Asia-Pacific Journal of Science and Technology: Volume: 26. Issue: 04. Article ID.: APST-26-04-11. Research Article

APST

Asia-Pacific Journal of Science and Technology

https://www.tci-thaijo.org/index.php/APST/index

Published by the Research and Technology Transfer Affairs Division,
Khon Kaen University, Thailand

Volatility linkages among the returns of oil, gold, and stock market: Evidence from Thailand

Parichat Sinlapates[1], Nattawadee Romklang[2] and Surachai Chancharat[1,*]

[1] Faculty of Business Administration and Accountancy, Khon Kaen University, Khon Kaen, Thailand
[2] Faculty of Economics, Khon Kaen University, Khon Kaen, Thailand
[*]Correspondent author: csurac@kku.ac.th

Received 27 January 2021
Revised 19 April 2021
Accepted 14 May 2021

Abstract

This paper examines the return and volatility linkages between oil, gold, and Thai stock markets by applying the multivariate Baba-Engle-Kraft-Kroner (BEKK)-GARCH model to daily data from January 1, 1996 to December 31, 2020. To better understand the impact of the global financial crisis, we divide the data into three sub-periods: the pre-crisis period (January 1, 1996 to December 31, 2006), the crisis period (January 1, 2007 to December 31, 2009), and the post-crisis period (January 1, 2010 to December 31, 2020). We find that the return spillovers vary across the whole and three sub-periods for oil, gold, and stock. Moreover, the volatility transmissions are found to be different during the whole and three sub-periods for oil, gold, and stock in Thailand. These findings provide useful information to investors, portfolio managers, and policymakers regarding portfolio diversification and risk management.

Keywords: Oil, Gold, Stock, Volatility spillover, BEKK-GARCH, Thailand

1. Introduction

In recent years, an increasingly close relationship has emerged between commodity and capital markets due to the increased cross-border movement of capital and goods, causing co-movement in prices between these markets [1]. Oil price is an essential factor for the policymakers of countries that have this commodity as a primary source of energy and those who include oil price as part of their energy matrix [2]. Therefore, the oil price has always been considered a leading indicator of stock price movements in the world economy. This is because many companies are consumers of oil, and a higher price allows these firms to increase prices in parallel, thus making them less competitive. Higher energy costs increase the cost of goods sold, thus decreasing profit margins. Moreover, fluctuating oil prices due to variations in demand and supply lead to stock price instability for all companies in the economy.

The relationship between oil prices and the fundamental of economics is found in the original work of Hamilton [3], who showed that oil price increases were responsible for almost every post-World War II recession in the United States (US). Several studies have investigated the relationship between price of oil and macroeconomic factors, for example, Amano and van Norden [4], Wu and Chung [5], Gupta and Goyal [6], and Bedoui and Braiek [2]. In addition to these studies on the influence of oil prices on many macroeconomic factors, the effects of oil prices on stock markets have been precisely modeled on others. Several investigations by Narayan and Narayan [7] found a long-term positive relationship between oil price and the stock market in Vietnam. This finding indicates that the growth of the Vietnam stock market was followed by rising oil prices, which is inconsistent with theoretical expectations. On the other side, for example, the results of Singhal and Ghosh [8] showed that the spillover of direct volatility from the oil market to the Indian stock market was not large at the aggregate stage. Further, Al-hajj and Al-Mulali [9] indicated that oil price shocks harmed the stock market returns in most cases, regardless of whether oil price shocks appreciated or depreciated.

Precious metals, especially gold, are also traded in financial markets. The authorities also hold ample gold reserves to turn all currency into a defined quantity of gold on demand as gold has been used for the monetary policy's instrument [10]. The demand for gold depends on the view of both individual and institutional investors, including fund managers and policymakers, that gold is an effective hedge or a haven contrary to inflation and other forms of risk like stock prices [11]. Commodities such as oil and gold have recently become a well-known investment asset class. Both individual and institutional investors are most concerned about the relationship between commodities and stock prices, given the impressive peaks and troughs among the commodity prices [12]. The leading economic factors are both oil and gold prices, guiding the evolution of the world economy. International trade and economic growth in all countries are greatly influenced by their shifts [2]. Several fund managers and policymakers now manage their portfolios by including essential assets such as gold and oil to improve the returns after controlling for risk [13, 14].

Thailand is a substantial oil importer, ranked 15th in the world's leading oil importers [15]. The country is also a considerable gold consumer, the world's fifth greatest gold consumer, totaling approximately 7% of overall demand [16]. The Thai people are traditionally and culturally oriented toward gold, which plays a significant role in weddings, engagements, and other routine life features. Apart from demanding gold for cultural reasons, it is also demanded to hedge against currency depreciation and inflation. Consistent with the global price, the domestic price of gold bullion with 96.5% purity has surged nearly 11% to 21,800 Thai Baht (THB) per THB-weight. Thailand has become an Asian hub, the third largest after China and Japan for gold trading, and Thai gold traders are among the most prominent performers in the precious metals market, noting that Southeast Asia's second largest economy has shipped precious metal to other Asian markets, for example, Hong Kong and Singapore [17].

