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Volatility Spillover Effect of the International Crude Oil Futures Price on Composite and Sector Indices between the Chinese and Australian Stock Markets

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Abstract

As a type of non-renewable industrial resource, petroleum is of great strategic significance to the development of each nation. Ever since the 19th century, an array of oil crises have incurred certain downturn of the world economy. Pertinent studies have implied that financial crisis is always prone to be accompanied with oil crisis, yet the relevance of crude oil to the stock market, the barometer of the macro-economy, is ambiguous. In order to avoid the risks induced by the volatility of oil price, the oil futures market has appeared, and at the same time, the financial property of crude oil has become far more evident. Owing to lack of mature mining and refining technology, China still imports large amounts of oil from abroad at present. Thus, the economy of China is susceptible to fluctuation in petroleum price. As for Australia, the only net importer among the member countries of the International Energy Agency (IEA), it fails to attain the target of holding 90 days of fuel reserves set by the agency. However, in 2013, *Australian Lincoln Energy* announced that a gigantic shale oil field with an estimated value of 21 trillion US dollars was found in the South of Australia, and that if that field is mined, Australia has the possibility to turn into a net exporter of crude oil. It can be expected that the Australiaʹs economic conditions would be closely related to the international oil to a certain extent. Based on the approaches of the first difference and co-integration, this paper delves into the volatility spillover effect of crude oil futures on the Chinese and Australian stock markets. According to the empirical findings, in the short run, the price of crude oil futures has a greater impact on the Australian composite index than on the Chinese composite index. However, crude oil futures are negatively related to the Chinese composite index in the long run. The price of crude oil futures has no significant impact on the Chinese sector indices, but it has a certain impact on the Australian utilities, energy, materials, and industrial sector indices. In the Chinese stock market, the movement of short-run effect to long-run effect of crude oil futures on sector indices is in the reverse direction. Finally, the price of crude oil futures has a significant volatility spillover effect only on the Australian utilities sector index.

Keywords: Crude Oil Futures, Composite Index, Sector Index, Volatility Spillover Effect, BEKK-GRACH Model

1 INTRODUCTION

In 1859, the first oil well was drilled in America. Since its advent, the technology of oil exploitation and utilization has progressively improved. Hence, petroleum and its derivatives have been widely used in industrial production. Furthermore, as a type of non-renewable resource, crude oil is of great strategic significance to the world economic landscape. Thus, demand for petroleum will not stop until a more sustainable substitute has been found. In fact, oil crisis may have a devastating impact on the national economy. When the U.S. underwent the oil crisis of 1973, its economy shrunk by a third, simultaneous with a growth in the unemployment rate from 4.9% to 8.5% and an inflation rate change from 3.4% to 12.2%. A second oil crisis erupted in the 1980s, which damaged the economy of the U.S. and British so severely that it caused a negative growth in GDP for the two countries. This growth was at the rate of 0.2% and 2.4%, respectively.

The previous oil crises, however, did not affect China’s economy, which was in a relatively low degree of economic openness. Nowadays, with the acceleration of globalization, China’s economy has become closely connected to the world economy. Although Chinese crude oil reserves account for 1.1% of the total aggregate, China still imports petroleum from abroad due to its deficiency in mining and refining technology. Since modern industry in China started in 1950s, the demand for petroleum in China is still growing fast in the present moment, whereas the demand in developed countries has peaked since the 1970s. In 2003, China became the second largest oil consumer in the world. *Report on the Development of the Domestic and Foreign Oil and Gas Industry in 2013* predicts that China’s dependence on imported crude oil will exceed 60% of the total demand by 2020, and it will continue to rise in the following 20 years. Clearly, oil will play a significant role in China’s economy in the upcoming years. Nevertheless, domestic oil production cannot meet the demand for petroleum in China. As a consequence, such high reliance on petroleum implies that the undulation of international crude oil prices is capable of exerting a distinctive impact on the Chinese economy.

As the only net importer among the member countries of the International Energy Agency (IEA), Australia fails to attain the target of holding 90 days of fuel reserves set by the agency. In 2013, however, *Australian Lincoln Energy*, one of the principal enery company in Australia, announced that a gigantic shale oil field with an estimated value of 21 trillion US dollars was found in the South of Australia, and that if that field is mined, Australia may turn into a net exporter of crude oil. Hence, it can be predicted that the Australia′s economic conditions would be closely related to the international oil to a certain exten, and the effects of the fluctuation of the crude oil price on the economy of Australia is expected to be a contentious issue.

