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The dynamic causality between gold and silver prices in China market: A rolling window bootstrap approach

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ABSTRACT

This paper examines the dynamic causality between the returns of gold and silver in China market for the period October 2006–October 2017. With the existence of structural changes in full sample, a rolling window bootstrap approach is employed to revisit the dynamic causal relationship. Our results demonstrate that gold has both significant positive and negative impacts on silver in multiple sub-periods while not vice versa. It is critical for investors to notice the unidirectional causal relationship from gold to silver under specific backgrounds. Our findings provide implications on the trading strategies of portfolio investment, producers hedging and statistical arbitrage.

1. Introduction

This paper aims to examine the dynamic causality between the returns of gold and silver in China market. Gold and silver have been seen as the symbols of fortune in human history, and play closely important roles even in ancient times (Gil-Alana et al., 2015a). As recorded in history, the gold-silver price ratio is set to 16:1 (Ciner, 2001) and stands at this level until the early 20th century. Particularly, gold prices are fixed in terms of dollar during the period 1945 ~ 1968, while the U.S. Department of Treasury manages to keep silver price below $1.29 (O'Connor et al., 2015). After the breakout of the first oil crisis and the collapse of Bretton-Woods system in 1970s, the relationship between gold and silver has been free of government interference and up to the market force. The prices of gold and silver are all considered as leading indicators on inflation risk, and can transmit monetary policy to the economy system. With the virtues of reserve of fortune, hedge for money, anti-inflation instrument (Gokmenoglu and Fazlollahi, 2015), gold and silver offer valuable diversification opportunities to investors and serve as monetary medium when the market is uncertain. Therefore, gold and silver have the similarity of hedging against inflation risk in investment portfolio and substitute for each other in investment (Zhu et al., 2016). With gold and silver as potential diversifiers for portfolio investment, the routine cointegration test between gold and silver prices is required (Lucey and Tully, 2006). Further, the causality between the returns of gold and silver means value to statistical arbitrage (Wahab et al., 1994). As silver accompanies gold in production, then how to hedge the production separately is important to producers. Therefore, the existence and the evolving process of causality between the returns of gold and silver deserve to be examined for better performances of portfolio investment, producers hedging and statistical arbitrage.

Our study on China market is motivated by different reasons. Firstly, as the biggest emerging country (Cheng et al., 2007), the biggest consumer and top three producer of silver, and the biggest consumer and producer of gold in the world (see Word Gold Council Report (2016)), the representativeness of China is unique. Second, in contrast to the developed markets, Shang Hai Gold Exchange (SGE) is young (starts in 2002) and starts gold and silver futures in 2004 and 2006, respectively. In addition, both gold and silver flows between China and foreign countries are still in control of the government (Hoang et al., 2015). The deposits of domestic

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and foreign gold are differentiated strictly although SGE has developed an international trade system in September 2014. China also implements a strict export quota management system in silver market, and does not grant the same preferential policy of refundable value-added-tax to silver market as that in gold market. Based on the China`s actual condition, whether gold and silver prices are separate since 1990`s as the same as the finding of Escribano and Granger (1998)? What are the possible innovations of the linkage? Our study aims to fill the knowledge gap and is helpful to fund managers, producers and investors interested in emerging markets.

Among the growing literature on the relationship between gold and silver, three focuses can be concluded from the recent literature: the comparison of responses under different economic situations (Christie-David et al., 2000; Sensoy, 2013; Lucey and O'Connor, 2016), the price predictability (Gokmenoglu and Fazlollahi, 2015; Auer, 2016; Pierdzioch et al., 2016) and the causality between the prices (Pierdzioch et al., 2015; Zhu et al., 2016; Schweikert, 2018). For example, Bampinas and Panagiotidis (2015) examine the long-run hedging ability of gold and silver against multiple indicators of consumer price index, and find that gold can fully hedge while silver not. In this paper we follow the third focus and examine the dynamic causality between gold and silver prices, using a rolling-window bootstrap analysis.