Gold is also a significant part of the central bank policy, making a substantial contribution to the Thai financial system. A reserve option mechanism is utilized as a monetary policy instrument for the central bank, the Bank of Thailand (BOT). This mechanism allows commercial banks to hold their required reserves in foreign currency or gold [18, 19]. The mechanism is intended to limit exchange rate fluctuations and encourage banks to accumulate gold and foreign currency to prevent shocks. According to this policy framework, gold reserves have increased, mobilized gold in Thailand, and enhanced Thailand's banking system liquidity. Nevertheless, the BOT's implementation of inflation targeting, despite uncertainties in this mechanism, might result in the extreme instability of the inflation rate and the real interest rate and exchange rate, damaging economic growth [20, 21].

Volatility plays a vital role in risk management, hedging, derivative pricing, and optimal portfolio selection. The concept of volatility in global gold and oil prices could significantly influence the stock market and other macroeconomic factors. The reasons for this improvement are apparent: high-frequency data are available as a result and there is increasing evidence of the presence of statistically significant correlations between observations, which are a considerable distance apart; in connection with the high frequency of data, there is also the possibility of time-varying volatility [22, 23]. We next continue to examine the volatile parts of commodity futures. This step involved graphical plotting of the daily return series, followed by descriptive statistics. All data are tested for stationarity, then we explore the generalized autoregressive conditional heteroscedasticity, hereafter referred to as the GARCH model [24], for the return volatility of the select futures. GARCH models are considered enormously beneficial for modeling and forecasting movements in asset return volatilities over time, for example, for use in pricing financial options or in the context of risk management [25].

Several studies have been conducted to analyze the causal relationship between economic factors and stock prices. Solnik [26] has studied stock market returns and the movement of currency exchange rates, recognizing that exchange rate risk levels will impact a business's value due to cash flow, as the future business depends on currency exchange volatility rate in an individual country. The study found a significant negative correlation, which correlates with Ma and Kao [27]. Furthermore, they found that the positive movement of the currency exchange rate will only impact the country that appears to have an outstanding economy, which was also observed in the study by Luehrman [28]. The depreciation of foreign currency will exceed the limitations of international business competition, as supported by Adler and Dumas' [29] study, which stated that the volatility of currency exchange influences export and import levels. Therefore, the currency exchange proves an essential factor for international trading.

However, the correlation between the stock market and currency exchange has gradually disappeared in the long term. According to the study by Tabak [30] of Brazil's stock market, the trend of correlation between currency exchange and stock market decreased by other factors such as a rise in the price of oil, which contributed to a lower valuation of the industrial stock exchange. In terms of commodity-based relationships, many evidence-based studies show the concordance between oil price, an essential commodity in a financial market, especially a study by Sadorsky [31] that illustrated the importance and volatility of oil prices through an explanation of stock market returns. While Oluseyi [32] has reviewed the concordance between shifts in oil prices and growth in Nigeria's stock market using a vector correlation method, the study has uncovered the long-term relationship between oil price and currency exchange and stock market growth. According to the results, the oil price positively impacts stock market growth but only temporarily: the oil price fluctuation results in the stock market growth in the first period.

Over the past two decades, additional studies have been released that consider the relationship between crude oil price and stock markets. As noted by Narayan and Narayan [7] and Bedoui and Braiek [2], initial research in this area aims to examine the effect on macroeconomic factors of oil price movements. Hamilton [3], who analyzed the impact of oil price shocks on per capita income growth, performed the most important research in this field. The impact of shocks of oil price on various macroeconomic factors (e.g., economic growth, exchange rate, inflation rate, interest rates, and market capitalization) was then studied by several researchers [6, 10, 14, 33, 34]. They reached the conclusion that oil prices significantly influence macroeconomic variables.

Several previous studies have investigated whether a variation in the prices of oil influences stock returns. Kilian and Park [35] found that the US stock returns' reaction to an oil price shock differs greatly depending on whether the change in oil price is driven by demand or supply shocks in the oil market. However, another study in the same country conducted by Mohanty and Akhigbe [36] highlighted a significant relationship between oil prices and stock returns. Nevertheless, stock returns associated with adverse oil price changes are higher than those related to favorable oil prices. Also, Kocaarslan and Soytas [37] for the US, Nusair and Al-Khasawneh [38] for Gulf Cooperation Council countries, and Bouri [39] for Lebanon disclosed a positive relationship between oil prices and stock returns. Conversely, Al-hajj, Al-Mulali [9], and Narayan [40] indicated that oil price shocks harm stock returns in most cases, regardless of whether oil price shocks appreciate or depreciate. Dutta and Hasib Noor [41] and Kumar and Pradhan [42] disclosed no relationship between oil price and stock returns.