Before 1879, crude oil was in its earliest stage of development. On account of underdeveloped mining and exploring techniques, the output of petroleum was limited, which resulted in a high price. From 1879 to 1973, thanks to the improving technologies, the cost of mining abated substantially and the demand for oil increased gradually. Therefore, the price of oil fluctuated moderately at a comparatively low interval. During this phase, the oil industry remained under the control of European and American countries. After the Second World War, oil-producing countries became independent, and, subsequently, OPEC was founded, subsequently taking over much of the control of oil. Since 1973, the demand for oil has slowed down. Oil production in non-OPEC countries has changed. At the same time, all of the countries in the world have established oil reserves in succession. Consequently, the unilateral pattern of oil pricing dominated by OPEC or MNCs has collapsed. The oil market has been constantly oscillating due to this collapse, and the international oil price is in dramatic fluctuation.

In order to avoid the risks induced by the volatility of oil prices, the oil futures market has emerged. In the last few decades, an array of financial derivatives pertinent to crude oil have appeared in the international oil futures market, and the trade volume of options, swaps, forwards, and other derivatives has continuously increased. Thus, the financial value of crude oil has become far more evident. At present, the Brent crude oil futures contract is a principal trading classification at the London International Petroleum Exchange, one of the four futures markets in the world. Over half of the world's crude oil pricing falls under the Brent crude oil pricing mechanism. Thus, the price of Brent crude oil futures factors greatly in the overall price of petroleum.

The stock market is one of the direct indicator of the macro-economy, which reflects the process of capital game and the confidence of investors. Ever since 2005, more than one hundred million investors have struggled in the Chinese stock market. There is no doubt that even a tiny change in the stock price would alter the economic condition of the participants.

This impact is actually reflected in the pricing mechanism of the stock index, which involves two aspects: discount rate and the enterprise’s future cash flows. Specifically, the first aspect emphasizes the influence of oil on the macro-economy as a whole, whereas the second aspect emphasizes the influence of oil on specific industries.

Currently, the majority of international crude oil futures use the U.S. dollar as the currency for pricing and settlement. Once the exchange rate between the U.S. dollar and other currencies fluctuates drastically, international crude oil prices fluctuate violently even if the supply is unchanged. As a result, the interest rate policy implemented by the Federal Reserve as well as the exchange rate would impose significant influence on the price of crude oil, which thereby affects the prevailing discount rate in the stock market. Apart from that, via the macro-economy, international crude oil price volatility could influence the stock market. If the price of crude oil goes up, there would be wealth transfers from net importers to net exporters. Thus, for net importers, aggregate consumption and the purchasing power of money plunge, while inflation pressure worsens. Nevertheless, as the number of net importers for crude oil far exceeds that of net exporters, the world's economy would generally experience a downturn. Due to the international economic recession in the late 20th century, the return is low, while the risks are high in the stock market. As a result, plenty of investors have lost confidence and are likely to withdraw their capitals out of the financial market, which leads to a further decrease in the rate of return. Additionally, when investors anticipate inflation pressure in the future, the inflation rate will naturally rise. Thus, stocks might be priced even lower than the present value and consequently, the yield will decline. Additionally, there exists a competitive relation between the crude oil futures market and the stock market as both of them belong to the financial market. When the amount of funds injected into one market increases, funds available for the other market tend to decrease. Thus, it is almost impossible to guarantee a high rate of return in the stock market all the time.

Referring to the classification standard of China's national economy, six (6) sectors were selected for the purposes of this paper to illustrate how crude oil affects specific industries. As for the consumer sample sector, consumer discretionary sector and industrial sector, given that oil and its derivatives are the raw materials or the energy in production, the price of crude oil is predicted to be negatively related to stock indices. By contrast, in terms of the energy sector, materials sector and utilities sector, the relations between crude oil and stock indices are ambiguous, depending on the position of petroleum and its substitutes.

