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The relationship between Asian equity and commodity futures markets

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Abstract

In this paper, we test spillover effects between Asian equity market volatility and the volatility of the two most dominant commodities, namely, crude oil and gold futures. We consider a total of 14 Asian markets. We find that volatility shocks in established and mature equity markets, such as the Japanese market, spill over to the crude oil and gold futures markets, while immature markets tend to have spillover effects from commodity futures to equity markets. We also report evidence of increased bi-directional volatility transmission during the recent global financial crisis period. Like the volatility of crude oil futures, the volatility of gold futures matters to the equity market. As far as equity market volatility is concerned, the impact of volatility shocks from the gold futures market is as important as the volatility shocks from the crude oil futures market.

Key words: Equity Markets; Gold Futures; Oil Futures; Volatility Spillover

1. INTRODUCTION

The role of commodity markets in influencing financial markets has been an active area of research in financial economics. This literature was re-invigorated in light of the rise in commodity prices, particularly the price of gold and crude oil, over the last half-decade. Recent studies, for instance, have documented that oil price is both a determinant and predictor of stock returns (Driesprong *et al*., 2008; Narayan and Sharma, 2011) and that gold is referred to as a "safe haven asset" (Baur and McDermott, 2010; Baur and Lucey, 2010). Baur and McDermott (2010) define haven as "a place of safety or refuge … a safe haven asset must, therefore, be an asset that holds its value in 'stormy weather' or adverse market conditions. Such an asset offers investors the opportunity to protect wealth in the event of negative market conditions" (Baur and McDermott, 2010, p. 1886). Oil market volatility has received research attention from different perspectives. Narayan and Narayan (2007), examining oil price volatility across the various sub-samples, conclude that price behaviour in crude oil is dominated by regime switching behaviour. Hayat and Narayan (2011) examine supply and demand shocks to explain the patterns of US volatility of oil stock. They find supply and demand factors contribute to about 70% of the variation in the growth of crude oil stock.

The literature closest to our work considers volatility spillover from crude oil to the equity market. Studies which find significant volatility spillover between oil and stock markets are Arouri *et al*. (2011), Malik and Hammoudeh (2007), Malik and Ewing (2009), and Tansuchat *et al*. (2009). Malik and Hammoudeh (2007) examine the volatility and shock transmission mechanism between the US equity, global crude oil market, and Gulf equity markets (Saudi Arabia, Kuwait and Bahrain). They document that, in all cases, volatility spillover is from the oil market to equity markets except in the case of Saudi Arabia, where volatility spillover is

from the equity market to the oil market. Malik and Ewing (2009) apply a bivariate GARCH model to simultaneously estimate the mean and conditional variance between the five US sectoral indices, namely, financials, industrials, consumer services, health care and technology, and the oil prices. They find significant evidence of transmission of shocks and volatility between oil prices and financials, industrials, consumer services, health care, and technology sectors.

Moreover, the most recent study by Arouri *et al*. (2011) examines the extent of volatility transmission between oil and stock markets in Europe and the US at the sector level. They apply a generalised VAR-GARCH approach and discover volatility spillover between oil and sector stock returns. They also document that the spillover is uni-directional, from oil markets to stock markets in Europe, but bi-directional in the US.

Most studies examining the relationship between commodity prices and financial markets use spot price series to understand price movements (see, inter alia, Arouri *et al*., 2011; Baur and McDermott, 2010; Narayan and Narayan, 2010; Ferson and Harvey, 1994). In this paper we use futures series to examine the second order linkages between major commodities and equity markets in the Asian region. Futures series are used because empirical evidence reveals that price discovery takes place in the futures market (Garbade and Silber, 1983; Kavussanos and Visvikis, 2004; Kavussanos and Nomikos, 2003). Given the relationship between commodity markets and equity markets (see Narayan and Sharma, 2011, for instance), we expect that any volatility shocks resulting from the commodity futures market[1] will, potentially, have implications for the equity market, and vice versa.

[1] See Narayan, Narayan and Zheng (2010) for efficiency of gold and oil futures. They found these two markets were jointly inefficient, at least during their sample period – 1995 to 2009.

From this literature, we learn that oil price volatility spillover exists and mostly emerges from the oil market and affects the equity market. Yet, the literature is incomplete in that it only considers oil market volatility. Other commodities, such as gold, also affect the performance of stock markets, therefore, what about gold market volatility? In other words, is the spillover from the gold market also statistically significant, and is it relatively more important than oil price volatility spillover? These questions have not been addressed by the literature and are important for the following reasons. Baur and McDermott (2010) examine the role of gold in the global financial system. They find that gold is both a hedge and a safe haven for major European stock markets and the US. They also argue that gold may act as a stabilising force for the financial system by reducing losses in the face of extreme negative market shocks. In addition, they also report that gold was a strong safe haven for most developed markets during the peak of the recent Global Financial Crisis (GFC)[2].