Nevertheless, financial researchers have examined the relationship between the price of gold and stock returns. According to the literature, an essential examination topic centers on whether gold is a harmless investment asset against stock return volatility. The hedging ability of gold has been confirmed in some literature: Ibrahim [43] for Malaysia; Tursoy and Faisal [44] and Akkoc and Civcir [12] for Turkey; Jain and Biswal [13], Singhal and Ghosh [8], and Mukherjee and Goswami [22] for India; and Pandey and Vipul [1], Ansari and Sensarma [45], and Kocaarslan and Soytas [46] for BRICS (Brazil, Russia, India, China, and South Africa) countries. Arfaoui and Ben Rejeb [47] found a negative relationship between oil and stock prices but argued that oil price is significantly and positively affected by gold. Moreover, the price of gold is a net contributor to volatility spillover. In contrast, the oil price is the net receiver of volatility spillover [48] and thus risks contagion running from oil price and gold price to stock returns [49]. The literature on the Turkish stock exchange and commodity market is rare. Raza and Jawad Hussain Shahzad [50] showed that gold prices positively impact stock prices in BRICS countries and negatively impact the stock prices of Mexico, Malaysia, Thailand, Chile, and Indonesia. However, oil prices harm the stock prices of all emerging countries.

Therefore, our study aims to fill the gap of literature by examining the volatility spillover of oil and gold prices into the Thai stock market, using daily data from January 1, 1996 to December 31, 2020. This study aims to provide three vital contributions to the literature. First, the estimation technique that has not been previously used to examine the relationship among gold prices, oil prices, and stock markets are employed in this paper. In particular, in testing the volatility spillover of gold and oil prices into the stock market, the multivariate Baba-Engle-Kraft-Kroner (BEKK)-GARCH model [51] was employed. Second, the study investigates whether the spillover mechanism has outperformed a change after the global financial crisis in 2008. This is in the context of the argument that after the global financial crisis, the correlation between commodities prices such as gold and oil and the stock markets increased. Third, the relationship between gold prices, oil prices, and stock markets are mainly examined in the developed financial market. Our research, however, contributes to the literature on the overall development of financial markets and, in particular, emerging financial markets.

2. Materials and methods

This paper examines the volatility linkages among oil price, gold price, and Thailand's stock market. As the US is Thailand's leading trading partner for energy products, the US oil price index for West Texas Intermediate (WTI) crude oil price is taken as a proxy for global oil prices. The foreign gold spot price is taken as a guide for the movement of gold prices. It is weighed and expressed by gold in USD/ounce. The Thai stock exchange is also known as SET. Consequently, in our research on stock market movements, the SET index is used as the benchmark index. Our sample period starts from January 1, 1996 to December 31, 2020 and the data is obtained from Datastream. Consequently, this study separated the sample period into three sub-periods: the pre-crisis period (January 1, 1996 to December 31, 2006), the global financial crisis period (January 1, 2007 to December 31, 2009), and the post-crisis period (January 1, 2010 to December 31, 2020). The daily returns (r_t) are defined as:

$$r_t = \ln(p_t) - \ln(p_{t-1}) \tag{1}$$

where p_t is the price of oil, gold, and stock on day t, respectively; our empirical analysis begins with calculating summary statistics for the returns. The augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests are also performed to examine the existence of unit roots in the price returns.

In this paper, we examine volatility transmission effects between oil, gold, and stock captured through the conditional covariance matrix. Consequently, we use a simple methodological specification for the conditional mean equation, excluding potential exogenous variables that could have an effect on the volatility of the returns considered, which is given as:

$$R_t = \alpha + \beta R_{t-1} + \varepsilon_t \tag{2}$$

where R_t is the vector of the price returns, α is the vector of parameters that estimates the mean of the returns, β is the matrix of coefficients, and ε_t is the vector of residuals.

We employ the unrestricted BEKK-GARCH methodology of Engle and Kroner [51]. The BEKK-GARCH model permits the interaction of the conditional variances and covariances of time series. It, therefore, allows us to identify volatility transmission effects. The conditional variance-covariance matrix (H_t) of a simple diagonal BEKK-GARCH specification with order 1 is as follows:

$$H_t = C'C + A'\varepsilon'_{t-1}\varepsilon_{t-1}A + B'H_{t-1}B \tag{3}$$

where C is a lower triangular matrix to represent constant components, and A and B are diagonal 3 × 3 matrices of ARCH and GARCH coefficients, respectively.

