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Abstract

This paper examines the inter-relationships among gold prices in five global gold markets, namely London, New York, Japan, Hong Kong (since 1 July 1997, a Special Administrative Region (SAR) of China), and Taiwan. We investigate the linkages between Taiwan and the other global gold markets to provide insights for useful investment strategies. The augmenting level-VAR models proposed by Toda and Yamamoto (1995) show that the empirical results find bi-directional causality between the London and New York gold markets, and uni-directional causality from New York to the other markets. In this sense, the New York market has gained a leading role in affecting global gold markets. This empirical finding serves as a predictor for the gold price in global markets.

Keywords: Global gold market, Dynamic price integration, Toda-Yamamoto Procedure, Augmenting level-VAR models.

JEL Classifications: C22, C58, E31, G15.

I. Introduction

Gold is widely regarded as representative of precious metals. In the history of international currencies, gold has not only contributed significantly to the stabilization of the international money market, but has also served as an important financial asset in international currency reserves. For example, most countries around the world hold a certain proportion of their foreign exchange reserves in gold. Apart from its superior industry characteristics, gold has also served as a medium of exchange for several thousand years.

According to a report prepared by the World Gold Council, there are approximately 166,000 tons of gold in the world, and the growth rate of the stock of gold on earth increases by only 2% per year. In 2011, the global demand for gold was 4,067.1 tonnes, which was 6.5% higher than the previous year's level of 3818.2 tonnes. However, the total supply of gold was 3,994 tonnes in 2011, which was 8% below the previous year's level of 4163.9 tonnes. When the smaller global gold reserves are in even shorter supply, the cost of gold production reduces the shortfall in supply increases, and vice-versa.

Since the Global Financial Crisis began in late 2007, global investors have not aggressively sought complicated portfolios of financial assets, but have rather resorted to simpler financial and risk management. Investing in gold can provide a store of value and hedge risks (Kolluri, 1981; Morre, 1990; Dooley, Isard and Taylor, 1995; Taylor, 1998; Capie, Mills and Wood, 2005; Hammoudeh, Yuan, McAleer and Thompson, 2010). Even though gold prices will change due to fluctuations in market prices, gold will not lose its value over time.

In order to avoid currency depreciation and low interest rates, particularly during times of recession, investors prefer to provide a store of value for their wealth by holding gold (Koutsoyiannis, 1983; Mishra and Rahman, 2005; Hammoudeh, Malik, and McAleer, 2011). An increase in the demand for gold can increase gold prices, which can subsequently lead to a high value of the gold investment. Consequently, this can push up gold prices even further. When all factors are considered, there is still optimism that the gold market will remain bullish.

Due to the openness of financial markets, the impacts of changes in international financial markets on Taiwan have become increasingly rapid. Thus, the relationship between Taiwan and international financial markets has received greater attention. This paper investigates the dynamic linkages among international spot gold prices, using data from London, New York, Japan, Hong Kong and Taiwan. The empirical results not only help to shed light on the interdependence among these global markets, but are also able to serve as a valuable reference for gold investors in global markets.

The remainder of the paper is organized as follows: Section II introduces the data and sample descriptive statistics for the empirical analysis, Section III discusses the research methods, Section IV analyzes the empirical results, and Section V provides a conclusion and some suggestions for further research.

II. Data and Empirical Analysis

The paper examines daily spot gold trading prices from five countries, namely UK, USA, Japan, Hong Kong and Taiwan. The details regarding the variable definitions and data sources are displayed in Table 1, and the global gold price returns data are displayed in Figure 1.

It is clear from Figure 1 that Japan has the highest variation, with a range of (-7%, 12%), followed closely by both Hong Kong and New York, with a range of (-7%, 11%), then Taiwan, with a range of (-6%, 10%), and finally London, with a range of (-8%, 7%). Overall, the ranges of fluctuations in the global gold price returns are very similar.

The sample period extends from 01/02/2007 to 12/31/2010. In terms of the fund trading practices for these five countries, the closing or pm fixing prices are used. As the trading days for each country are slightly different, due to holidays or specific factors, missing observations are replaced by the closing price for the previous trading day. The common days off are excluded. Thus, the daily trading data comprise 1,039 observations. In order to be consistent, all samples are expressed in dollars per ounce.