The causality between the prices of gold and silver has been extensively studied in previous literature, from which two assertions may be classified: The separation and the non-separation. First, the returns of gold and silver are found to be separate after 1990s (Escribano and Granger, 1998). However, the sample scale of 1971–1994 restricts its persuasiveness. Then, Ciner (2001) certifies the separation of the causality between gold and silver with the data from TOCOM since 1990. Further, Pierdzioch et al. (2015) studies the data from COMEX in the period 1970–2015, and argues that the cointegrated relationship only exists in the mid 1990s and the early 2000s with a very short time, and has disappeared in all other sub-periods.

On the contrary, much literature exhibits evidence of non-separation (Adrangi et al., 2000; Lucey and Tully, 2006; Sari et al., 2010; Zhu et al., 2016; Schweikert, 2018). For example, the existences of robust bidirectional cointegrated relationships are discovered in the period 1993–1995 (Adrangi et al., 2000). However, the results are not conclusive for the short period. Then, Lucey and Tully (2006) and Sari et al. (2010) reexamine the linkage in longer period, and argue that there exist weak relationships during some sub-periods and an overall stable relationship in long run. Furthermore, the linkage is examined to be cointegrated in quantile regression (Zhu et al., 2016; Schweikert, 2018). Besides, further characteristics of the relationship are explored including long memory properties (Gil-Alana et al., 2015b), instability and asymmetry (Kucher and McCoskey, 2016; Poshakwale and Mandal, 2016; Batten et al., 2016).

However, these aforementioned findings on the causality exhibit two shortcomings. First, most studies focus only on the bidirectional causalities between the returns of gold and silver, taking no account of the structural changes. Second, although some authors find the structural breaks or the time-varying characteristic of the linkage, they do not examine the relationship in detail.

Our study extends the current literature with a rolling-window bootstrap approach, which could demonstrate the detailed time-varying causalities. The previous literature mainly concerns whether the long-run causality exists, and it is prone to misinterpreting results if there exist structural changes indeed. Based on the time-varying findings, we can catch the time-varying causalities across sub-periods, hence the possible investment opportunities. The cointegration coefficients also reflect the shocks from gold or silver in the corresponding sub-periods. Further, the time-varying causality may bring about more efficient trading strategies in portfolio investment, hedging and statistical arbitrage. With the distinct time-varying causalities, we can achieve whether and when gold and silver prices are cointegrated excluding the use of mass dummy variables.

The paper is organized as follows: Section 2 will introduce methodology. Further, Section 3 presents the data description and empirical findings. Section 4 concludes.

2. Methodology

2.1. The bootstrapping full-sample causality test and stability test

To analyze the causality between the returns of gold and silver, a two-variable Granger non-causality test under the VAR is employed here. Besides, this paper uses the *RB* modified-*LR* method (Shukur and Mantalos, 2000) to examine the causality between RG and RS. Then, based on the *RB* modified-*LR* method, the VAR (*p*) process for two variables may be expressed as follows:

$$Y_t = \phi_0 + \phi_1 Y_{t-1} + \ldots\ldots\ldots\ldots + \phi_p Y_{t-p} + \varepsilon_t,\ t = 1, 2, \ldots\ldots T \tag{1}$$

where $\varepsilon_t = (\varepsilon_{1t}, \varepsilon_{2t})'$ follows a zero mean, independent, white noise process with nonsingular covariance matrix, and the optimal lag length p can be obtained from the Schwarz Information Criteria (*SIC*). By splitting y_t into two sub-vectors, $y_t = (y_{1t}, y_{2t})'$, thus the above equation can be rewritten as follows:

$$\begin{bmatrix} RS_{1t} \\ RG_{2t} \end{bmatrix} = \begin{bmatrix} \varphi_{10} \\ \varphi_{20} \end{bmatrix} + \begin{bmatrix} \varphi_{11}(L) & \varphi_{12}(L) \\ y_{21}(L) & \varphi_{22}(L) \end{bmatrix} \begin{bmatrix} RS_{1t} \\ RG_{2t} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix} \tag{2}$$

where RG and RS denote the growth of gold and the growth of silver, respectively. In the empirical analysis, the growth of price also refers to the return of gold or silver. $\varphi_{ij}(L) = \sum_{k=1}^{p+l} \varphi_{ij,k} L^k$, $i, j = 1, 2$ and L is the lag operator ($L^k x_t = x_{t-k}$).