Baur and Lucey (2010) investigate gold as a hedge and a safe haven by examining the constant and time-varying relations between the US, the UK, and German stock and bond returns and gold returns. They document that gold served as a hedge against equity and a safe haven in extreme stock market conditions. They also perform a portfolio analysis and find that the safe haven is short-lived. Lucey *et al.* (2006) examine the seasonality in the conditional and unconditional mean and variance of daily gold and silver contracts. They find that there is a negative Monday effect in both gold and silver cash and futures markets.

Capie *et al.* (2005) examine the role of gold as a hedge against the dollar. They document that gold served as a hedge because it is unlike a homogenous asset and, therefore, is easily traded

[2] Other examples of studies that examine the financial characteristics of gold include Baur and Lucey (2010), McCown and Zimmerman (2006), Lucey *et al*. (2006), Faugere and Van Erlach (2006), Capie *et al*. (2005), and Sherman (1982).

in a continuously open market. They also show that gold has served as a hedge against fluctuations in the foreign exchange value of the dollar.

Moreover, Faugere and Van Erlach (2006) develop a gold asset pricing theory that treats gold as a store of wealth. They demonstrate a theoretical and empirical link between gold price, inflation, and foreign exchange rates and the general valuation of the stock market. They show that the real price of gold varies inversely with the stock market price-earnings ratio.

In this paper, we take the literature on equity market volatility and commodity market volatility forward by testing the following hypotheses:

1) That the volatility spillover from the oil market and the gold market to the equity market is statistically significant; and
2) That the oil and gold price volatility spillover to equity markets was statistically different during the recent GFC compared to the pre-crisis period.

We test these hypotheses for a total of 14 Asian countries, namely, Indonesia, India, Singapore, Malaysia, the Philippines, Vietnam, Taiwan, Japan, China, South Korea, Pakistan, Thailand, Sri Lanka, and Hong Kong[3]. Our data set is daily and spans the period 05 July 2005 to 14 December 2011. Briefly, foreshadowing the main results, we find that volatility shocks from developed equity markets, such as the Japanese market, spillover to the crude oil and gold futures markets, while immature markets, such as the Sri Lankan and Thailand equity markets, tend to have spillover effects from the crude oil futures market. We also document evidence of increased bi-directional volatility interactions between crude oil futures and

[3] Examining stock return response to US exchange rate and short-rate, Narayan and Narayan (2012) find majority of Asian countries in their study responded to exchange rate depreciation in the long run, while all of the countries responded to short-rate in the short run.

equity markets, whereas the bi-directional interaction between gold futures and equity markets has decreased during the most recent global crisis period.

The rest of the paper is organised as follows. In the next section, we discuss the methodology. In Section 3, we provide a detailed discussion on the data used in this study, followed by a discussion of the results. In the final section, we provide concluding remarks.

2. Methodology

In order to understand volatility interactions between the equity markets of Asia and commodity (crude oil and gold) futures, we utilise the bivariate BEKK-GARCH (1,1) framework of Engle and Kroner (1995) to capture the joint process underpinning any given pair of markets. Given the non-stationary nature of the volatility series in our study, we utilise the logarithmic return form of the series, as identified in Equations (1) and (2), and the joint process is captured by Equation (3).

$$R_{1,t} = ln\left(\frac{P_{1,t}}{P_{1,t-1}}\right) \times 100 \quad (1)$$

$$R_{2,t} = ln\left(\frac{P_{2,t}}{P_{2,t-1}}\right) \times 100 \quad (2)$$

$$R_t = \alpha + u_t \quad (3)$$

$$u_t|\Omega_{t-1} \sim N(0, H_t) \quad (4)$$

The joint process capturing the equity market and commodity futures in this study can be represented by Equation (3), where $R_t = \left(R_{1,t}\ and\ R_{2,t}\right)$, $\alpha = (\alpha_1\ and\ \alpha_2)$, and $u_t = (\varepsilon_{1,t}\ and\ \varepsilon_{2,t})$ are vectors of equity and futures series, the constant, and the residuals, respectively. The residual vector u_t is bivariate and conditionally normally distributed. H_t

represents the conditional covariance matrix, where $\{H_t\} = h_{ij,t}$for $i, j = 1,2$. The information set available at time t is represented by Ω_{t-1}.

The conditional covariance matrix of Engle and Kroner (1995) for a BEKK GARCH (1,1) is represented by Equation (5), where C_0 is restricted to be a lower triangular matrix.

$$H_t = C_0'C_0 + A_{11}'\varepsilon_{t-1}\varepsilon_{t-1}'A_{11} + G_{11}'H_{t-1}G_{11} \quad (5)$$

Equation (5) is represented in matrix form through Equation (6) in order to show the expansion through matrix multiplication resulting in h_{11}, h_{12} and h_{22} of the unrestricted model which is represented by Equation (7).

