fp} \end{bmatrix} \quad (4)$$

In the formula, α_0 is the vector composed of intercept term and A_1 to A_n are all 2×2 coefficient matrices.

The results are shown in Table 4. According to LR, HQ, FPE, and AIC information criteria, order 2 is the optimal lag order of the model.

Table 4. The result of Var

Lag	1	2	3
LogL	-13221.13	-13209.36	-13208.19
LR	NA	23.46827*	2.335449
FPE	10302510	10171207*	10218759
AIC	21.82365	21.81083*	21.81549
SC	21.84048*	21.84449	21.86598
HQ	21.82999	21.82350*	21.8345

Next, Johanson cointegration test was performed. As shown in Table 5, there is a cointegration relationship, which means there is a long-term equilibrium relationship between the silver futures price and spot price.

Table5. The result of the cointegration test

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized		Trace	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None *	0.3251	480.56	15.495	0.0001
At most 1	0.0029	3.56	3.841	0.0592
There is 1 co-integration relationship at the significance level of 0.05				
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized		Max-Eigen	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**

None *	0.3251	477.001	14.2646	0.0001
At most 1	0.0029	3.559	3.841466	0.0592
There is 1 co-integration relationship at the significance level of 0.05				
* Reject the null hypothesis at the significance level of 0.05				
**MacKinnon-Haug-Michelis (1999) p-values				

3.3.Vector error correction model(VECM)

3.3.1.Model Introduction

Vector error correction model is a statistical model combining cointegration and error correction model. The vector error correction model requires that there must be a cointegration relationship between variables so that the VECM can be derived from the autoregressive distributed lag term of the model. The vector error correction model is also called the vector autoregressive model with cointegration constraints. In the vector autoregressive model, each equation can be considered as VECM by adding an autoregressive distribution lag term. Vector error correction model is used for non-stationary time series most times, but it has a cointegration relationship [7].

The vector error correction model is expressed as:

$$\Delta y_t = \alpha ecm_{t-1} + \sum_{t=1}^{m} \tau_t \Delta y_{t-1} + \varepsilon_t \quad (5)$$

Among them, ecm_{t-1} is the error correction term, and the coefficient of the error correction term α represents an adjustment speed from the state deviating from the long-term equilibrium to equilibrium. The coefficient of Δy_{t-1} expresses the influence of the change of each variable on the change.

3.3.2.Model Result

The cointegration test has been carried out in this paper. It can be seen that both silver futures price and spot price are first-order single integration data, and there is only one cointegration relationship, which proves that there is a long-term equilibrium relationship between them. In order to further study the short-term relationship between them, the VECM is used to test the data. Knowing that the lag term of the VAR model is 2, it can be seen that the optimal lag order of VECM should be 1. The estimated results of VECM are displayed in Table 6. The values in brackets are t-test values.

Table6. The result of VECM

Error Correction:	$\Delta(SP_t)$	$\Delta(FP_t)$
CointEq1	-0.751866	0.194584
	[-11.2443]	[2.61562]
ΔSP_{t-1}	-0.093489	-0.007681
	[-2.03699]	[-0.15042]
FP_{t-1}	0.113494	0.086346
	[2.18744]	[1.49581]
C	0.624284	0.598318
	[0.30445]	[0.26227]

According to the table6, the following correction models can be established:

$$\Delta(SP_t) = -0.75e_{t-1} - 0.09\Delta SP_{t-1} + 0.11\Delta FP_{t-1} + 0.62 \quad (6)$$

$$\Delta(FP_t) = 0.19e_{t-1} - 0.01\Delta SP_{t-1} + 0.09\Delta FP_{t-1} + 0.60 \quad (7)$$

From the first formula, it can be easily discovered that the spot price lagging 1 phase has a negative influence on the current spot price, while the futures price lagging 1 phase has a negative influence on the current spot price. Compared with the two, the influence of futures price lagging 1 phase is greater.

From the second formula, it can be easily discovered that the spot price lagging 1 phase has a negative influence on the current futures price, while the futures price lagging 1 phase has a negative influence on the current futures price. Compared with the two, the future price lagging 1 phase has a greater influence on the current futures price.

3.4.Granger causality Test

3.4.1.Model Introduction

Granger put forward the definition of non-causality, which established the basis for the empirical causality between two variables. Assume the model as:

$$Y_t = \sum_{t=1}^{k} \alpha_i Y_{t-i} + \sum_{t=1}^{k} \beta_i X_{t-i} + \mu_t \quad (8)$$

Among them, μ_t is white noise. The intercept term, trend term and seasonal dummy variable can also be added to the expression. The null hypothesis for testing the noncausal relationship of X towards Y is:

$$H_0: \beta_1 = \beta_2 = \ldots = \beta_k = 0 \quad (9)$$

If the null hypothesis cannot be rejected, that is, the estimated values of parameters β_i(i= 1,2,3... K) are all 0 or not significant, that is, there is no Granger causality for X_t to Y_t. On the contrary, if any estimate in the parameter β_i(I = 1,2,3... K) is not equal to 0 and is signed under the t-test, then the null hypothesis must be rejected, that is, there is a Granger causality for X_t to Y_t[8].