If the underlying full sample has structural changes, the causality between the variables in the full sample would be unstable and invalid (Balcilar and Ozdemir, 2013). In our study, the parameters` stability in short run is examined with the *Sup-F, Mean-F* and *Exp-F* tests proposed by Andrews (1993) and Andrews and Ploberger (1994). Besides, the $L_c$ test (Nyblom, 1989) is employed to examine the parameters` stability in long run.

Table 1
Descriptive Statistics.

	RG	RS
Skewness	−0.3022	−0.3542
Kurtosis	3.6036	5.0287
Mean	0.0044	0.0009
Std. Dev.	0.0501	0.0865
J-B Test	4.0133	25.3958
p-value	0.1344	0

2.2. The bootstrap rolling-window causality test

The structural changes can be examined by some techniques, such as the use of dummy variables and the sample splitting. Nevertheless, these methods have shortcomings of biases including subjective judgment and pre-setting. To avoid such biases referred above, it is necessary to employ the rolling-window bootstrap method (Balcilar et al., 2010) to locate the structural changes.

Supposing a rolling window with the constant l observations and one step forward for each regression, the full sample with T observations is changed into a series of sub-samples, that is to say, $t-l+1$ for T. Definitely, a larger window size can increase the accuracy while decreasing the representativeness of heterogeneity for the sub-sample. On the contrary, a smaller window size may improve the representativeness while reducing the accuracy of estimation. Here, we take 24 months as the window size.[1] Afterward, the *RB* modified-*LR* test is used in each sub-sample, and the possible time-varying causality between the two variables can be intuitively located by the corresponding *p*-values of *LR* statistic rolling through all sub-samples. Besides, the effects between the variables can also be estimated.

3. Data and empirical analysis

3.1. Data description

The paper uses the monthly data spanning from 2006:10 to 2017:10 provided by SGE. Firstly, it can be observed from Table 1 that the volatility of RS is wider than RG with a kurtosis value of 5.0287 and a larger standard deviation of 0.0865. This finding demonstrates that silver price is more volatile than gold price, and is consistent with Zhu et al. (2016). Further, RG and RS have the overlapped paths during some sub-periods in Fig. 1. These characteristics mean that there should be mutual factors functioning for RS and RG. Also, the two series are not normally distributed according to the J-B test results.

3.2. Empirical findings

Firstly, we employ Augmented Dickey-Fuller test (ADF) (Dickey and Fuller, 1981) and Phillips-Perron test (PP) (Ouliaris et al., 1988) and the KPSS test (Kwiatkowski et al., 1992), to examine the stationarity of return series in logarithm (denoted by LG and LS). As illustrated in Table 2, both *ADF* test and *PP* test reject the null hypothesis of nonstationarity in first difference at the significance level of 1%, and the *KPSS* test couldn`t reject the null hypothesis of stationarity in the first difference while rejecting the null hypothesis in levels, indicating that LG and LS are both *I(1)* series.

Next, we examine the full-sample causality based on Eq. (2). The optimal lag length based on *SIC* is 1. In Table 3, the *p*-values of 0.665 and 0.896 all can`t reject the null hypotheses, indicating that neither RG nor RS plays a role in each other. The above findings are in accord with the assertion of separation (Escribano and Granger, 1998; Ciner, 2001; Lucey and Tully, 2006).

