CSCanada
International Business and Management
Vol. 10, No. 3, 2015, pp. 35-39
DOI:10.3968/6901

ISSN 1923-841X [Print]
ISSN 1923-8428 [Online]
www.cscanada.net
www.cscanada.org

Empirical Research on Price Discovery of the China's Gold Futures Market Based on High-Frequency Data

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Received 20 March 2015; accepted 17 May 2015
Published online 30 June 2015

Abstract
This paper uses high-frequency data of China's gold futures market and gold spot market to make empirical research on price discovery between them. We adopt Johansen co-integration regression test, vector error correct model and Granger causality test and other econometric methods .The result shows that there is co-integration relationship between China's gold futures market and gold spot market, and they guide each other. This illustrates that the China's gold futures market exists price discovery, which indicate China's gold futures market has became more mature.

Key words: High-frequency data; Futures market; Spot market; Price discovery

Zheng, J., & Dong, L. (2015). Empirical Research on Price Discovery of the China's Gold Futures Market Based on High-Frequency Data. *International Business and Management, 10*(3), 35-39. Available from: http://www.cscanada.net/index.php/ibm/article/view/6901
DOI: http://dx.doi.org/10.3968/6901

INTRODUCTION
China's gold futures has founded in Shanghai Futures Exchange on January,2008, showing a new development era in gold futures as well as a more mature and internationalized gold futures market. Such volume was on the increase with the enlarging transaction scale since appearing on the market. In 2013, the gold output in China has reached 428.16 tons, increasing by 6.23% on year-on-year basis, ranking the first in the world in successive 7 years according to the latest statistical data of Chinese Gold Association. Meanwhile, the gold consumption in China has broken through 1,000 tons for the first time, reaching 1,176.40 tons, increasing 41.36% on year-on-year basis, indicating the gold demand will remain exuberant and huge market potential will appear on the gold market in the future, based on the huge population base and faster economic growth rate in China.

1. LITERATURE REVIEW
Gradually rising researches by scholars on the price discovery function are emerging though China has a relatively short time to market in gold futures. It is indicated from a comprehensive survey of such researches that the main issues they draw attention to: Which market in futures (or spot) market is playing the leading role and how to describe the contributions of futures or spot market in price discovery? To answer these questions, two trains of thought are usually adopted in domestic literatures about gold futures price discovery ability: 1) to research whether price discovery ability exist in the gold futures market, i.e. the price leadership-lag relationship between futures and spot market; 2) to research the contribution magnitude of gold futures and spot market in the course of price discovery.

Whether price discovery ability exists in gold futures market, the conclusion is mainly divided into two categories: One considers price discovery function exists. Daily closing price for 273 trading days ranging from Jan 9th, 2008 to Jan 23th, 2009 was selected by Xu Xu as research object to examine such function of the gold futures in our country. Results showed that gold futures market did sufficiently function as price discovery. The influence of transaction cost on price discovery was

excluded by Siu-Kai Choy & Hua Zhang (2010) based on e-commerce platform in Hong Kong. The price discovery function of 791 trading days ranging from the year 2009 to 2003 was adopted. It showed that standard futures contract played a leading role in price discovery while mini futures contract and spot index played a relative less role. Also, the transaction cost hypothesis was demonstrated. The price discovery function of gold futures price in our country was analyzed by Pan Yue (2010) using the price data of gold futures from Mar 4th, 2009 to Mar 29th, 2009. It was indicated by main results the stronger guiding function existed in gold futures price on spot price, explaining the existence of price discovery function of gold futures. The guiding function of domestic gold futures price on gold spot price was found by Zhu Heliang and Xu Guiyang (2010), indicating the development of price discovery function in futures market has started but with larger promotion space. 972 sample data in gold futures and gold spot were used by Chen Qiuyu, Chen Chong and Feng Wei (2012) to conduct quantitative research the function exertion conditions of gold futures market. Results showed the futures market had gradually given play to its price discovery function but not completely significant. The five-minute high-frequency trading data in China's futures market and spot market were selected by Liu Fei, Wu Weifeng and Wang Kaike (2013) and the preliminary emergence of price discovery function of gold futures function was found in our country.