3.4.2.Model Result

Because the original time series is unstable, the Granger causality test still uses the series after the first-order difference. Granger causality test results are shown in Table 7.

Table7. The result of granger causality test

Dependent variable: D(SP)			
Excluded	Chi-sq	df	Prob.
D(FP)	4.784878	1	0.0287
All	4.784878	1	0.0287
Dependent variable: D(FP)			
Excluded	Chi-sq	df	Prob.
D(SP)	0.022627	1	0.8804
All	0.022627	1	0.8804

It can be seen from Table7 that FP is the Granger reason of SP, that is, the futures price has a guiding relationship with the spot price; SP is not the Granger reason of FP, that is, the guiding relationship between the spot price and futures price has not been recognized. Therefore, it can be concluded that the two-way causal relationship can not be proved. What exists is that the futures price has a Granger one-way guiding effect on the spot price, that is, the futures market plays a price discovery function.

3.5.Impulse Response Model

3.5.1.Model Introduction

Impulse response model is used to study the interaction relationship and influence degree between variables. Its economic significance is to describe the impact of an endogenous change on other endogenous changes in VAR model, and further evaluate the importance of different structural shocks.

3.5.2.Model Result

Before impulse response analysis, the stationarity test shall be carried out, which is called inverse roots of AR characteristic polynomial. The test results are shown in Figure 4. All points are in the circle, that is, they have passed the stability test.

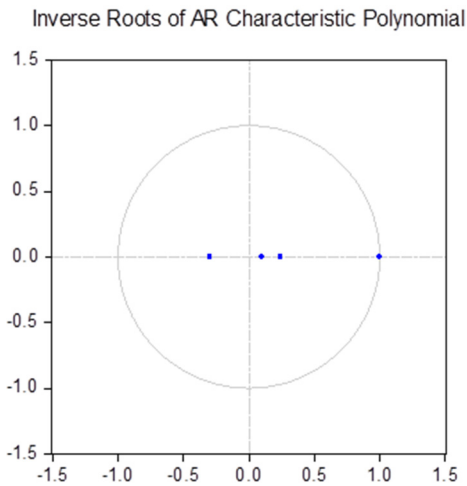

Figure 4 Inverse Roots of AR Characteristic Polynomial

The impulse response results are shown in Figure 5.

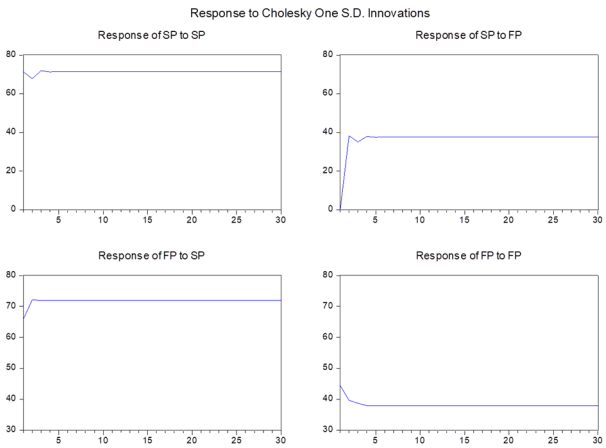

Figure 5 The Result of Impulse Response

It can be easily discovered from figure 5 that when impacted by the price of silver futures, the spot price of silver quickly reached the peak in the first period, fluctuated slightly in the second to fourth periods, and remained at a high level as a whole. By the fifth period, the impact disappeared and tended to be stable. When impacted by the spot price of silver, silver futures respond in the current period, fluctuate slightly in period 1 to 3, and disappear and tend to be stable in period4. The response of silver spot price to the change of futures price

is more intense, and the time cycle of the response is longer. In contrast, futures prices can respond to the impact of spot prices faster and absorb the impact of price changes.

Further, the paper use variance decomposition to explore the contribution of the structural shock of endogenous variables. The spot price of silver has a great impact on its own price. The contribution in the first 10 periods is more than 80%, and it remains at the level of more than 78% until the 100th period, showing a slow downward trend on the whole. In contrast, the impact of futures on itself is low, gradually decreasing from about 31% in period 1 to about 21%. From the perspective of interaction, the impact of futures on spot and spot on futures rises with the number of periods.