In this case, the diagonal BEKK-GARCH model can be expressed as follows:

$$\begin{bmatrix} h_{11,t} & h_{12,t} & h_{13,t} \\ h_{21,t} & h_{22,t} & h_{23,t} \\ h_{31,t} & h_{32,t} & h_{33,t} \end{bmatrix} = \begin{bmatrix} c_{11} & 0 & 0 \\ c_{21} & c_{22} & 0 \\ c_{31} & c_{32} & c_{33} \end{bmatrix}' \begin{bmatrix} c_{11} & 0 & 0 \\ c_{21} & c_{22} & 0 \\ c_{31} & c_{32} & c_{33} \end{bmatrix} + \begin{bmatrix} a_{11} & 0 & 0 \\ 0 & a_{22} & 0 \\ 0 & 0 & a_{33} \end{bmatrix}' \begin{bmatrix} \varepsilon_{1,t-1} \\ \varepsilon_{2,t-1} \\ \varepsilon_{3,t-1} \end{bmatrix}' \begin{bmatrix} \varepsilon_{1,t-1} \\ \varepsilon_{2,t-1} \\ \varepsilon_{3,t-1} \end{bmatrix} \begin{bmatrix} a_{11} & 0 & 0 \\ 0 & a_{22} & 0 \\ 0 & 0 & a_{33} \end{bmatrix}$$
$$+ \begin{bmatrix} b_{11} & 0 & 0 \\ 0 & b_{22} & 0 \\ 0 & 0 & b_{33} \end{bmatrix}' \begin{bmatrix} h_{11,t-1} & h_{12,t-1} & h_{13,t-1} \\ h_{21,t-1} & h_{22,t-1} & h_{22,t-1} \\ h_{31,t-1} & h_{32,t-1} & h_{33,t-1} \end{bmatrix} \begin{bmatrix} b_{11} & 0 & 0 \\ 0 & b_{22} & 0 \\ 0 & 0 & b_{33} \end{bmatrix} \tag{4}$$

To estimate the parameters of the BEKK-GARCH model, a maximum likelihood estimation was employed since the consistency of the maximum likelihood estimators has been proved [52]. The conditional log-likelihood function $L(\Theta)$ is denoted as follows:

$$L(\theta) = -\frac{TN}{2}\ln(2\pi) - \frac{1}{2}\sum_{t=1}^{T}(\ln|H_t| + \varepsilon_t' H_t^{-1}\varepsilon_t) \tag{5}$$

where θ denotes all the unknown parameters to be estimated, T is the number of observations, and N is the number of variables.

3. Results and discussion

Table 1 shows the statistical properties of the return series for the full period and the three sub-periods. All mean returns were positive during the full sample period, while gold had the highest (0.02%). In addition, gold had the least volatility, as measured by a standard deviation of 1.02%, suggesting that gold was more stable than other markets. While all return series were skewed and had high values for the kurtosis statistic, all returns had negative skewness. This finding implies that significant negative returns were more common than large positive returns were in oil, gold, and stock return. The Jarque-Bera (JB) test conclusively rejected the null hypothesis of normality in the return distribution at conventional levels for all series. The JB test measures the departure from the normality of a sample based on skewness and kurtosis. The abovementioned characteristics of return distributions supported our choice to estimate the BEKK-GARCH model using the quasi-maximum likelihood estimation method.

Looking at the three sub-samples, the average returns are both positive and negative for all three variables, ranging from -0.02% (stock in the pre-crisis period and oil in the post-crisis period) to 0.07% (gold in the global financial crisis period). Furthermore, oil return is the most volatile asset, as measured by a standard deviation in all the sub-periods, while gold is the least volatile. It can also be observed that all returns are leptokurtic, with oil exhibiting the highest excess kurtosis in the post-crisis period. Moreover, both gold and stock returns are negatively skewed in the global financial crisis period and post-crisis period, indicating that the two assets have a longer left tail. The departure from normality for all the three returns series is also confirmed by the JB test results, which reject the null hypothesis of normally distributed returns for all the three returns series in all the sub-periods.

Table 1 Descriptive statistics for the return series.

	Mean	Median	Max	Min	SD	Skewness	Kurtosis	JB	Obs.
The full period									
Oil	0.0001	0.0000	0.3002	-0.6455	0.0276	-1.6482	61.7189	940,209[a]	6,524
Gold	0.0002	0.0000	0.0738	-0.1016	0.0102	-0.2871	9.8622	12,890[a]	6,524
Stock	0.0000	0.0000	0.1135	-0.1606	0.0147	-0.0891	12.6529	25,337[a]	6,524
The pre-crisis period									
Oil	0.0004	0.0000	0.1587	-0.1722	0.0242	-0.2586	6.8846	1,836[a]	2,870
Gold	0.0002	0.0000	0.0738	-0.0582	0.0089	0.1558	9.9171	5,733[a]	2,870
Stock	-0.0002	0.0000	0.1135	-0.1606	0.0175	0.2946	10.0212	5,937[a]	2,870
The global financial crisis period									
Oil	0.0003	0.0000	0.2128	-0.1307	0.0319	0.3923	7.8775	797[a]	784
Gold	0.0007	0.0007	0.0687	-0.0714	0.0150	-0.1843	6.1176	321[a]	784
Stock	0.0000	0.0000	0.0755	-0.1109	0.0164	-0.7355	9.1660	1,312[a]	784
The post-crisis period									
Oil	-0.0002	0.0000	0.3002	-0.6455	0.0295	-3.0517	101.2420	1,158,611[a]	2,870
Gold	0.0002	0.0002	0.0543	-0.1016	0.0098	-0.7283	10.4582	6,905[a]	2,870
Stock	0.0002	0.0001	0.0765	-0.1142	0.0104	-1.0723	17.6031	26,051[a]	2,870