$$A = C_0'C_0 + \begin{bmatrix} a_{11}a_{12} \\ a_{21}a_{22} \end{bmatrix}' \begin{bmatrix} \varepsilon_{1,t-1}^2 & \varepsilon_{1,t-1,}\varepsilon_{2,t-1} \\ \varepsilon_{1,t-1,}\varepsilon_{2,t-1} & \varepsilon_{2,t-1}^2 \end{bmatrix} \begin{bmatrix} a_{11}a_{12} \\ a_{21}a_{22} \end{bmatrix} + \begin{bmatrix} g_{11}g_{12} \\ g_{21}g_{22} \end{bmatrix}' H_{t-1} \begin{bmatrix} g_{11}g_{12} \\ g_{21}g_{22} \end{bmatrix} \quad (6)$$

$$h_{11,t} = c_{11}^2 + a_{11}^2\varepsilon_{1,t-1}^2 + 2a_{11}a_{21}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a_{21}^2\varepsilon_{2,t-1}^2 + g_{11}^2h_{11,t-1} + 2g_{11}g_{21}h_{12,t-1} + g_{21}^2h_{22,t-1}$$

$$h_{12,t} = c_{11}c_{21} + a_{11}a_{12}\varepsilon_{1,t-1}^2 + (a_{21}a_{12} + a_{11}a_{22})\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a_{21}a_{22}\varepsilon_{2,t-1}^2 + g_{11}g_{12}h_{11,t-1} + (g_{21}g_{12} + g_{11}g_{22})h_{12,t-1} + g_{21}g_{22}h_{22,t-1}$$

$$h_{22,t} = c_{21}^2 + c_{22}^2 + a_{12}^2\varepsilon_{1,t-1}^2 + 2a_{12}a_{22}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a_{22}^2\varepsilon_{2,t-1}^2 + g_{12}^2h_{11,t-1} + 2g_{12}g_{22}h_{12,t-1} + g_{22}^2h_{22,t-1} \quad (7)$$

To establish the spillover effects from the equity markets of individual Asian countries to the commodity futures markets, we constrain the cross-market terms ($a_{12} = g_{12} = 0$) – the lagged squared residuals and lagged conditional variance of the equity market that do not enter the equation. This restricted model, testing the causality from the equity market to the commodity futures, is represented in a reduced form as follows:

$$h_{11,t} = c_{11}^2 + a_{11}^2\varepsilon_{1,t-1}^2 + 2a_{11}a_{21}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a_{21}^2\varepsilon_{2,t-1}^2 + g_{11}^2h_{11,t-1} + 2g_{11}g_{21}h_{12,t-1} + g_{21}^2h_{22,t-1}$$

$$h_{12,t} = c_{11}c_{21} + a_{11}a_{22}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a_{21}a_{22}\varepsilon_{2,t-1}^2 + g_{11}g_{22}h_{12,t-1} + g_{21}g_{22}h_{22,t-1}$$

$$h_{22,t} = c_{21}^2 + c_{22}^2 + a_{22}^2\varepsilon_{2,t-1}^2 + g_{22}^2 h_{22,t-1} \quad (8)$$

To test the volatility spillover effects from the commodity futures returns to the equity return of Asian markets, we now restrict a_{21} and g_{21} to be equal to zero. This restriction effectively cancels the lagged squared residuals and lagged conditional variance of the commodity return futures. This restricted model, represented by Equation (9), captures the causality effect from returns of commodity futures to returns of equity markets.

$$h_{11,t} = c_{11}^2 + a_{11}^2\varepsilon_{1,t-1}^2 + g_{11}^2 h_{11,t-1}$$

$$h_{12,t} = c_{11}c_{21} + a_{11}a_{12}\varepsilon_{1,t-1}^2 + a_{11}a_{22}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + g_{11}g_{22}h_{12,t-1} + g_{11}g_{22}h_{12,t-1} + g_{21}g_{22}h_{12,t-1}$$

$$h_{22,t} = c_{21}^2 + c_{22}^2 + a_{12}^2\varepsilon_{1,t-1}^2 + 2a_{12}a_{22}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a_{22}^2\varepsilon_{2,t-1}^2 + g_{12}^2 h_{11,t-1} + 2g_{12}g_{22}h_{12,t-1} + g_{22}^2 h_{22,t-1} \quad (9)$$

In order to investigate the volatility interaction and spillover between pairs of markets, BEKK-GARCH models with restricted off-diagonal terms are estimated, and likelihood ratio tests are then conducted to assess the direction of causality. The unrestricted model is represented by Equation (7), and the off-diagonal terms of the A_{11} and G_{11}matrices are restricted to be zero to generate the restricted versions of the models identified in Equations (8) and (9). The log likelihood value from Equation (8) is compared against the log likelihood value of the unrestricted model through a likelihood ratio test to examine the volatility spillover from the equity market to the commodity futures market.

In the same way, we impose restrictions on the diagonal terms, a_{21} and g_{21}, to generate the restricted version of the model identified in Equation (9). This allows us to eliminate the

lagged effects of both the squared residuals and the conditional variance to test the causality effect from the commodity market to the equity market. The log likelihood value from Equation (9) is compared against the unrestricted model (Equation (7)) using the likelihood ratio test to see the volatility spillover from the commodity futures to the equity market.