3.6.Impact of Other Futures Varieties on Silver Spot Price

Through the above analysis, it can be seen that silver futures have a good guiding function for a silver spot [9-10]. Therefore, this paper further explores the impact of other kinds of futures on the silver spot price. This paper takes gold as an example. The futures price of gold is also a non-stationary series, and its first-order difference series is stable. Therefore, the first-order difference sequence of gold futures and the silver spot is substituted into VECM, and the result is:

$$\Delta(\mathrm{SP_t}) = -0.013\mathrm{e_{t-1}} - 0.294\Delta\mathrm{SP_{t-1}} - 0.003\Delta\mathrm{SP_{t-2}} - 0.014\Delta\mathrm{SP_{t-3}} - 0.098\Delta\mathrm{SP_{t-4}} + 10.127\Delta\mathrm{AuFP_{t-1}} + 2.224\Delta\mathrm{AuFP_{t-2}} + 0.695\Delta\mathrm{AuFP_{t-3}} + 0.201\Delta\mathrm{AuFP_{t-4}} - 0.22 \quad (10)$$

$$\Delta(\mathrm{AuFP_t}) = -0.0008\mathrm{e_{t-1}} + 0.00008\Delta\mathrm{SP_{t-1}} + 0.0006\Delta\mathrm{SP_{t-2}} - 0.002\Delta\mathrm{SP_{t-3}} - 0.004\Delta\mathrm{SP_{t-4}} + 0.025\Delta\mathrm{AuFP_{t-1}} - 0.014\Delta\mathrm{AuFP_{t-2}} - 0.008\Delta\mathrm{AuFP_{t-3}} - 0.006\Delta\mathrm{AuFP_{t-4}} - 0.09 \quad (11)$$

It can be easily discovered that the price of gold futures has a great influence on the spot price of silver, especially the coefficient lagging behind phase 1 is the largest, followed by the coefficient lagging behind phase 2. And according to the coefficient, the influence is positive. In contrast, the silver spot has little impact on gold futures.

4. CONCLUSION

From the above empirical analysis, it can be concluded that there is a close relationship between silver futures and spots. From the daily data trend chart of silver spot price and futures price from 2015 to 2021, the trend of the two is very similar and highly synchronous, which shows that the silver futures market has a certain risk-aversion function. The futures price will affect the spot price of the next period. The futures price can guide the spot price, but the degree of influence is limited. The spot price changes sharply to the futures price, and the response time cycle is longer. Futures prices can respond to the impact of spot prices faster and absorb the impact of price changes. Further analysis of the impact of other futures on the silver spot shows that gold and other futures can also guide the silver spot.

There are some differences between the conclusions of the paper and some previous literature. Some kinds of literature believe that the price discovery function of silver futures is weak. Through the interpretation of this literature, it can be found that the time range of data is short, usually within 2 years, which leads to the one-sidedness of the results.

Futures prices have a price discovery function on spot prices, and other commodity futures also affect the spot price of silver. These conclusions can provide a decision-making basis for investors to make scientific decisions and help them have a better understanding of the market. According to the results of the article, the following suggestions can be provided.

(1)Increase the construction of new futures varieties and enhance the vitality of silver futures. Continuously increase the varieties of silver futures and derivatives, promote silver options, silver ETF, silver leasing, and other businesses, and enrich silver futures investment tools, attracting more hedgers and investors. At the same time, we should expand the field of trading, strengthen the link between up upstream and downstream industries, and reduce transaction costs, so as to further improve the continuity of silver futures contracts and fully stimulate the price discovery function of the silver futures market. Cultivate professional talents engaged in the research of silver futures varieties, and develop innovative products in time and regularly, so as to make the silver futures market more active. The futures trading center and other relevant institutions should propagate more to improve the popularity and exposure of products. Investment activities can also be carried out across markets.

(2)Reduce silver market risks and promote the transparency of the silver market. Relevant institutions need to set up a department aiming to manage the future market to ensure the openness and transparency of the market, so that investors can accurately and timely obtain market price information and relevant information, thus making reasonable decisions.

(3)Develop and scale of silver future investors and optimize the investor structure. Investors are the main part of the futures market. The quality and quantity of investors play a vital role in the stability of the futures market. Establish investor training institutions, launch relevant investment courses, improve investors' investment level and ability to obtain information, strengthen risk prevention awareness and reduce speculation.

(4)Pay attention to investor sentiment and give appropriate guidance. In the noisy market environment,

investors may overreact and make the mood of the whole market rise a lot, so that the price of the whole market will be distorted, and finally hinder the realization of the function of the futures market. Therefore, in order to give better play to the function of the futures market, the regulatory authorities need to carry out timely guidance and let investors make rational decisions.

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