On the other hand, it was considered that price discovery function was not existed in gold futures market. Theoretical analysis for the price discovery mechanism of gold futures and spot market was firstly made by Shi Yunping (2008), following empirical research on the two price series. It was concluded that the price discovery function was not developed in the gold futures market in China. 175 dominant contracts of gold futures and the closing price data of Au(T+D) extended settlement kinds in Shanghai Gold Exchange were analyzed by Yu Hushan, Qin Xuezhi (2009), showing that gold futures market was not the efficient market. It was indicated by Granger Causality Test the spot price other than spot price was the reason for the variation of futures price. 208 data was used by Zhao Rui (2009) to analyze the function exertion of gold futures market, indicating the one-way guidance by gold spot price for futures price. 85 samples in 0806 contract of gold futures were adopted by Tian Zhipeng, Zhu Guoyan（2009）to make analysis for the relationship in price between gold futures and gold spot, finding no casual relationship between them as well as poor performance in the futures price discovery function. 563 sample data from Jan 9th 2008 to May 6th 2010 were selected totally by Gan Yong, Duan Daofei (2010) to make empirical analysis for the relationship between gold futures price and spot price. It was considered there was mutual casual relationship between gold future price and spot price. Spot price played a decisive role among the gold price discovery function while the price discovery function of gold futures was weaker, requiring future improvement. Empirical analysis was conducted by Du Juntao (2011) for the function of gold futures market, considering the price discovery function has not yet been significantly embodied. It was difficult for domestic gold futures price to guide spot price, while international gold futures price has a greater influence on domestic price. It was derived from empirical analysis by other scholars such as Cui Meng, Zheng Zhiming that the gold futures market has not achieved the price discovery function.

Through the combination of the above-mentioned literature, no consistent conclusion was drawn whether gold futures market in our country was dominant in price discovery function. Then, with the development of economy and the constant improvement of exchange mechanism, the price discovery function in gold futures market of our country was the key point discussed in this paper. Meanwhile, daily data were mainly used for the discussion of price discovery function for gold futures market, from which the dynamic change features of gold futures price cannot be revealed and plenty of daily information will be lost, resulting in the loss of scientificity of the conclusion. Therefore, in this paper, 5-minute high-frequency data of gold futures and spot market were selected to research its price discovery function.

2. RESEARCH METHODS AND MODELS

This paper has made empirical research on price discovery of gold futures price in China through the exertion of vector auto-regression, vector error correction model and other econometric methods using 5493 groups of high-frequency data.

3. EMPIRICAL RESEARCH BASED ON HIGH-FREQUENCY DATA

3.1 Data Selection and Processing

In this paper, we select the 5-minute high-frequency data in closing price of gold futures continuous contract and gold spot Au9999 contract in Shanghai Gold Exchange. The time span of data was from July 9th 2013 to March 31th 2014,and we exclude the mismatch time to obtain 5493 groups of valid data. The data is derived from Wind database. Eviews 8.0 software was used for variable inspection in this paper.

f and s are used to express the futures and spot price series. And we take logf as f_t and logs as s_t so that we can eliminate the heteroskedasticity of time series and decrease the fluctuation of high frequency data.

3.2 Correlation Analysis

According to Figure 1, the variation trend diagram of gold futures and spot price series, it can be seen that no differences exist in both basic trends. Through correlation test, the

correlation coefficient between f_t and s_t is 0.9797, indicating a high correlation. Therefore, there may be co-integration relationship between them through preliminary judgment.

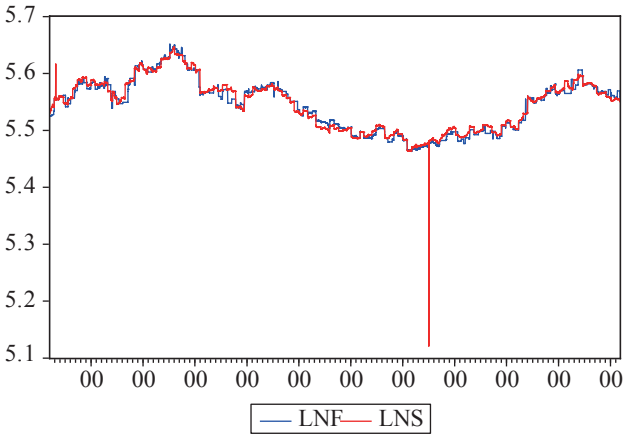

Figure 1
Variation Trend Diagram of Gold Future and Spot Price

3.3 Unit Root Test

ADF unit root test is conducted for gold futures and spot price series before performing co-integration test. Then ADF unit root test was performed for f_t and s_t and its first difference sequence, df_t and ds_t. We select intercept and temporal trend terms for f_t and s_t, and select terms without intercept and temporal trend for its first difference sequence, df_t and ds_t. The results derived are shown in Table 1.

It is indicated from the test results in Table 1 that the ADF value of f_t is greater than the critical value (1%, 5%, 10% of significance level).Than we accept the null hypothesis, i.e. such time series has roots of unity, the process is nonstationary. Similarly, roots of unity exist in s_t with the nonstationary course. The ADF value of its first order difference sequence df_t and ds_t, however, is smaller than the critical value (1%, 5%, 10% of significance level), so we refuse the null hypothesis, i.e. it refused the null hypothesis and there were no roots of unity with the stationary process. Therefore, f_t series was the integrated of order, i.e. $f_t \sim I(1)$, s_t was the first-order integrated series, i.e. $s_t \sim I(1)$. Thus, we can perform co-integration test for f_t and s_t series.