The remaining part of this paper is arranged as follows. Section 2 reviews related literature on the interaction between the price of crude oil futures and stock indices. Section 3 is devoted to descriptive analysis of data. Empirical research based on the first difference and co-integration test is carried out in Section 4. This paper applies different models according to the properties of the variable groups. Finally, Section 5 concludes the paper and proposes suggestions for the Chinese stock market.

2 RELATED LITERATURE

Based on the stock pricing model, a great deal of literature discusses the interrelation between crude oil futures and the stock market. In stock valuation, the price of a stock corresponds to the present value of the expected future cash flows. Hence, both future cash flows and the discount rate are determinants of the stock price. Previous research points out that the price of oil is closely related to the macro-economy, and since the price of crude oil futures is the proxy for the price of oil, whereas the stock market is the barometer of the macro-economy, the price of crude oil futures is associated with the stock market. Huang, Masulis and Stoll (1996) suggest that the variation of crude oil futures price is associated with the expected discount rate and future cash flows of the corporation.

Expected discount rate is determined by factors including interest rate, supply and demand of capitals and expected inflation rate. Hamilton (1996) argues that the international oil price is supposed to affect inflation and interest rates mainly by affecting monetary policy. When confronted with the high volatility of petroleum prices, the government would intervene with the interest rate and inflation rate in order to stabilize the economy and to reassure investors, as crude oil is essential to a considerable number of enterprises, especially in terms of production and operation. According to Hooker (2002) and LeBlance and Chinn (2004), the relation between crude oil futures prices and inflation are asymmetric since the monetary policy cannot be adjusted as frequently as the price of crude oil futures fluctuates.

Expected future cash flows of the enterprise are pertinent to the conditions of the macro-economy, the development of the industry, and the operation of the enterprise. Fried and Schultze (1975) stated that the escalating price of crude oil is prone to incur falling demand for commodities and, ultimately, economic depression. Rasche and Tatom (2005) illustrated that a 1% increase in the price of international crude oil brings about a 7% decrease in real GNP in the long term. By constructing a six-variable system that is analogous to the real macro-economy, Hamilton (2011) finds that the surging international oil price could lead to the downturn of the economy. Enterprises engaged in extracting and processing of crude oil would be directly struck by the rising price of petroleum. In addition, for enterprises that apply petroleum as a sort of fuel, the volatile price would undoubtedly affect its operation, thereby affecting expected future cash flows.

The initial studies of crude oil prices and stock markets are not satisfactory. In the early 20th century, the multiple-factor model was regarded as the paradigm for empirical analysis. However, neither the research on the U.S. stock index performed by Chen, Roll and Ross (1986) nor the research on the Japanese stock index performed by Hamao, Masulis and Ng (1990) present evidence that the oil price has a significant impact on the stock market. Likewise, Huang, Masulis and Stoll (1996) fail to verify the negative correlation between the price of crude oil and the return on investment of the stock market. By means of the VAR approach, Maghyereh (2004) demonstrates that the impact of the price of crude oil on the stock market in emerging countries is rather weak. Nevertheless, most subsequent studies corroborate the influence of crude oil price on the stock market. Qi and Zhu (2011) and Zhang and Wang (2010) affirm that the international oil price has varying degrees of impact on the capital market in different countries. Specifically, the degree of such influence is higher for countries whose stock market is relatively mature. By establishing a VAR model, Sadorsky (1999) proves that the actual rate of return of the stock market is in relation to the price of crude oil, and such relation is asymmetric. Zhuge and Hao (2009) illustrate the long-term co-integration between the volatility of the Chinese stock market and that of the international crude oil price. The impulse response shows that from 2002 to 2008, the increase of the international crude oil price positively affected the Chinese stock market, but later on that impact moved in the opposite direction, which is similar to the conclusion drawn by Zhang (2013) when using the data from 2006 to 2010. On the basis of the asymmetrical BEKK model and Wald test, Zhu (2015) confirms the presence of a two-way volatility spillover effect between the crude oil futures market and the stock market.