The likelihood ratio test outlined in Equation (10) compares, separately, the log likelihood values of the restricted models identified in Equations (8) and (9) with the unrestricted model identified in Equation (7). The test statistics from this test are compared against the Chi-Square critical values to establish the existence and direction of volatility spillover between the equity market of individual countries and the commodity futures:

$$D = -2LLR = -2\ln\left(\frac{L_0}{L_1}\right) = -2(lnL_0 - lnL_1) \tag{10}$$

where LLR is the Log Likelihood Ratio and L_0 is the value of the likelihood function of the restricted model, and $L_1$is the value of the likelihood function of the unrestricted model. The statistic D follows a Chi-Square distribution with k degrees of freedom, with k being the number of restrictions imposed in the restricted model. The Chi-Square distribution with 2 degrees of freedom is used as the critical value. The critical values with $df = 2$ at 1%, 5% and 10% are 9.21, 5.99, and 4.61, respectively, for the nested model. As is typical in the literature, all the maximum likelihood estimations are optimized by the BHHH algorithm developed by Berndt, Hall, Hall and Hausman (1974). The conditional log likelihood function $L(\theta)$ for a sample of T number of observations has the following form:

$$L(\theta) = \sum_{t=1}^{T} l_t\,(\theta)$$

$$l(\theta) = -\log 2\,\pi - 1/2\log|H_t(\theta)| - 1/2\varepsilon_t'\,(\theta)H_t^{-1}(\theta)\varepsilon_t(\theta) \tag{11}$$

3. Data and Results

3.1 Data

We use stock market indices belonging to 14 Asian countries (China, Hong Kong, India, Indonesia, Japan, Malaysia, Pakistan, the Philippines, Singapore, South Korea, Sri Lanka, Taiwan, Thailand and Vietnam) together with the two major commodity market futures – crude oil and gold futures - to understand the binding relationship at the second moment between these distinct categories of markets in the Asian region[4]. As outlined in Section 2, using daily data sourced from the Bloomberg database, we use the Engle and Kroner (1995) BEKK type of bivariate GARCH framework to capture the volatility interactions between equity and commodity futures series from 05 July 2005 to 14 December 2011. Accounting for structural breaks and extreme financial market volatility during the financial crisis, we also separately investigate the nature of volatility interaction between these two categories of markets in the region by stratifying the sample into the pre-crisis period (5/07/2005 to 26/02/2007) and the crisis period (27/02/2007 to 31/12/2010).

A brief discussion of data is in order. We report descriptive statistics for oil futures, gold futures, and equity returns of 14 Asian countries in Table 1. Equity returns are computed as $\log(P_t/P_{t-1}) * 100$, where P_t is the equity index. Mean returns, standard deviation, skewness, and kurtosis statistics are reported. Panel A reports statistics based on daily data for the period 5/07/2005 to 31/12/2011. The descriptive statistics of data suggest that daily equity returns are in the -0.02 – 0.051% range. The highest mean return is recorded for Indonesia, while the lowest is observed for Japan. The coefficient of variation reveals that China's (1.65) equity market is most volatile, followed by Hong Kong (1.54), Vietnam (1.51), and India

[4] Yilmaz (2010) and Colavecchio and Funke (2009) have examined volatility dynamics of equity and currency forward markets for the Asian region.

(1.50). The standard deviations for the rest of the countries are reported at less than 1.5. All countries' equity returns have a negative skew except for Hong Kong and India. Malaysia has the most negative skewness. Similar statistics are produced by kurtosis, suggesting that the return distributions are all leptokurtic, and are more so for Thailand.

INSERT TABLE 1

In Panels B and C, we report descriptive statistics of 14 Asian countries' equity returns for the pre-crisis and crisis periods, respectively. We notice that the statistical behaviour of equity returns is different during the crisis period compared to the pre-crisis period. In particular, we observe that for all 14 countries mean returns are much higher in the pre-crisis period compared to the crisis period. On the other hand, we notice that the volatility of equity returns for all countries is higher in the crisis period compared to the pre-crisis period, except in the case of Pakistan and Sri Lanka. The kurtosis statistics reveal that equity returns for 10 countries, that is, except in China, Taiwan, Thailand and Vietnam, are relatively more leptokurtic in the crisis period compared to the pre-crisis period.

To understand the pattern of volatility spillover from commodity markets to equity markets, we have estimated the correlation between equity markets and the respective commodity markets (see columns 6 and 7 of Table 1). The correlation between equity and gold significantly varies over the full sample period and ranges between -0.77 (Japan) and 0.91 (Indonesia). The correlation between equity markets and crude oil has been steadier and the average correlation between equity markets and crude oil falls in the range of -0.13 to 0.67. However, once we divide the sample into the pre-crisis and crisis periods, the correlations change, suggesting a change in the relationship between equity and commodity markets. Surprisingly, the pre-crisis period's correlation between the equity market and the crude oil

market has been largely negative for all countries. For the same period, the correlation between the equity and the gold markets has been largely positive. The higher correlation between financial and commodity markets suggests greater interdependence between these markets, implying potentially greater spillover from one market to another. However, the correlation might not provide a definitive answer on the directional spillover from one market to another; therefore, further analyses are required to ascertain such interaction between these two markets.