The countries examined are located in different time zones, and so the trading times are also different. In order to avoid estimation bias resulting from confusion over trading orders, the time lag needs to be modified before the empirical analysis is performed (see Table 2). If we want to understand the lead-lag relationship between the New York (or London) gold spot price and the Taiwan gold passbook price, for example, we should use the one-period lagged gold spot price from New York (or London) while considering the current gold passbook price in Taiwan. Conversely, if we want to explore whether the gold price in the Asian market will affect the gold price in New York or London, we can directly apply the price to the original series.

Specifically, we not only estimate a VAR model with five variables, but also estimate five other types of VAR models that are characterized by the trading time and regions. The first set combines both the European and American markets, that is, the London and New York markets, which are two of the most important global gold trading markets. It is worth understanding their interactions, and thereby also those of other markets.

The second set of models places emphasis on the Asian markets, including Japan, Hong Kong and Taiwan, which have similar trading times and are located close to each other. The remaining sets are composed of one European market, one American market and one Asian market, which have different trading times and are located in different regions.

The relationship characterized by interdependence for each classification allows us to discuss whether or not the early-opening market provides some information as to the late-opening market, and discover which market is more powerful. Do the markets in different regions have any linkages? Do gold prices in relatively highly-capitalized markets (such as New York and London) have a significant influence on gold prices in Japan, Hong Kong and Taiwan? Understanding the dynamic linkages among these markets will contribute to providing useful information in relation to investments in the global gold market.

III. Empirical Methodology

Granger (1969, 1988) proposes a VAR-based method for inferences on the causal relationships among endogenous variables. However, Sims, Stock and Watson (1990), among others, have suggested that the asymptotic distributions cannot be applied to the traditional Wald test for exact linear restrictions on the parameters when the variables in a levels VAR are integrated or cointegrated. As Engle and Granger (1987) indicated, statistical inference for a VAR in levels can be undertaken appropriately only if all the variables are stationary. Otherwise, one can use VAR in differences if all the variables are integrated of order one but are not cointegrated, and through the specification of a VEC model if all variables are integrated of order one and are cointegrated. However, in most cases, the orders of integration and cointegration are not known *a priori* and pretestings for unit roots and cointegration are necessary before conducting Granger causality tests. Accordingly, any biases in testing for unit roots and cointegration among the variables may distort the efficacy of Granger causality tests. The pre-testing biases might be severe because unit root tests generally have low power, and Johansen cointegration tests can be unreliable in finite samples (Johansen, 1988; Johansen and Juselius, 1990; MacKinnon, 1996; Pesaran, Shin and Smith, 2001).

In order to avoid the potentially biased pre-tests for unit roots and cointegration, the procedure developed by Toda and Yamamoto (1995) uses the Wald test statistic for testing linear restrictions on the coefficients in an augmented VAR. The modified Wald (MWALD) statistic for the Granger non-causality test has an asymptotic chi-squared distribution with p degrees of freedom in the limit when a VAR (p+d_{max}) is estimated, where p is the optimal lag length in the unrestricted levels VAR and d_{max} is the maximal order of integration of the variables in the VAR.

The Granger non-causality procedure is implemented in two steps. In the first step, the optimal lag length of the unrestricted level VAR (p) is to be determined using appropriate information criteria, and d_{max} is determined using a unit root test. The specified VAR(p) is then augmented by the maximal order of integration and a VAR of order (p+d_{max}) is estimated. For instance, testing for causality in a bivariate system entails estimating the following augmented VAR of order (p+d_{max}):

$$X_t = \alpha_1 + \sum_{i=1}^{p+d_{\max}} \beta_{11,i} X_{t-i} + \sum_{i=1}^{p+d_{\max}} \beta_{12,i} Y_{t-i} + \varepsilon_{1t}$$

$$Y_t = \alpha_2 + \sum_{i=1}^{p+d_{\max}} \beta_{21,i} X_{t-i} + \sum_{i=1}^{p+d_{\max}} \beta_{22,i} Y_{t-i} + \varepsilon_{2t}$$

In this framework, the causal relationship from variable Y to X is evaluated by testing the null hypothesis that $\beta_{12,1} = \beta_{12,2} = \ldots = \beta_{12,p} = 0$, and causality from variable X to Y is examined by testing the null hypothesis that $\beta_{21,1} = \beta_{21,2} = \ldots = \beta_{21,p} = 0$. Toda and Yamamoto (1995) proved that the Wald statistic for testing the null hypothesis converges in distribution to a χ_p^2 random variable. Zapata and Rambaldi (1997) have ensured that the statistic for Toda and Yamamoto's (1995) Granger non-causality test has the standard asymptotic distribution and valid inferences can be carried out. Thus, this paper adopts Toda and Yamamoto's (1995) procedure to investigate the lead-lag relationships among the gold spot prices in London, New York, Japan, Hong Kong and Taiwan.