Table 1
ADF Test Result

	ADF value	1%level	5%level	10%level	Prob	Conclusion
f_t	-1.8893	-3.9597	-3.4106	-3.1271	0.6599	non-stationary
df_t	-80.7492	-2.5654	-1.9409	-1.6167	0.0001	stationary
s_t	-1.8082	-3.9597	-3.4106	-3.1271	0.7009	non-stationary
ds_t	-39.61775	-2.5654	-1.9409	-1.6167	0.0000	stationary

3.4 Construction of Vector Autoregression Model (VAR)

We should establish the VAR(2) model because four of the five evaluation indexes show that lag length 2 is the best according Table 2. It may be verified that the VAR (2) model was a stationary system by Stationary test of VAR model. The estimation of VAR(2) model is:

FT = 0.8733FT(-1) + 0.0882FT(-2) + 0.0789ST(-1) - 0.0401ST(-2) - 0.0017

ST = 0.0610FT(-1) - 0.0559FT(-2) + 0.7986ST(-1) + 0.1953ST(-2) + 0.0053

Table 2
Choice of Lag Length

Lag	LogL	LR	FPE	AIC	SC	HQ
0	28350.07	NA	1.10e-07	-10.34601	-10.34360	-10.34517
1	52281.51	47836.68	1.78e-11	-19.07865	-19.07142	-19.07613
2	52421.46	279.6346	1.69e-11*	-19.12827*	-19.11621*	-19.12406*
3	52424.53	6.130926	1.69e-11	-19.12793	-19.11105	-19.12204
4	52428.13	7.198206	1.69e-11	-19.12779	-19.10608	-19.12021
5	52429.63	2.982881	1.69e-11	-19.12687	-19.10034	-19.11761
6	52430.07	0.876570	1.69e-11	-19.12557	-19.09422	-19.11463
7	52430.27	0.417167	1.70e-11	-19.12419	-19.08801	-19.11157
8	52431.64	2.714666	1.70e-11	-19.12322	-19.08222	-19.10892
9	52440.02	16.70183	1.70e-11	-19.12482	-19.07900	-19.10884
10	52442.48	4.907607	1.70e-11	-19.12426	-19.07361	-19.10659
11	52449.15	13.27772*	1.69e-11	-19.12524	-19.06976	-19.10588
12	52451.63	4.936610	1.70e-11	-19.12468	-19.06438	-19.10364

3.5 Johansen Co-integration Regression Test

In order to research whether long-run equilibrium relationship existed between time series, Johansen co-integration regression test is adopted to test whether the co-integration relationship existed between gold futures price and gold spot price in China. Lag length 1 was selected for JJ test and the co-integration regression test results were shown in Table 3 and Table 4.

Table 3
Johansen Co-integration Regression Test (1)

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.021317	120.2785	15.49471	0.0001
At most 1	0.000361	1.981556	3.841466	0.1592

Table 4
Johansen Co-integration Regression Test (2)

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.021317	118.2969	14.26460	0.0001
At most 1	0.000361	1.981556	3.841466	0.1592

Seen from the results in the above two tables, both trace test and eigenvalue of maximum test refuse the null hypothesis that no co-integrated vector exists at 1% of significance level. However, the null hypothesis that at least one co-integrated vector existed can't be rejected. Therefore, there was long-run co-integration relationship between gold futures price and gold spot price. The co-integration equation was: s_t=0.104+0.981f_t. It can be seen that the co-integration relationship between the gold futures and gold spot is（1, - 0.981）.

3.6 Vector Error Correct Model (VECM)

Based on the co-integration relationship between the existing variables, the vector error correct model (VECM) will be further established combining rapid fluctuation and long-run equilibrium.

Since lag length 2 is selected for lag phase of VAR model and VECM is established on the first difference for the original series, we choose lag length 1 in VECM. The empirical results of VEC model is shown in Table 5:

The magnitude of error correction is determined by the coefficient of error correction term, the coefficients of error correction term of the above two equations were -5.52% and 3.91%, with opposite correction directions. It is indicated that the correction magnitude of disequilibrium degree of the last phase by futures market is greater than that by spot market, which is mainly completed by the adjustment of futures price, that is to say, the futures market is predominant in the process of price discovery.