Based on the possible ignorance of the short-term causality (Zeileis et al., 2005), the parameters` stability test is needed to certify the existence of structural changes. As shown in Table 4, firstly among these three statistics, with the hypothesis of constancy for parameters, the *Sup-F* test on RG equation indicate that there exists one sharp shift in the parameters at the significance level of 5%, and in VAR system at the significance of 1%. Further, the results of RG equation from the *Exp-F* test indicate that the parameters may be in a process of gradual evolution at significance level of 10% and 1% in VAR system (Andrews and Ploberger, 1994). In general, these above results indicate that the parameters estimated from the full sample are unstable and inaccurate. Considering the possible structural changes in long run, we employ the rolling-window bootstrap estimation to test the causality between RG and RS.

With the null hypotheses that RG does not Granger cause RS and RS does not Granger cause RG, the *p*-values for LR statistic and the effects from each other can be calculated from the estimation. Figs. 2 and 4 demonstrate the *p*-values of *LR* statistic considering RG and RS as dependent variable respectively. Correspondingly, Figs 3 and 5 illustrate the effects on gold and silver from each other. Overall, in contrast with the results from the full-sample test, the rolling-window bootstrap approach demonstrates more detailed and time-varying causalities across the sub-periods.

Fig. 2 demonstrates the null hypothesis that RS does not Granger cause RG can be accepted mostly except a short time (2015:05–2015:06) at the significance level of 10%, indicating that RS has no intensive effects on RG. Further, Fig. 3 presents the sum

[1] We also use 12, 36 months to test the choices of window size and find that the results are affected, but very little.

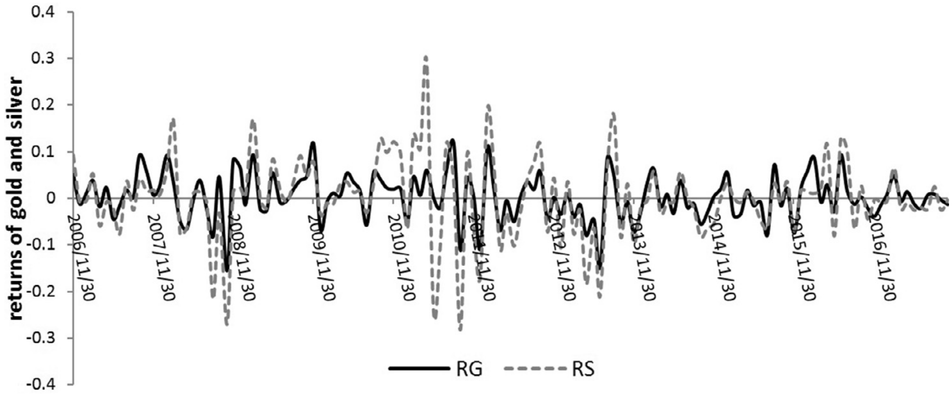

Fig. 1. The returns comparison.

Table 2
Unit root test results.

Series	Levels			First differences		
	ADF	PP	KPSS	ADF	PP	KPSS
LAU	−2.2450	−2.2277	0.6067**	−12.8363***	−12.8363***	0.2838
LAG	−1.7352	−1.8134	0.2258***	−11.6299***	−11.6301***	0.0708

Notes: *** and ** indicate the significance level of 1% and 5% respectively.

Table 3
Full-sample Granger causality tests.

Test	H_0: RG does not Granger cause RS		H_0: RS does not Granger cause RG	
	statistics	*p*-value	statistics	*p*-value
Bootstrap LR test for China	0.1883	0.6650	−0.0171	0.8962

Notes: These tests are calculated by Eviews software.

Table 4
Parameters Stability Test.