Note: [a] indicate the statistical significance at 1% level.

As mentioned above, the return series was used for all three variables. Table 2 indicates that both the ADF and PP tests existing large negative values of t-statistics rejecting the null hypothesis of a unit root at the 1% level of significance, and therefore the daily returns of all the three assets are stationary in full and all three sub-periods. Next, we estimated the diagonal BEKK-GARCH model. Table 3 presents the return and volatility transmission between oil, gold, and stock. Regarding estimates of the conditional mean equations, the reported results for the whole period indicate that the coefficients of own-mean spillover are significantly negative for oil (-0.0312) and positive for stock (0.0608). The result indicated that the lagged returns inversely affect their current returns in oil. On the other hand, the lagged returns directly affect their returns in stock. These results are consistent with Kocaarslan and Soytas [46], who find that all markets are affected by their own lags. These findings highlight the possibility of short-term predictions of current returns through past returns for oil and stock. Looking at the three sub-samples, it is clear that the short-term predictability of return in each market was not always significant. In addition, the interdependence of returns between markets was mixed. Similar results were reported by Bouri [39] for Lebanon.

Table 2 Unit root tests.

	ADF test		PP test	
	Constant	Constant and trend	Constant	Constant and trend
The full period				
Oil	-39.4934[a]	-39.4971[a]	-82.8900[a]	-82.8917[a]
Gold	-80.6978[a]	-80.6995[a]	-80.6980[a]	-80.6998[a]
Stock	-52.3625[a]	-52.3840[a]	-77.1496[a]	-77.1006[a]
The pre-crisis period				
Oil	-40.0172[a]	-40.0153[a]	-53.2631[a]	-53.2679[a]
Gold	-53.1949[a]	-53.3024[a]	-53.3434[a]	-53.4135[a]
Stock	-48.9360[a]	-49.0077[a]	-49.0938[a]	-49.1451[a]
The global financial crisis period				
Oil	-29.6899[a]	-29.6731[a]	-29.6649[a]	-29.6715[a]
Gold	-27.8761[a]	-27.8582[a]	-27.8944[a]	-27.8758[a]
Stock	-26.7930[a]	-26.7837[a]	-26.8629[a]	-26.8528[a]
The post-crisis period				
Oil	-21.4272[a]	-21.4238[a]	-55.7021[a]	-55.6928[a]
Gold	-53.8958[a]	-53.8885[a]	-53.9280[a]	-53.9209[a]
Stock	-54.5308[a]	-54.5768[a]	-54.5704[a]	-54.6002[a]

Note: [a] indicate the statistical significance at 1% level.

Table 3 Estimates of the diagonal BEKK-GARCH model.