Research on how crude oil price affects specific industries is sparse. Sadorsky (2001) argues that the stock returns of oil companies are positively related to the oil price, while the stock returns of natural gas companies are negatively related to the oil price. By means of the GED-GARCH (1,1)-M model, Jin (2010) illustrates that the international oil price has significant negative impacts on the automobile, construction, and finance industries, but that it has significant positive impacts on the oil and natural gas industries. However, in the GARCH test, the author adds the Shanghai Composite Index as an explanatory variable into the regression, without considering the relationship between index and crude oil price. Lao (2008) conducts multi-variable regression and elaborates the distinctive positive impacts of oil price on the first level sector indices derived from the Wind database. Hence, different approaches utilized in the empirical analysis are responsible for the discrepancy in the findings. Dai (2014) constructs an ARMA-EGARCH-M model for the data from 2009 to 2013, finding that the rising international oil price is positively correlated to the mining industry, but negatively correlated to industries that are energy consuming or sensitive to exogenous shocks, such as the transportation and commercial industries.

3 EMPIRICAL ANALYSIS

This paper pertains to the impact of crude oil on the stock market. There is only one explanatory variable, the WTI (West Texas Intermediate) futures price, which is the proxy for the international crude oil price. In terms of explained variables, two (2) composite stock indices, the CSI 500 and the S&P/ASX 300, were adopted on behalf of the Chinese and Australian stock markets, accordingly. Apart from that, six (6) sector indices in both the Chinese and Australian stock markets were selected as dependent variables, which involve the consumer staples sector, consumer discretionary sector, energy sector, materials sector, industrial sector, and utilities sector. Relevant data spanning from June 1st, 2008 to May 31st, 2018 are gathered from the global financial portal and internet brand *Investing.com*, the Wind database, and the Australian Securities Exchange.

This paper performs an Augmented Dickey-Fuller (ADF) unit root test to determine whether time sequences of crude oil futures prices, 2 composite stock indices, and 12 sector stock indices are stationary or not. Referring to the test results, except for the stock index of the Australian material sector, all of the six Chinese stock indices and the rest five Australian stock indices are unstable. Given that non-stationary series cannot be used for regression, this paper proposes two (2) approaches to tackle such phenomena: taking the first difference or performing a co-integration regression.

a) The first difference

The first difference on a non-stationary series was computed for the purpose of observing whether variables become stable. By means of taking the first difference, all the research objects reject the null hypothesis that implies the presence of the unit root at the 1% significance level. Therefore, all the variables are stationary at the moment.

After converting all the original variables into the stationary forms, this paper discusses the causality between the WTI futures price and 14 stock indices by implementing a Granger causality test. According to the test results, only the WTI futures price and the stock index of the Australian utilities sector present two-way Granger causality, whereas the WTI futures price is a one-way Granger causality to the Australian composite index, the Australian consumer discretionary sector index, and the Australian industrial sector index. In addition, the Australian energy sector index and the Australian materials sector index are a one-way Granger causality to the WTI futures price. There exists no Granger causality in the remaining variable groups.

Subsequently**, a** VAR (Vector Autoregression) test was conducted on the variable group with two-way Granger causality: the WTI futures price and the Australian utilities sector index. This was done so that the underlying interrelation could be analyzed.

In fact, improper lag order could incur biased estimation. Specifically, if the lag length is too large, the loss of the degree of freedom will appear; if lag length is too small, significant autocorrelation will appear. Thus, the optimal lag length needs to be figured out before establishing a VAR model on the DWTI and the DASXUT. Relevant results are available in Table I.[1]

As indicated by Table I, among 5 information criteria, an LR that denotes a sequential modified LR test statistic, an FPE that denotes a final prediction error, and an AIC that denotes an Akaike information criterion selected 5 as the optimal lag order.

Subsequently, this paper carries out an unrestricted VAR test on variables of the DWTI and the DASXUT, in which the lag length is 5. Table II presents the pertinent results.

Judging from Table II, the WTI futures price presents a negative impact on the Australian utilities sector index except under the lag order of 4. However, such an impact is significant at the 5% level only under the second lag order. Therefore, there was a delayed effect of the WTI on the DASXUT. The Australian utilities sector index has a positive impact on the WTI futures price under the second and fourth lag order, but such a relation turns out to be negative under the other lag orders. Nevertheless, the effect is significant only on the second phase. Consequently, the impact of the DASXUT on the WTI shows the hysteretic attribute.