Table 5
Result of VECM

Error Correction:	D(ST)	D(FT)
CointEq1	-0.005521	0.039091
	(0.00367)	(0.00402)
	[-1.50511]	[9.71333]
D (ST(-1))	-0.195507	0.040007
	(0.01412)	(0.01549)
	[-13.8494]	[2.58300]
D (FT(-1))	0.055639	-0.088351
	(0.01284)	(0.01409)
	[4.33325]	[-6.27125]
C	4.13E-06	6.38E-06
	(2.7E-05)	(2.9E-05)
	[0.15385]	[0.21632]
R-squared	0.036215	0.027212
Adj. *R*-squared	0.035688	0.026680
Sum sq. resides	0.021733	0.026163
S.E. equation	0.001990	0.002184
F-statistic	68.71384	51.15293
Log likelihood	26356.78	25847.51
Akaike AIC	-9.600282	-9.414758
Schwarz SC	-9.595466	-9.409942
Mean dependent	3.75E-06	5.99E-06
S.D. dependent	0.002027	0.002214

3.7 Granger Causality Test

Co-integration test only explain the existence of long-run equilibrium relationship between variables. However, further test is required for the existence of casual relationship. Granger causality relationship is not a true causality relationship, but a predicted possibility, indicating X is helpful to predict Y. Granger causality test is adopted for continuous contract of gold futures and Au9999 contract of gold spot to further identify the influence between them. The test results are shown in the following Table 6.

Table 6
Result of Granger Causality Test

Null Hypothesis	F-statistic	Prob
DST does not Granger cause DFT	17.3556	0.000
DFT does not Granger cause DST	20.5442	0.000

Table 8 shows that the probability of the null hypothesis: DS_t does not Granger cause DF_t is extremely small, so we reject the null hypothesis, i.e. DS_t is the Granger causality of DF_t. In the same way, DF_t is the Granger causality of DS_t. Therefore, we can conclude that there is bidirectional Granger causality between China's gold futures price and gold spot price.

3.8 Impulse Response Function (IRF)

Impulse response function is used to measure the changing track by a standard deviation impact from random disturbance term on the current and future evaluation of endogenous variable, which may intuitively depict the dynamic interaction and its effect between variables. Based on the established VAR (2) model, the impulse response function between gold futures price and gold spot price in China is depicted to further analyze the short-term dynamic relation between them. The IRF analysis results of gold futures price and gold spot price are given in Figure 2 and Figure 3 respectively, with the horizontal axis referring to the order of lag length of impact effect and the vertical axis to the fluctuation level.

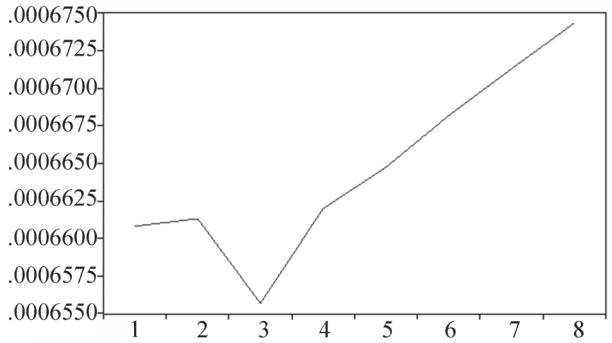

Figure 2
Impulse Response Function of Gold Futures Price

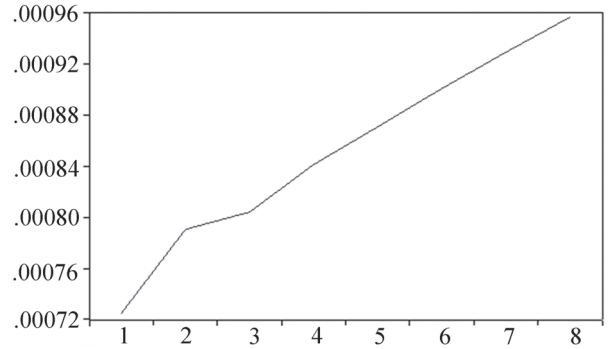

Figure 3
Impulse Response Function of Gold Spot Price

Seen from Figure 2, the response of standard deviation impact of spot price on futures price reaches the lowest at the 15th minute, however, it has approximate linear growth trend from the 20th minute, indicating the response is sustainable. It can be known from Figure 3 that the impact on gold spot price by gold futures market began to be on the rise at 5th minute and to gradually slow down from 10th minute to 15th minute. After 15th minute, steadily rising impact effect began to appear. Therefore, according the analysis of impact response model, there exists mutual influence between gold futures price and gold spot price in China, with a long-run sustainability.

CONCLUSIONS

The correlation analysis results indicate the significant positive correlation relationship exists between China's gold futures price and spot price; Johansen co-integration test show that China's gold futures and spot price have co-integration relationship, indicating a kind of long-run equilibrium relationship between them. The spot price will be adjusted by the price of gold futures in China. Also, our expectation of gold futures price will be altered by the gold spot price in China, in other words, the price discovery function exists in the gold futures market; It is showed in Granger causality test results that mutual casual relationship existed between the price of gold futures and of gold spot in China; Through impulse response analysis, we can find that mutual influence and sustainability exist between gold futures market and spot market, which reconfirm the price discovery function of gold futures market in China.

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