Tests	RG equation		RS equation		VAR system	
	statistics	Bootstrap *p*-value	statistics	Bootstrap *p*-value	statistics	Bootstrap *p*-value
Sup-F	18.2477	0.0486**	15.8389	0.1104	36.0118***	0.0024
Mean-F	6.5113	0.2033	5.2256	0.3857	7.8556	0.7486
Exp-F	5.4533	0.0822*	4.1700	0.2223	13.4738***	0.0047
L_c					1.4233	0.4397

Notes: We calculate *p*-values using 10,000 bootstrap repetitions. *, ** and *** denote significance at 10, 5 and 1% , respectively.

of the coefficients for the impacts from RS. These results demonstrate that the causes of RG should be lying beyond the silver market.

Fig. 4 reports that the null hypothesis that RG does not Granger cause RS should be rejected during six sub-periods (2010:08–2010:09, 2011:09:2013:03, 2013:05–2013:07, 2014:01–2014:06, 2014:09–2015:02, 2015:05–2015:07) at the significance level of 10%. These results demonstrate that RS could be led by RG in the six periods, and this finding is in accord with previous results (Baur and Tran, 2014; Zhu et al., 2016). However, as shown in Fig. 4, there are many breaks among the sub-periods, indicating that RS doesn`t always follow RG. As is argued by Lucey et al. (2014), China market is independent of international markets.

Firstly, with the plummeting of stock market index in the first half of 2008, the boom in housing market in 2009, and the accompanying rises of the reserve requirement ratio (RRR) from 2010–2011 by the central bank of China, the hedging demands fade out and the causality pops up only for the period (2010:08–2010:09). However, pushed by the immense money issuance (Liu and Huang, 2016), and the continuous lowering of interest rate and RRR, the hedging demands are reactivated accompanied with the significant positive causalities from gold to silver (see Fig. 5) in the period (2011:10–2015:07). Then, following the employment of strict regulating policies in financial market and the explosion of the great bubble in stock market, the causality fades out again, and gold and silver run into a long separated process.

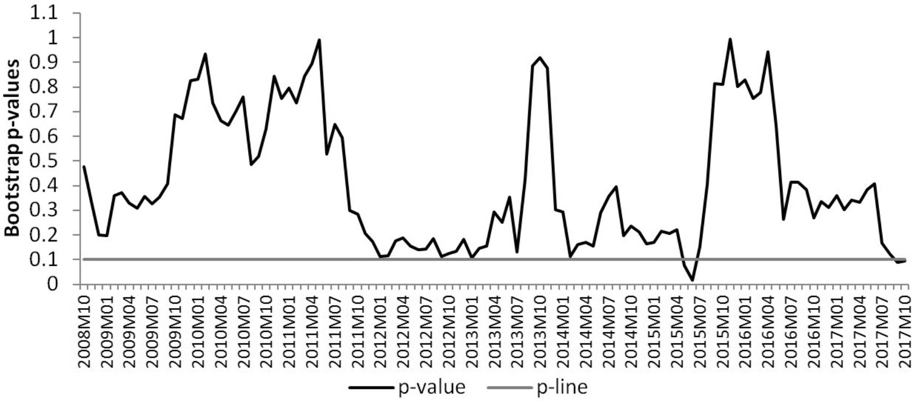

Fig. 2. p-value: RS does not Granger cause RG.

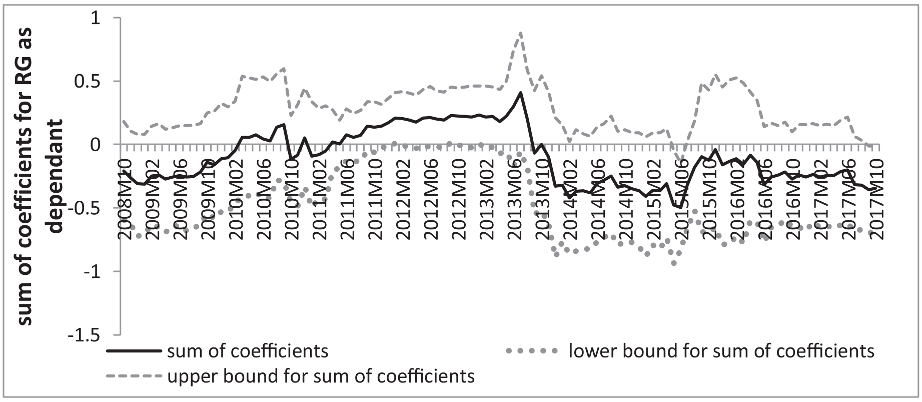

Fig. 3. The sum of coefficients for RG as dependant.