	The full period		The pre-crisis period		The crisis period		The post-crisis period	
	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE
Mean equation								
α_1	0.0003	0.0002	0.0003	0.0004	0.0019[b]	0.0008	0.0003	0.0003
β_{11}	-0.0312[a]	0.0119	-0.0014	0.0177	-0.0585[c]	0.0352	-0.0410[b]	0.0197
β_{12}	-0.0011	0.0237	-0.0197	0.0506	-0.0405	0.0617	0.0064	0.0321
β_{13}	-0.0254	0.0167	-0.0401	0.0254	0.0971[c]	0.0534	-0.0385	0.0310
α_2	0.0001	0.0001	-0.0001	0.0001	0.0008[c]	0.0004	0.0002	0.0002
β_{21}	0.0003	0.0115	0.0108	0.0178	-0.0072	0.0408	-0.0156	0.0183
β_{22}	0.0140[b]	0.0058	0.0109	0.0068	0.0390	0.0289	0.0093	0.0130
β_{23}	0.0115[a]	0.0040	0.0128[b]	0.0054	0.0553[a]	0.0188	0.0037	0.0064
α_3	0.0004[a]	0.0001	-0.0001	0.0003	0.0008[c]	0.0005	0.0004[a]	0.0001
β_{31}	0.0608[a]	0.0122	0.0912[a]	0.0173	0.0136	0.0376	0.0260	0.0191
β_{32}	0.0524[a]	0.0135	0.1316[a]	0.0288	0.0297	0.0369	0.0424[a]	0.0151
β_{33}	0.0281[a]	0.0060	0.0049	0.0130	0.0337[c]	0.0187	0.0297[a]	0.0065
Variance equation								
c_{11}	0.0000[a]	0.0000	0.0000[a]	0.0000	0.0000[b]	0.0000	0.0000[a]	0.0000
c_{12}	0.0000[a]	0.0000	0.0000[a]	0.0000	0.0000[c]	0.0000	0.0000[a]	0.0000
c_{13}	0.0000	0.0000	0.0000[a]	0.0000	0.0000	0.0000	0.0000[a]	0.0000
c_{22}	0.0000[a]	0.0000	0.0000	0.0000	0.0000[b]	0.0000	0.0000[a]	0.0000
c_{23}	0.0000	0.0000	-0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
c_{33}	0.0000[a]	0.0000	0.0000[a]	0.0000	0.0000[a]	0.0000	0.0000[a]	0.0000
a_{11}	0.2441[a]	0.0041	0.1582[a]	0.0090	0.2287[a]	0.0187	0.2896[a]	0.0069
a_{22}	0.1888[a]	0.0030	0.2281[a]	0.0062	0.1673[a]	0.0180	0.1892[a]	0.0052
a_{33}	0.2756[a]	0.0063	0.2189[a]	0.0094	0.3354[a]	0.0213	0.2887[a]	0.0085
b_{11}	0.9634[a]	0.0014	0.9740[a]	0.0032	0.9688[a]	0.0051	0.9512[a]	0.0022
b_{22}	0.9799[a]	0.0007	0.9701[a]	0.0016	0.9826[a]	0.0038	0.9765[a]	0.0013
b_{33}	0.9574[a]	0.0018	0.9640[a]	0.0030	0.9368[a]	0.0062	0.9568[a]	0.0024
Log L	56,398.9700		24,254.3100		6,275.7680		26,119.7600	
AIC	-17.2823		-16.8852		-15.9484		-18.18520	
SIC	-17.2574		-16.8354		-15.8056		-18.13535	

Note: [a, b,] and [c] indicate the statistical significance at 1%, 5%, and 10% level, respectively.

Regarding the return spillovers between oil and stock in the mean equation, the results indicate a unidirectional and positive return spillover from oil to stock in the whole period. This implies that oil returns were beneficial in forecasting stock returns. However, the return spillover is found to be bidirectional and positive between oil and stock during the global financial crisis period, suggesting that oil returns can be used to forecast stock during the crisis and vice versa. This indicates that when the oil returns decreased during the crisis period, investors were motivated to decline investment in stock due to fear of massive losses. Based on the return spillovers between gold and stock, the finding reveals a bidirectional and positive return transmission between gold and stock in the whole period. However, the results in all the sub-periods were mixed. This implies that gold (stock) returns cannot be used to forecast stock (gold) returns in the whole period. These results are consistent with findings of Pandey and Vipul [1], who find volatility spillover from both the oil and gold to the BRICS stock markets. A sub-sample analysis suggests that the volatility spillover from gold was not significant before the financial crisis but became significant post-crisis.

Regarding own-shock and own-volatility spillovers, the findings show that the lagged shocks and volatility significantly and positively influence their current conditional volatility in oil, gold, and stock in all sample periods. Based on cross-market shock spillover, the results indicate that the shock spillover is positive and bidirectional for the pairs of oil, gold, and stock during all sample periods. These results are similar to the findings of Pandey and Vipul [1] and Bouri [39], who find the own-shock spillover is positive and significant in both oil and stock markets, suggesting that past shocks directly affect the current volatility in all sample periods. Furthermore, the shock transmission is positive and unidirectional between oil, gold, and stock in all sample periods.

4. Conclusion

The relationship and volatility spillover of oil and gold returns to Thailand's stock market returns were empirically examined in this study. Using the diagonal BEKK-GARCH model, the data has been divided into 3 sub-periods to examine the impact of the global financial crisis: the pre-crisis from January 1, 1996 to December 31, 2006; the crisis from January 1, 2007 to December 31, 2009; and the post-crisis from January 1, 2010 to December 31, 2020. The findings reveal a unidirectional and positive return spillover from oil to stock in the whole period. However, the return spillover is found to be bidirectional and positive between oil and stock during the global financial crisis period. This suggests that, in the short run, oil returns can be used to forecast stock returns in the whole period, while during the global financial crisis, stock (oil) returns can be used to forecast oil (stock) returns period. For the pair of gold and stock, bidirectional return spillover is observed in the whole period, although the return spillover is not significant before the financial crisis but became significant post-crisis.