3.2 Preliminary Results

We begin by considering a test of the null hypothesis of a unit root in the equity index and in gold futures and oil futures indices for each of the 14 countries in our sample. The unit root test that we use is the familiar Augmented Dickey-Fuller (ADF, 1981) test. According to the ADF test, the unit root null is not rejected for all the series. All indices are found to be unit root non-stationary. The logarithmic return forms of the variables are, however, stationary. To conserve space we have not reported these results, but they are available upon request. Given the non-stationary nature of data, the logarithmic return form is used in the BEKK framework to capture volatility interactions between stock indices of individual countries and crude oil and gold futures returns.

3.3 Empirical Findings

In the following two sub-sections, we will discuss the volatility spillover effect between the equity market and the crude oil futures and gold futures markets using full sample and sub-samples representing the pre-crisis and crisis periods, respectively. Based on the test results, we categorise the second moment interaction in four categories: a) one-way volatility spillover from the equity market to the commodity market; b) one-way volatility spillover

from the commodity market to the equity market; c) bi-directional volatility, where shocks impact both markets; and d) an absence of volatility interactions between the two markets.

3.3.1 Volatility spillover - full sample

We report results based on volatility spillover between the crude oil futures market and the equity markets of 14 Asian countries (namely, China, Hong Kong, India, Indonesia, Japan, Malaysia, Pakistan, the Philippines, Singapore, South Korea, Sri Lanka, Taiwan, Thailand and Vietnam) for the full sample period in Panel A of Table 2. The likelihood ratio test statistics emanating from restrictions 1 and 2 are reported in columns 2 and 3, respectively. We find that for three out of 14 markets, namely, Japan, Taiwan and Vietnam, there is uni-directional volatility spillover from the equity market to crude oil futures. On the other hand, Hong Kong, Pakistan, Sri Lanka and Thailand experience volatility spillover from crude oil futures to the equity market. We also find bi-directional volatility spillover between the equity markets and the crude oil futures market for India, Malaysia, and South Korea. This implies that in the case of India, Malaysia and South Korea, the volatility shocks in both the equity and crude oil futures markets are important to each other. In addition, we find no evidence of statistically significant volatility spillover between the equity markets and the crude oil futures markets for China, Indonesia, Singapore, and the Philippines over the full sample period. This confirms that there is no lead-lag relationship between the equity and crude oil markets for these four countries.

INSERT TABLE 2

In Panel B of Table 2, we report the likelihood ratio test results for the volatility interactions between the equity markets and the gold futures market. We find uni-directional volatility spillover from the equity markets of Japan, Sri Lanka and Vietnam to the gold futures market. The volatility spillover from the gold futures market to the equity market is observed in India and Indonesia. We also find evidence of bi-directional volatility spillover in the case of China

and the Philippines. In addition, unlike crude oil futures, the interaction of volatility shocks between the equity market and the gold futures market is not found in Hong Kong, Malaysia, Pakistan, Singapore, South Korea, Taiwan and Thailand during the full sample period. It should be noted that the absence of volatility interaction could also be masked by the extreme volatility phase of the financial markets that was experienced during the 2007 GFC. We examine the volatility spillover effects in the pre-crisis and crisis periods later.

The main findings can be summarised as follows:

1. Like oil, gold volatility also influences stock market volatility;
2. In three countries, volatility transmission is from the equity to the oil futures market and, in four countries, volatility transmission is from the oil futures to equity markets;
3. In three countries, volatility transmission is from the equity to the gold futures market and, in two countries, volatility transmission is from the gold futures to the equity markets;
4. Bi-directional spillover is observed between oil futures and equity for three countries, and between gold futures and equity for two countries.
5. For four countries, there is no volatility relationship between the oil and equity markets, while, for seven countries, there is no volatility relationship between the gold and the equity markets.

3.3.2 Volatility spillover - pre-crisis and crisis periods

Given the extreme volatility experienced during the 2007 GFC, we subdivided the sample into a pre-crisis period (5 July 2005 to 26 February 2007) and a crisis period (27 February 2007 to 31 December 2010) to examine and unravel the volatility shocks in these markets. These results are reported in Table 3. The reason for starting the crisis window in February

2007 was that the downward trend in most of the equity markets, including the Asian region, started in the latter part of February 2007. Though there were pockets of recovery until early 2008, the downward trend was steady and clear from February 2007 (see Grammatikos and Vermeulen, 2012).