IV. Empirical Results

In order to apply the modified Wald test for Granger non-causality, it is necessary to determine the maximum order of integration of each of the gold price series, for which the Augmented Dickey-Fuller (1979) (ADF) unit root tests are used. As shown in Table 3, the results of the unit root tests for all series in levels indicate that the maximum order of integration is one, I(1), so that d_{max} = 1. In selecting the optimal lag length for levels VAR modelling, p, the Schwarz Bayesian criterion (SBC) is used, as in Table 4.

The order of the estimated VAR system, k, is determined by the sum of the optimal lag length (p) and maximum of integration (d_{max}), so that the empirical VAR($k = p + d_{\max}$) model is specified. Once the model is estimated, the modified Wald test proposed by Toda and Yamamoto (1995) is conducted to examine the causality relationships among the relevant variables.

According to the causality results shown in Table 5, the gold prices in the London and New York gold markets influence each other, leading to a bi-directional feedback relationship. Even in the cases where all the Asian markets are combined, or where just one of the Japan, Hong Kong and Taiwan markets is added, the bi-directional feedback relationship between the London and New York gold markets is evident. In particular, it should be noted that the Asian markets lie in between the London and New York markets, so as to play a key role in connecting these two markets. Due to the intermediary characteristic of the Asian markets, the global gold markets lead to a complete circulation, thereby enforcing the dynamic price integration between the London and New York markets.

Both the London and New York markets exercise authority over gold prices but adopt different price setting strategies. In open outcry systems, the gold price in the London market is fixed by the top five gold merchants around the world, including gold suppliers, demanders and speculators. The establishment and development of the New York gold market has led to a dramatic change in the structure of the world gold market. In particular, the tremendous trade volumes in the New York market deeply affect the authority over daily price fixing in the London gold market. The gold price in the New York market varies quickly, and responds immediately to the information in financial markets. In this respect, gold price fixing in the London market is less useful than in the New York market.

The empirical results show that there exist co-movement and correlation among gold prices in these five markets. The New York market uni-directionally affects the Asian markets (Japan, Hong Kong and Taiwan), while the Hong Kong and Taiwan markets uni-directionally affect the London market. Furthermore, the relationships between the New York and London markets, as well as between the London and Japan markets are bi-directional. When combining the above relationships, the New York market obviously dominates the other four markets, indicating that the gold price in the New York market plays an important role in the international gold market, and thereby influences other commodity markets. In this sense, the gold price in the New York market has the status of the key indicator.

On the other hand, the gold price in the London market directly affects the gold price in the New York market, consequently transmitting this effect to the gold price in Asian markets, and returning to the gold price in the London market after twenty-four hours. This leads to complete pricing circulation. Meanwhile, there exist bi-directional feedback connections among the Hong Kong, Japan and Taiwan markets. The fluctuations of the gold price in these three Asian markets exhibit significant co-movement, presumably resulting from the dynamic linkages by which the Hong Kong, Japan and Taiwan markets are all affected by the New York market.

The gold price in the London market is influenced by the New York and Asian markets, while the Hong Kong market has the most visible impact on the gold price in Asia. Hong Kong is a global financial centre, which has been attributed to some advantages, such as free capital flows, a sound legal system and the gathering of financial professionals. Hong Kong, with its prime status, has been an external financial hub of Greater China and Asia for a long time.

Since 1 July 1997, Hong Kong reverted to China, which has exhibited the most vigorous global economic development. Therefore, the Gold and Silver Exchange Society in Hong Kong has gained an increasingly important position as a world gold trading centre, along with the booming gold industry, the gradual maturity of the gold market in China, and continuously strengthening financial markets, such as Hong Kong, Shanghai and Shenzen. Accordingly, it is necessary to establish a more comprehensive pricing mechanism against other international gold markets, such as London and New York.

V. Conclusion

In order to avoid the estimation bias from non-stationary time series data, this paper used the Toda and Yamamoto (1995) procedure, based on the augmenting level-VAR models, to examine the dynamic linkages among gold prices in the global gold market. A primary analysis of gold prices in the London, New York, Japan, Hong Kong and Taiwan markets reported integrated series of order one in all cases. Furthermore, according to the characteristics of market size and trading time, the empirical framework is classified into six types. The modified Wald tests are conducted separately conducted to investigate the lead-lag relationship after each model has been estimated.