Impulse response displays the reaction of a variable when imposing a standard shock on a random error. In other words, it shows how the value of a variable varies both at present and in the future when confronted with an impulse from the error term. Before performing the impulse response, it is necessary to determine whether the VAR is stationary or not. According to the AR root graph, all the inverse roots of the AR characteristic polynomial are within the unit circle, which verifies the stationary property of VAR between the WTI and the DASXUT.

Variance decomposition interprets to what extent one variable contributes to the variation of the other variables. This paper applies orthogonalization to eliminate residual and contemporaneous correlation. On the basis of the VAR model, variance decomposition of the WTI futures price and the Australian utilities sector index was made. Table III summarizes the results.

[1] Due to space limit, Table I, Table II, Table IV, Table VII, and Figure 1 – Figure 6 can be found in an online appendix at https://www.jianguoyun.com/p/DSKx4LwQ38HrCBiIp_QD

TABLE III VARIANCE DECOMPOSITION OF DASXUT AND DWTI

Variance Decomposition of DASXUT				Variance Decomposition of DWTI			
Period	**S.E.**	**DASXUT**	**DWTI**	**Period**	**S.E.**	**DASXUT**	**DWTI**
1	55.31326	100.0000	0.000000	1	1.713759	0.004876	99.99512
2	55.43988	99.94279	0.057209	2	1.717015	0.017149	99.98285
3	55.48879	99.79881	0.201189	3	1.718329	0.165710	99.83429
4	55.51356	99.72998	0.270015	4	1.718419	0.176045	99.82395
5	55.51633	99.72692	0.273082	5	1.723201	0.260637	99.73936
6	55.55747	99.72496	0.275044	6	1.729426	0.382101	99.61790
7	55.55814	99.72483	0.275167	7	1.729531	0.388310	99.61169
8	55.55832	99.72428	0.275718	8	1.729561	0.391642	99.60836
9	55.55872	99.72335	0.276652	9	1.729598	0.392901	99.60710
10	55.55875	99.72322	0.276781	10	1.729722	0.395869	99.60413

In the first phase, the WTI futures price cannot explain the volatility of the Australian utilities sector index at all. However, in the following phase, 5.7209% of the fluctuation of the DASXUT is attributed to the DWTI. The proportion that the variation of the DASXUT can be explained by that of the DWTI proliferates to 20.1189% in the third phase. After that, it stabilizes at around 27% in the next 6 phases. Conversely, the stock index of the Australian utilities sector has greater a contribution to the variation of the WTI futures price. In the initial phases, the variation of the DASXUT only accounts for a relatively small proportion of that of the DWTI, but as the lag length increases, that phenomenon changes a lot. Such explanatory power surges in the fifth and sixth phase and subsequently levels out at approximately 40%.

In terms of the variable groups that present one-way or no Granger causality, this paper constructs an OLS regression. Results indicate that the WTI futures price is highly relevant to the composite index of both the Chinese and Australian stock markets, the stock index of Australian energy, and the materials and industrial sectors at the 5% level. Nevertheless, there is no significant relation between the WTI futures price and the rest of the stock indices.

In order to guarantee the validity of OLS regression, a Breusch-Godfrey serial correlation test was carried out. By introducing the ARMA model into OLS regression, the paper ameliorates the original OLS model, as shown in Table IV.

According to the ARCH test results, all the sequences possess an ARCH effect. Thereby, the GARCH model is applicable. An ARCH re-test illustrates that heteroskedasticity no longer exists in the residual sequences, which suggests that the modelling process is successful.

For the purpose of further investigating the volatility spillover effect of the WTI futures price on the stock indices, this paper applies the BEKK-GARCH model to the variable group that presents two-way Granger causality: the DASXUT and the DWTI. The BEKK-GARCH model is represented by the following equations,

$$Y_t = \varphi_0 + \varphi_1 Y_{t-1} + \cdots + \varphi_p Y_{t-p} + \varphi_0 X_t + \varepsilon_t, p > 0, \quad (1)$$

$$H_t = CC' + B' H_{t-1} B + A' \varepsilon_{t-1} \varepsilon_{t-1}' A, \quad (2)$$

where Y_t denotes stock price, and X_t denotes crude oil futures price. $H_t = \begin{bmatrix} h_{11,t} & h_{12,t} \\ h_{21,t} & h_{22,t} \end{bmatrix}$ is conditional covariance matrix. A and B are second-order parameter matrices. A reflects the ARCH effect of the volatility while B reflects the GARCH effect of the volatility. C is a second-order upper triangular matrix.