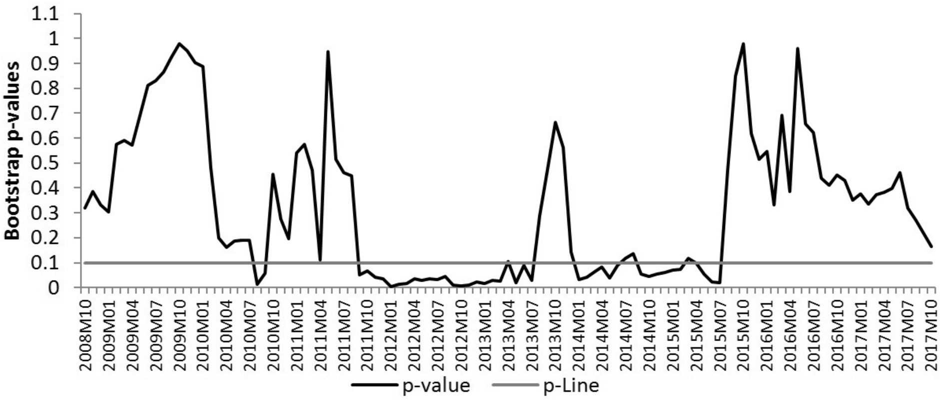

Fig. 4. p-value: RG does not Granger cause RS.

4. Conclusion

This paper examines the causality between the returns of gold and silver in China with a rolling-window bootstrap test. With the conclusion of non-causality from full-sample test, we further certify the instability and the structural changes of the causality across the sub-periods. Moreover, we evaluate the bidirectional relationship and identify the detailed structural changes. Our results demonstrate that there exist significant time-varying positive and negative effects from gold to silver while not vice versa. The time-varying causality also correlates intensively with the situations of macro-economy, different monetary and fiscal policies, and financial events. Our findings provide the evidence for weak efficient market hypothesis and mean value to portfolio investment, producers hedging, and statistical arbitrage.

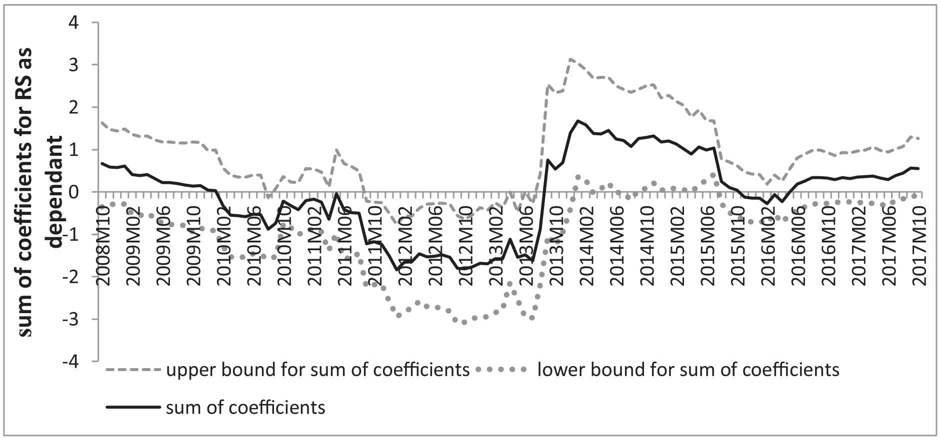

Fig. 5. The sum of coefficients for RS as dependant.

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