The fluctuations in the international gold price apparently contribute to co-movement and correlation, which may be attributed to the liberalization of financial markets, the explosive growth of the Internet, and the speedy transmission of global news, among others. The two leading global gold markets, namely London and New York, affect each other bi-directionally. The gold price in the London market, which is the oldest and biggest gold market in the world, directly influences the gold price in the New York market. The gold price in the London market is, however, affected by the other four markets. The price of gold in the New York market, which is not only the centre of international financial trade but also the center of global information, responds immediately to all pieces of news, and consequently leads to direct impacts on the other four markets. This draws the attention of all gold investors to the New York market. The empirical results also confirmed that the New York market plays a leading role in the global gold market.

As for the case of adding the Hong Kong market to the London and New York markets, the intensive interactions among these three markets are revealed since complete price circulation is constructed over twenty-four hours. This supports the claim that Hong Kong is not only an important economic hub in Asia, but also plays a crucial role in connecting the London and New York gold markets. The reason is that Hong Kong has a sound legal system, rigorous monitoring management and good subordinate facilities. As a result, even though Hong Kong is not the biggest gold trading market in the world, it has nevertheless become the first choice for gold investment in Asia. Thus, the Hong Kong gold market has gained a substantial position internationally.

Moreover, there exists bi-directional feedback relationship among the gold prices in the Hong Kong, Japan and Taiwan markets. These gold prices are all affected by the New York market, but lead to impacts on the London market. Japan is a country with poor gold, and its demand for gold mainly relies on imports. Therefore, the gold price in Japan is likely to be affected by the other four markets. The gold price in Taiwan, which is a small open economy, varies quickly following the changes in international markets. For instance, the gold price in the Taiwan market not only responds to changes in the New York market, but also closely interacts with the gold price in Hong Kong.

The gold prices in the London, New York and Hong Kong markets seem to be dominant driving forces, and also influence each other, exhibiting co-movements and correlation. This outcome is brought about by the fact that the explosive growth of the Internet reduces the costs of transferring information, and also promotes the efficiency of such transfers. Gold investors in the Taiwan market could set and adjust their investment strategies by not only referring to the one-day previous change in the gold price in the London and New York markets, but also by taking a closer examination of the price trend in the Hong Kong gold market on that day.

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Table 1

Data Description and Source

Country	Variable	Notation	Source
Taiwan	Taiwan gold passbook closing price	TG	Bank of Taiwan
UK	London spot gold pm fixing price	LG	London Bullion Market Association
US	New York spot gold closing price	NG	WWW.KITCO.COM
Japan	Japan spot gold closing price	JG	Mitsubishi Materials Corporation
Hong Kong	Hong Kong spot gold afternoon closing price (99 tael gold)	HG	Chinese Gold and Silver Exchange Society

Table 2

Opening Times in Gold Markets

Market	Local Time	Greenwich Mean Time (GMT)	Fixing Time (GMT)
London	8:30AM－5:30PM	08:30－17:30	10:30 AF and 15:00 PF
New York	9:00AM－4:00PM	14:00－21:00	-
Japan	9:00AM－3:30PM	00:00－06:30	-
Taiwan	9:00AM－3:30PM	01:00－07:30	-
Hong Kong	9:00AM－5:00PM	01:00－09:00	3:30 AF and 8:30 PF

Table 3

Results of ADF Tests

Type	Constant		Constant & Trend		None	
	t-value	p-value	t-value	p-value	t-value	p-value
LG	-0.257	0.929	-2.490	0.333	1.793	0.983
NG	-0.335	0.917	-2.623	0.270	1.698	0.979
JG	-0.308	0.921	-2.565	0.297	1.782	0.982
HG	-0.284	0.925	-2.563	0.298	1.736	0.980
TG	-0.448	0.898	-2.584	0.288	1.700	0.979
△LG	-31.963	0*	-31.962	0*	-31.870	0
△NG	-33.355	0*	-33.354	0*	-33.263	0*
△JG	-33.958	0*	-33.956	0*	-33.851	0*
△HG	-34.198	0*	-34.198	0*	-34.096	0*
△TG	-33.110	0*	-33.102	0*	-33.015	0*

Note: MacKinnon's (1996) one-sided p-values are used. * denotes significance at the 1% level

Table 4

Lag Lengths Based on SBC

VAR Model	Lags					
	1	2	3	4	5	6
LG, NG	14.594*	14.621	14.647	14.668	14.685	14.703
HG, JG, TG	21.158	21.119*	21.136	21.154	21.180	21.199
LG, NG, HG	21.094*	21.128	21.170	21.217	21.258	21.305
LG, NG, JG	21.402*	21.449	21.491	21.536	21.579	21.626
LG, NG, TG	21.369	21.321*	21.326	21.361	21.409	21.454
LG, NG, HG, JG, TG	34.093*	34.113	34.203	34.294	34.397	34.479

Note: * denotes the optimal lag length chosen by the Schwarz Bayesian Criterion (SBC).