Therefore, the conditional covariance matrices are expanded as follows:

$$h_{11,t} = C_{11}^2 + \beta_{11}^2 h_{11,t-1} + 2\beta_{11}\beta_{21} h_{12,t-1} + \beta_{21}^2 h_{22,t-1} + \alpha_{11}\alpha_{21}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + \alpha_{21}^2 \varepsilon_{2,t-1}^2 + 2\alpha_{11}\alpha_{21} h_{12,t-1}, \quad (3)$$

$$h_{22,t} = C_{21}^2 + C_{22}^2 + \beta_{12}^2 h_{11,t-1} + 2\beta_{12}\beta_{22} h_{12,t-1} + \beta_{22}^2 h_{22,t-1} + \alpha_{12}^2 \varepsilon_{1,t-1}^2 + 2\alpha_{11}\alpha_{22}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + \alpha_{22}^2 \varepsilon_{2,t-1}^2, \quad (4)$$

$$h_{12,t} = C_{11}C_{21} + \beta_{11}\beta_{12} h_{11,t-1} + (\beta_{12}\beta_{21} + \beta_{11}\beta_{12}) h_{12,t-1} + \beta_{21}\beta_{22} h_{22,t-1} + \alpha_{11}\alpha_{21}\varepsilon_{1,t-1}^2 + (\alpha_{12}\alpha_{21} + \alpha_{11}\alpha_{22})\varepsilon_{1,t-1}\varepsilon_{2,t-1} + \alpha_{21}\alpha_{22}\varepsilon_{2,t-1}^2, \quad (5)$$

where $h_{11,t}$ denotes the conditional variance of stock price at time t, $h_{11,t}$ denotes conditional variance of crude oil futures price, and $h_{12,t}$ denotes the conditional covariance of stock price and crude oil futures price. Therefore, the equation and principal parameters of the BEKK-GARCH model on the ASXUT and the WTI are presented in Table V.

TABLE V BEKK-GARCH MODEL ON ASXUT AND WTI

BEKK-GARCH Equation			
GARCH1=0.000000641601+0.026665257025*RESID1(-1)^2+0.966621282561*GARCH1(-1)			
GARCH2=0.000003181165+0.065008681024*RESID2(-1)^2+0.931180610529*GARCH2(-1)			
COV1_2=-0.000000112941+0.04163499956*RESID1(-1)*RESID2(-1)+0.948735472113*COV1_2(-1)			
Explained Variable	*Insignificant Variable*	*A(1, 2) & B(1, 2)*	*B(1, 1) & B(2, 2)*
ASXUT	M(1,2)	Significant	B(1, 1) > B(2, 2)

B(1, 1) is larger than B(2, 2), which implies that the Australian utilities sector index responds much more quickly than the WTI futures price when confronted with external shock. In order to provide a feedback relation between the Australian utilities sector index and the WTI futures price, a conditional correlation line chart was generated, as shown in Figure 4.

The condition correlation line chart shows that the correlation coefficient of the ASXUT on the WTI is not stable. Thus, the time-varying property is rather significant. Approximately 40% of the correlation coefficients turn out to be positive, which suggests that when the fluctuation of the WTI crude oil futures price becomes dramatic, the amplitude of the volatility of the Australian utilities sector index is prone to increase. Consequently, the volatility spillover effect of the international crude oil futures price on the utilities sector index in the Australian stock market is distinct.

b) Co-integration

As for variables that turn out to be stationary after taking the first difference, co-integration is applicable. In fact, the first difference may be accompanied with the loss of long-run relation between variables. Hence, the paper applies a co-integration test to assess whether the long-term relation exists or not. Relevant results are summarized in Table VI.