INSERT TABLE 3

There are more cases of significant volatility spillover between equity and oil futures market during the crisis period compared to the pre-crisis period (see Panel A, Table 3). During the pre-crisis period, we find significant uni-directional volatility spillover from two equity markets (Pakistan and South Korea) to the crude oil futures market. On the contrary, we note that the volatility spillover from crude oil futures to the equity market is observed for four markets, namely, China, Malaysia, Vietnam and Singapore during the pre-crisis period. We also note that for Japan and Thailand, there is bi-directional volatility spillover between their equity markets and oil futures markets during the pre-crisis period.

Further, there is significant volatility interaction between the equity markets of Asia and the crude oil futures market during the crisis period. A noticeable feature during the crisis period is that in the 50% of our sample of countries (Hong Kong, India, Malaysia, Pakistan, South Korea, Taiwan and Thailand) there is a bi-directional volatility interaction. Moreover, we find a uni-directional spillover effect from the equity markets of China, Indonesia and the Philippines to the crude oil futures market. On the other hand, in the case of Sri Lanka during the crisis period, volatility spillover is from the crude oil futures market to the equity market. This could be attributed to the unfavourable position inherited by the country through the oil futures position taken by its Central Bank.

Panel B of Table 3 reports results for volatility spillover interactions between the equity markets of Asia and the gold futures market. Unlike the case of crude oil futures, the volatility shocks of the gold futures market and the equity market seem to be high during the pre-crisis period compared to the crisis period. Bi-directional volatility spillover is found in the case of seven countries - Indonesia, the Philippines, Singapore, South Korea, Taiwan, Thailand and Vietnam - during the pre-crisis period. Volatility spillover from the gold futures market to the equity market is evident in the case of China, India and Japan. Volatility spillover from the equity market to the gold futures market is only found for Sri Lanka during the pre-crisis period. This marks a period during which the country's financial market was relatively inactive due to an ongoing civil war. Only in three countries (Hong Kong, Malaysia and Pakistan) did we observe the absence of volatility interaction during the pre-crisis period.

Moreover, we see that China and Japan experience uni-directional spillover from the gold futures market to equity markets during the pre-crisis period, but the direction is reversed during the crisis period. In the crisis period, these two markets experience volatility spillover from the equity markets to the gold futures market. In the case of India, in both the pre-crisis and the crisis period, the uni-directional volatility spillover is observed from the gold futures market to the equity market. In addition, we find that there is bi-directional volatility spillover between Indonesia's equity market and the gold futures market during the pre-crisis period, and this changed to uni-directional spillover from the gold futures to the equity market during the crisis period. In addition, bi-directional volatility spillover is observed in the case of Malaysia, the Philippines and South Korea during the crisis period. It is worth noting that the Malaysian equity market, which had no volatility interaction during the pre-crisis period, experienced bi-directional volatility spillover during the crisis period.

Plausible explanations for the changing shape of volatility dynamics during the pre-crisis and crisis windows for oil futures and gold futures could be attributed to their relationship with the equity market over those two windows. Examining the last two columns of Table 1, it is clear that the relationship between the Asian equity markets and the oil futures market during the pre-crisis period was negative, with the exception of Pakistan and Thailand. However, the correlation coefficient between oil futures and equity markets for all 14 countries increased dramatically during the crisis period, and the correlation coefficient (which ranges between 0.001 – 0.63) was noted positive for all 14 countries. During the pre-crisis period, the oil price was on the rise reaching the peak point of $147 per barrel during the crisis window. On the other hand, the correlation between gold futures and equity markets was intense during the pre-crisis period, ranging between 0.2-0.9. However, this relationship becomes weaker during the crisis period in most of the countries with the exception of South Korea and Indonesia. Notably, the correlation between gold futures and the equity market also turned negative during the crisis period for China, Japan, Pakistan and Vietnam.

The main findings can be summarised as follows:

1. Like oil, gold volatility also affected stock market volatility during both the pre-crisis and crisis periods;
2. Volatility interaction is greater between oil futures and equity markets during the crisis period compared to the pre-crisis period;
3. Unlike oil, the volatility transmission is greater between gold futures and equity markets during the pre-crisis period compared to the crisis period;
4. The bi-directional spillover between oil futures and the equity markets, and between gold futures and the equity markets, is observed in 9 and 11 countries during the crisis and pre-crisis periods, respectively.

4. Conclusion

In this paper, we examine the volatility interactions between equity markets and crude oil, and between equity markets and gold futures markets. We consider 14 Asian countries and use a multivariate GARCH model. We investigate the volatility dynamics during the entire sample period (5 July 2005 to 14 December 2011) and the sub-samples, characterised by the 2007 GFC.

First, the results from the whole sample reveal that, like oil price volatility, gold price volatility is also statistically significantly related to Asian stock market volatility. We find that for three countries (India, Malaysia and South Korea), there is bi-directional spillover between oil futures and equity markets, and for two countries (China and the Philippines), there is bi-directional spillover between gold futures and equity markets. For three countries (Japan, Taiwan and Vietnam), we observe uni-directional spillover from equity to oil futures markets, and uni-directional spillover from equity to gold futures markets for three countries (Japan, Sri Lanka and Vietnam).