Table 5
Results of Causality Tests

Model	Hypothesis	Chi-sq Stat.	p-value	Causality
VAR(1+1) = {LG, NG}	NG $\Rightarrow$ LG	798.8415	0.0000***	Bi-direction
	LG $\Rightarrow$ NG	1509.230	0.0000***	
VAR(2+1) = {HG, JG, TG}	JG $\Rightarrow$ HG	164.9232	0.0000***	Bi-direction
	HG $\Rightarrow$ JG	181.0251	0.0000***	
	TG $\Rightarrow$ HG	1039.695	0.0000***	Bi-direction
	HG $\Rightarrow$ TG	1051.010	0.0000***	
	JG $\Rightarrow$ TG	95.4408	0.0000***	Bi-direction
	TG $\Rightarrow$ JG	79.8773	0.0000***	
VAR(1+1) = {LG, NG, HG}	NG $\Rightarrow$ LG	81.6921	0.0000***	Bi-direction
	LG $\Rightarrow$ NG	1202.270	0.0000***	
	HG $\Rightarrow$ LG	313.9037	0.0000***	Uni-direction
	LG $\nRightarrow$ HG	1.4412	0.2300	
	NG $\Rightarrow$ HG	1187.596	0.0000***	Uni-direction
	HG $\nRightarrow$ NG	1.4672	0.2258	
VAR(1+1) = {LG, NG, JG}	NG $\Rightarrow$ JG	863.3475	0.0000***	Uni-direction
	JG $\nRightarrow$ NG	0.1679	0.6820	
	JG $\Rightarrow$ LG	41.1280	0.0000***	Bi-direction
	LG $\Rightarrow$ JG	9.0926	0.0026***	
	LG $\Rightarrow$ NG	1444.002	0.0000***	Bi-direction
	NG $\Rightarrow$ LG	287.7110	0.0000***	
VAR(2+1) = {LG, NG, TG}	NG $\Rightarrow$ TG	996.4737	0.0000***	Uni-direction
	TG $\nRightarrow$ NG	0.525184	0.7691	
	TG $\Rightarrow$ LG	170.2884	0.0000***	Uni-direction
	LG $\nRightarrow$ TG	1.5189	0.4679	

	$NG \Rightarrow LG$ $LG \Rightarrow NG$	198.9768 1283.873	0.0000*** 0.0000***	Bi-direction
VAR(1+1) = {LG, NG, HG, TG, JG}	$LG \Rightarrow NG$ $NG \Rightarrow LG$	1182.400 50.1630	0.0000*** 0.0000***	Bi-direction
	$NG \Rightarrow HG$ $HG \nRightarrow NG$	136.8195 2.098779	0.0000*** 0.1474	Uni-direction
	$HG \Rightarrow LG$ $LG \nRightarrow HG$	145.3003 0.1205	0.0000*** 0.7285	Uni-direction
	$HG \Rightarrow TG$ $TG \Rightarrow HG$	536.2272 509.9051	0.0000*** 0.0000***	Bi-direction
	$NG \Rightarrow TG$ $TG \nRightarrow NG$	25.4636 0.3333	0.0000*** 0.5637	Uni-direction
	$HG \Rightarrow JG$ $JG \Rightarrow HG$	15.4744 16.3374	0.0001*** 0.0001***	Bi-direction
	$TG \Rightarrow LG$ $LG \Rightarrow TG$	4.8053 0.0019	0.0284** 0.9648	Uni-direction
	$LG \Rightarrow JG$ $JG \Rightarrow LG$	11.4204 2.8197	0.0007*** 0.0931*	Bi-direction
	$NG \Rightarrow JG$ $JG \nRightarrow NG$	154.5512 0.3965	0.0000*** 0.5289	Uni-direction
	$TG \Rightarrow JG$ $JG \Rightarrow TG$	33.1450 36.9387	0.0000*** 0.0000***	Bi-direction

Note: ***, ** and *denote significance at the 1%, 5% and 10% levels, respectively.

Figure 1. Return of gold price in the market of London, New York, Hong Kong, Japan and Taiwan