Regarding volatility spillover, the findings reveal that the lagged shocks and volatility significantly and positively influence their current conditional volatility in oil, gold, and stock in all sample periods. Furthermore, the shock spillover is positive and bidirectional for the pairs of oil, gold, and stock during all sample periods. The abovementioned volatility linkages suggest that investors cannot get the maximum benefit of diversification by making portfolios of these assets. Besides shedding new light in the literature, statistically significant and valuable knowledge was provided to risk managers by unraveling the scale of stock return and volatility ties between oil and SET returns and the changes over the various sub-periods. Suggestions concerning the valuable addition of oil in an investment portfolio and the changes in conditional correlations suggest investors use oil prices, gold, and the SET as effective financial instruments for an investment portfolio hedging and diversification policy. A further study is suggested to expand from Thailand's stock market to consider additional stock markets in emerging financial market countries such as the Association of Southeast Asian Nations (ASEAN) countries.

5. Acknowledgments

The authors gratefully acknowledge funding from the Faculty of Business Administration and Accountancy, Khon Kaen University, under grant number 009/2564. Moreover, we are also indebted to participants who helped with an early version of this paper presented at the SIBR Conference, Osaka, Japan, July 5-6, 2018.

6. References

[1] Pandey V, Vipul V. Volatility spillover from crude oil and gold to BRICS equity markets. J Econ Stud. 2018;45(2):426-40.
[2] Bedoui R, Braiek S, Guesmi K, Chevallier J. On the conditional dependence structure between oil, gold and USD exchange rates: nested copula based GJR-GARCH model. Energy Econ. 2019;80:876-89.
[3] Hamilton JD. Oil and the macroeconomy since world war II. J Political Econ. 1983;91(2):228-48.
[4] Amano RA, van Norden S. Oil prices and the rise and fall of the US real exchange rate. J Int Money Finance. 1998;17(2):299-316.
[5] Wu CC, Chung H, Chang YH. The economic value of co-movement between oil price and exchange rate using copula-based GARCH models. Energy Econ. 2012;34(1):270-82.
[6] Gupta P, Goyal A. Impact of oil price fluctuations on Indian economy. OPEC Energy Rev. 2015; 39(2):141-61.
[7] Narayan PK, Narayan S. Modelling the impact of oil prices on Vietnam's stock prices. Appl Energy. 2010;87(1):356-61.
[8] Singhal S, Ghosh S. Returns and volatility linkages between international crude oil price, metal and other stock indices in India: evidence from VAR-DCC-GARCH models. Resour Policy. 2016;50:276-88.
[9] Al-hajj E, Al-Mulali U, Solarin SA. Oil price shocks and stock returns nexus for Malaysia: fresh evidence from nonlinear ARDL test. Energy Rep. 2018;4:624-37.
[10] Akbar M, Iqbal F, Noor F. Bayesian analysis of dynamic linkages among gold price, stock prices, exchange rate and interest rate in Pakistan. Resour Policy. 2019;62:154-64.
[11] Ghosh D, Levin Eric J, Macmillan P, Wright Robert E. Gold as an inflation hedge?. Stud Econ Finance. 2004;22(1):1-25.
[12] Akkoc U, Civcir I. Dynamic linkages between strategic commodities and stock market in Turkey: evidence from SVAR-DCC-GARCH model. Resour Policy. 2019;62:231-9.
[13] Jain A, Biswal PC. Dynamic linkages among oil price, gold price, exchange rate, and stock market in India. Resour Policy. 2016;49:179-85.
[14] Singhal S, Choudhary S, Biswal PC. Return and volatility linkages among international crude oil price, gold price, exchange rate and stock markets: evidence from Mexico. Resour Policy. 2019;60:255-61.
[15] Central Intelligence Agency. The world factbook 2019-2020. New York: Skyhorse; 2019.
[16] Statista. Consumer gold demand in major consuming countries in 2015. Hamburg: Statista; 2016.
[17] Polkuamdee N. Will gold keep shining?: Business. Bangkok Post. 2019 Sep 30.
[18] Ghosh A. What drives gold demand in central bank's foreign exchange reserve portfolio?. Finance Res Lett. 2016;17:146-50.
[19] Gopalakrishnan B, Mohapatra S. Turning over a golden leaf? global liquidity and emerging market central banks' demand for gold after the financial crisis. J Int Financial Mark Inst Money. 2018;57:94-109.