Finally, the sub-sample results show that most of the volatility interaction between oil futures and equity markets occurred during the crisis period, whereas the volatility transmission between gold futures and equity markets mostly occurred during the pre-crisis period. This implies there are heterogeneous volatility impacts from oil and gold markets on stock market volatility.

There are three implications from our results. First, our findings challenge the popular view that it is the oil price volatility that matters for the volatility of equity markets. We document

strong evidence of gold price volatility influencing equity market volatility, at least to the extent that oil price volatility matters. Second, our analysis over the crisis and pre-crisis periods suggests that oil price volatility was dominant mostly during the crisis period, while gold price volatility was significantly related to the Asian markets mostly in the pre-crisis period. This finding is not surprising because it was during the crisis window that oil price was not only the most volatile but, for the first time, reached over US$100 per barrel. By comparison, gold prices have been increasing in a gradual manner. Third, not all 14 Asian stock markets have volatility linkages with the commodity futures markets. For example, in four countries there is no spillover effect between oil price volatility and equity price volatility, while for seven countries there is no spillover effect between gold price volatility and equity price volatility. This suggests that stock markets in the region have heterogeneous responses to commodity market volatility shocks.

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Table 1

Descriptive Statistics

	Sample of Countries	Mean	Std. Dev.	Skewness	Kurtosis	Correlation with Gold	Correlation with Oil
Panel A: Full Sample Period							
1	China	0.044	1.648	-0.530	7.992	0.343	0.438
2	Hong Kong	0.011	1.535	0.075	15.205	0.371	0.669
3	India	0.033	1.493	0.023	15.047	0.725	0.603
4	Indonesia	0.051	1.337	-0.763	13.340	0.910	0.589
5	Japan	-0.020	1.298	-0.473	15.492	-0.770	-0.127
6	Malaysia	0.021	0.714	-1.493	24.665	0.747	0.571
7	Pakistan	0.020	1.136	-0.308	8.347	0.187	0.630
8	Philippines	0.036	1.195	-0.821	16.152	0.759	0.482
9	Singapore	0.049	0.937	-0.270	15.214	0.281	0.555
10	South Korea	0.009	1.152	-0.207	10.803	0.863	0.406
11	Sri Lanka	0.026	1.305	-0.663	13.750	0.690	0.659
12	Taiwan	0.004	1.172	-0.468	8.193	0.356	0.584
13	Thailand	0.018	1.239	-1.280	25.421	0.641	0.605
14	Vietnam	0.017	1.510	-0.047	4.716	-0.209	0.049
1	CRUDE OIL	*0.020*	*2.157*	*0.145*	*11.059*		
2	GOLD	*0.056*	*1.138*	*-0.237*	*9.427*		
Panel B: Pre-crisis Period							
1	China	0.182	1.263	-1.065	12.804	0.700	-0.219
2	Hong Kong	0.055	0.749	-0.386	5.519	0.741	-0.232
3	India	0.087	1.235	-0.649	8.240	0.863	-0.124
4	Indonesia	0.072	1.065	-0.803	10.533	0.797	-0.176
5	Japan	0.065	0.902	-0.286	5.765	0.796	0.029
6	Malaysia	0.047	0.471	-0.799	11.842	0.534	-0.380
7	Pakistan	0.069	1.195	-0.650	6.701	0.844	0.109
8	Philippines	0.087	1.009	-0.734	13.363	0.730	-0.306
9	Singapore	0.056	0.716	-0.671	7.590	0.701	-0.298
10	South Korea	0.055	0.930	-0.413	5.224	0.438	-0.443
11	Sri Lanka	0.076	1.075	-1.342	20.185	0.809	-0.035
12	Taiwan	0.039	0.789	-0.571	7.446	0.757	-0.218
13	Thailand	0.003	1.123	-3.563	84.342	0.246	0.277
14	Vietnam	0.253	1.514	0.074	4.987	0.760	-0.165
1	CRUDE OIL	0.077	1.092	-0.899	9.374		
2	GOLD	0.006	1.576	0.230	4.745		
Panel C: Crisis Period							
1	China	0.000	1.761	-0.411	7.088	-0.277	0.255
2	Hong Kong	-0.005	1.726	0.103	12.737	0.043	0.633
3	India	0.012	1.575	0.143	15.321	0.529	0.538
4	Indonesia	0.044	1.419	-0.735	12.971	0.852	0.492
5	Japan	-0.051	1.411	-0.438	14.604	-0.693	0.163
6	Malaysia	0.010	0.785	-1.470	22.340	0.590	0.485
7	Pakistan	0.003	1.116	-0.169	9.089	-0.024	0.622
8	Philippines	0.014	1.268	-0.931	16.281	0.660	0.388
9	Singapore	-0.009	1.272	-0.153	9.582	0.064	0.528
10	South Korea	0.015	1.412	-0.653	13.136	0.885	0.316
11	Sri Lanka	0.039	0.885	0.381	10.747	□.513	0.596
12	Taiwan	-0.007	1.278	-0.423	7.416	0.192	0.558
13	Thailand	0.024	1.278	-0.741	12.929	0.682	0.589
14	Vietnam	-0.065	1.502	-0.096	4.612	-0.513	0.001
1	CRUDE OIL	0.051	1.149	-0.011	9.418		
2	GOLD	0.027	2.321	0.132	10.744		

Source: All data used in this analysis are sourced from Bloomberg database.

Notes: This table reports the summary statistics separately for the full sample, pre-crisis sample and crisis sample and, in addition, the correlation between the equity markets of Asia and the crude oil and gold futures markets.

Table 2

Volatility between Crude Oil/Gold Futures and Equity Markets of Asia (05/07/2005-14/12/2011)

	Panel A: Oil-Equity		**Panel B: Gold-Equity**	
Sample of Countries	**LLR – Test 1**	**LLR – Test 2**	**LLR – Test 1**	**LLR – Test 2**
China	1.78	1.124	**25.830*** **	**12.768*** **
Hong Kong	0.788	**4.658***	0.618	0.052
India	**8.862****	**5.672***	3.998	**5.76***
Indonesia	1.606	1.606	3.326	**6.536****
Japan	**9.834*** **	4.304	**4.910***	0.334
Malaysia	**13.828*** **	**11.282*** **	3.156	2.42
Pakistan	2.448	**10.134*** **	0.562	1.062
Philippines	1.61	0.94	**10.032*** **	**7.766****
Singapore	2.964	1.85	1.112	0.168
South Korea	**5.736***	**4.616***	3.036	2.068
Sri Lanka	2.982	**10.646*** **	**9.164****	1.32
Taiwan	**25.404*** **	4.554	3.804	2.03
Thailand	0.968	**36.328*** **	1.996	1.024
Vietnam	**4.964***	1.432	**8.396****	3.102

Source: All data used in this analysis are sourced from Bloomberg database.

Notes: A Chi-squared distribution with 2 degrees of freedom is used as the critical value for the nested testing.

*** Statistical significance at 1% level.

** Statistical significance at 5% level

* Statistical significance at 10% level.

Table 3

Volatility between Crude Oil/Gold Futures and Equity Markets of Asia (pre-crisis and crisis periods)

	Panel A: Crude Oil Futures and Equity Markets				**Panel B: Gold Futures and Equity Markets**			
	Pre-crisis (05/07/2005-26/2/2007)		**Crisis period (27/2/2007-31/12/2010)**		**Pre-crisis (05/7/2005-26/2/2007)**		**Crisis period (27/2/2007-31/12/2010)**	
Sample of Countries	LLR test 1	LLR test 2	LLR test 1	LLR test 2	LLR test 1	LLR test 2	LLR test 1	LLR test 2
China	0.528	**7.272****	**4.814***	2.078	2.486	**7.076****	**19.792*** **	1.862
Hong Kong	-	-	**5.476***	**6.776****	-	-	1.832	0.29
India	1.296	4.244	**5.624***	**4.836***	4.916	**5.238***	2.344	**5.410***
Indonesia	0.26	2.098	**7.460****	3.044	**6.288****	**14.168*** **	1.096	**5.070***
Japan	**12.796*** **	**13.542*** **	3.27	1.376	5.162	**4.696***	**4.622***	4.402
Malaysia	1.286	**9.372*** **	**13.142*** **	**13.722*** **	0.176	3.256	**9.834*** **	**24.332*** **
Pakistan	**10.016*** **	0.226	**8.188****	**6.914****	3.996	2.13	1.812	1.366
Philippines	0.042	0.41	**7.346****	2.822	**24.348*** **	**27.558*** **	**8.102****	**9.504*** **
Singapore	2.642	**9.780*** **	3.186	2.186	**9.366*** **	**7.680****	0.314	0.442
South Korea	**11.564*** **	2.26	**12.190*** **	**15.708*** **	**6.406****	**6.344****	**14.342*** **	**13.872*** **
Sri Lanka	2.21	2.198	1.512	**10.992*** **	**7.068****	2.346	2.878	3.23
Taiwan	0.718	2.164	**31.060*** **	**12.618*** **	**17.860*** **	**18.134*** **	4.132	3.598
Thailand	**8.900****	**29.072*** **	**7.560****	**12.394*** **	**24.004*** **	**27.592*** **	3.686	2.352
Vietnam	3.984	**6.81****	1.186	0.118	**12.800*** **	**9.918*** **	**6.302****	1.91

Source: All data used in this analysis are sourced from Bloomberg database.

Notes: (1) A Chi-squared distribution with 2 degrees of freedom is used as the critical value for the nested testing.

*** Statistical significance at 1% level.

** Statistical significance at 5% level

* Statistical significance at 10% level.

(2) "-" indicates no meaningful convergence achieved.