[20] Hossain AA, Arwatchanakarn P. Does money have a role in monetary policy for price stability under inflation targeting in Thailand?. J Asian Econ. 2017;53:37-55.
[21] Mahathanaseth I, Tauer LW. Monetary policy transmission through the bank lending channel in Thailand. J Asian Econ. 2019;60:14-32.
[22] Mukherjee I, Goswami B. The volatility of returns from commodity futures: evidence from India. Financial Innov. 2017;3(1):15.
[23] Salisu AA. Modelling oil price volatility before, during and after the global financial crisis. OPEC Energy Rev. 2014;38(4):469-95.
[24] Bollerslev T, Engle RF, Wooldridge JM. A capital asset pricing model with time-varying covariances. J Political Econ. 1988;96(1):116-31.
[25] Brooks C, Burke SP, Persand G. Benchmarks and the accuracy of GARCH model estimation. Int J Forecast. 2001;17(1):45-56.
[26] Solnik B. Using financial prices to test exchange rate models: a note. J Finance. 1987;42(1):141-9.
[27] Ma CK, Kao GW. On exchange rate changes and stock price reactions. J Bus Finance Account. 1990; 17(3):441-9.
[28] Luehrman TA. Exchange rate changes and the distribution of industry value. J Int Bus Stud. 1991;22(4): 619-49.
[29] Adler M, Dumas B. Exposure to currency risk: definition and measurement. Financ Manage. 1984;13(2): 41-50.
[30] Tabak BM. The dynamic relationship between stock prices and exchange rates: evidence for Brazil. Brazil: Research Department, Central Bank of Brazil; 2006.
[31] Sadorsky P. Oil price shocks and stock market activity. Energy Econ. 1999;21(5):449-69.
[32] Oluseyi AS. An empirical investigation of the relationship between stock market prices volatility and macroeconomic variables' volatility in Nigeria. EJAE. 2015;2(11):1-12.
[33] Pradhan RP, Arvin MB, Ghoshray A. The dynamics of economic growth, oil prices, stock market depth, and other macroeconomic variables: evidence from the G-20 countries. Int Rev Financ Anal. 2015;39: 84-95.
[34] Mollick AV, Sakaki H. Exchange rates, oil prices and world stock returns. Resour Policy. 2019;61:585-602.
[35] Kilian L, Park C. The impact of oil price shocks on the U.S. stock market. Int Econ Rev. 2009;50(4): 1267-87.
[36] Mohanty SK, Akhigbe A, Al-Khyal TA, Bugshan T. Oil and stock market activity when prices go up and down: the case of the oil and gas industry. Rev Quant Finance Account. 2013;41(2):253-72.
[37] Kocaarslan B, Soytas U. Dynamic correlations between oil prices and the stock prices of clean energy and technology firms: the role of reserve currency (US dollar). Energy Econ. 2019;84:104502.
[38] Nusair SA, Al-Khasawneh JA. Oil price shocks and stock market returns of the GCC countries: empirical evidence from quantile regression analysis. Econ Change Restruct. 2018;51(4):339-72.
[39] Bouri E. Return and volatility linkages between oil prices and the Lebanese stock market in crisis periods. Energy. 2015;89:365-71.
[40] Narayan PK. Can stale oil price news predict stock returns?. Energy Econ. 2019;83:430-44.
[41] Dutta A, Hasib Noor M. Oil and non-energy commodity markets: an empirical analysis of volatility spillovers and hedging effectiveness. Cogent Econ Finance. 2017;5(1):1324555.
[42] Kumar S, Pradhan AK, Tiwari AK, Kang SH. Correlations and volatility spillovers between oil, natural gas, and stock prices in India. Resour Policy. 2019;62:282-91.
[43] Ibrahim MH. Financial market risk and gold investment in an emerging market: the case of Malaysia. Int J Islam Middle East Finance Manag. 2012;5(1):25-34.
[44] Tursoy T, Faisal F. The impact of gold and crude oil prices on stock market in Turkey: empirical evidences from ARDL bounds test and combined cointegration. Resour Policy. 2018;55:49-54.
[45] Ansari MG, Sensarma R. US monetary policy, oil and gold prices: which has a greater impact on BRICS stock markets?. Econ Anal Policy. 2019;64:130-51.
[46] Kocaarslan B, Soytas U, Sari R, Ugurlu E. The changing role of financial stress, oil price, and gold price in financial contagion among US and BRIC markets. Int Rev Finance. 2019;19(3):541-74.
[47] Arfaoui M, Ben Rejeb A. Oil, gold, US dollar and stock market interdependencies: a global analytical insight. Eur J Manag Bus Econ. 2017;26(3):278-93.
[48] Husain S, Tiwari AK, Sohag K, Shahbaz M. Connectedness among crude oil prices, stock index and metal prices: an application of network approach in the USA. Resour Policy. 2019;62:57-65.
[49] Lin L, Kuang Y, Jiang Y, Su X. Assessing risk contagion among the Brent crude oil market, London gold market and stock markets: evidence based on a new wavelet decomposition approach. North Am J Econ Finance. 2019;50:101035.

[50] Raza N, Jawad Hussain Shahzad S, Tiwari AK, Shahbaz M. Asymmetric impact of gold, oil prices and their volatilities on stock prices of emerging markets. Resour Policy. 2016;49:290-301.
[51] Engle RF, Kroner KF. Multivariate simultaneous generalized ARCH. Econ Theory. 1995;11(1):122-50.
[52] Brooks C. Introductory econometrics for finance. 2nd ed. Cambridge: Cambridge University Press; 2008.