TABLE VI CO-INTEGRATION TEST

Variable Group	**Statistics**	**Variable Group**	**Statistics**
CSI 500 & WTI	5.082495*	S&P/ASX 300 & WTI	1.433082
CSIST & WTI	7.871290*	ASXST & WTI	2.711655
CSIDIS & WTI	5.929431*	ASXDIS & WTI	0.530816
CSIEN & WTI	9.536682*	ASXEN &WTI	6.173367*
CSIMA & WTI	10.03195*	ASXINDUS & WTI	0.331775
CSIINDUS & WTI	6.519734*	ASXUT & WTI	0.007908
CSIUT & WTI	5.937906*		

Judging from Table VI, only the Chinese composite index, the Chinese consumer staples sector index, the Chinese consumer discretionary sector index, the Chinese energy sector index, the Chinese materials sector index, the Chinese industrial sector index, the Chinese utilities sector index, and the Australian energy sector index present the co-integration relation with the WTI futures price, which implies the presence of a long-term effect.

Therefore, this paper constructs a co-integration regression for variable groups that possess co-integration relation. According to the co-integration regression results, all the correlation coefficients are significant at the 1% level. Except for the Australian energy sector index, the remaining stock indices are negatively related to the WTI futures price. The correlation coefficient of the WTI on the ASXEN is 81.43327, which signifies that the growth of the stock price in the Australian energy sector is driven by the increasing price of the petroleum futures.

A Granger causality test was performed on the variable groups that pass the co-integration test, and the results demonstrate that only the stock index of the Australian energy sector has a two-way Granger causality with the crude oil futures price. As for the Chinese stock market, the composite index, the sector index of consumer staples, consumer discretionary, materials, and the industrial and utilities sectors present a one-way Granger causal relation to the WTI. However, there exists no Granger causality between the stock index of the Chinese energy sector and the crude oil futures price.

With the precondition of co-integration, the VECM (Vector Error Correction Model) is applicable for non-stationary data. In addition to a long-term co-integration equilibrium relationship between variables, such a model presents a short-term relation between variables. Thus, it conduces to evaluate that a short-run relation is a temporary or permanent deviation.

This paper constructs a VECM model for the variable group of the WTI and the ASXEN that is two-way Granger causal. The process is analogous to the VAR model under the first difference. Based on the information criteria, the optimal lag order is determined, and the results are shown in Table VII.

According to Table VII, the criterion of LR, FPE, and AIC implies that the optimal lag length is 6 in the VECM model on the WTI and the ASXEN. Subsequently, this paper implements an unrestricted VAR test on the variable group of the WTI and the ASXEN and the results are summarized in Table VIII.

TABLE VIII UNRESTRICTED VAR TEST ON WTI AND ASXEN IN VECM MODEL

	ASXEN	WTI		ASXEN	WTI
ASXEN(-1)	1.057222	-0.000153	WTI(-1)	0.478987	0.939668
	(0.02076)	(0.00017)		(2.52009)	(0.02065)
	[50.9148]	[-0.90171]		[0.19007]	[45.4948]
ASXEN(-2)	-0.047290	0.000570	WTI(-2)	1.489208	0.042755
	(0.03022)	(0.00025)		(3.40531)	(0.02791)
	[-1.56507]	[2.30352]		[0.43732]	[1.53190]
ASXEN(-3)	-0.083396	-0.000479	WTI(-3)	-2.038687	0.018243
	(0.03009)	(0.00025)		(3.39697)	(0.02784)
	[-2.77128]	[-1.94024]		[-0.60015]	[0.65527]
ASXEN(-4)	0.076673	0.00063	WTI(-4)	6.875494	0.060485
	(0.03010)	(0.00025)		(3.38708)	(0.02776)
	[2.54732]	[2.55393]		[2.02992]	[2.17883]

As presented in Table VIII, the first, second, and fourth lag order of the WTI futures price have positive impacts on the Australian energy sector index. Conversely, the third, fifth, and sixth lag phase of the WTI futures price are negatively correlated to the Australian energy sector index. Thus, only the fourth and fifth lag order are substantially significant at the 1% level. As a result, the impact of the WTI on the ASXEN is rather weak in the initial three phases, but strengthens in the following 2 phases, and then gradually attenuates. As for the Australian energy sector index, only the first and fourth lag orders are positively related to the WTI futures price, while the others exert negative impacts on the WTI futures price. Except for the first lag order, the impact of the ASXEN on the WTI is significant at the 10% level.

As the AR root graph in the VECM model hints that autoregression is stationary, this paper conducts the impulse response on the WTI and the ASXEN, as shown in Figure 5 and Figure 6. When imposing a standard impulse on the WTI, the ASXEN vibrates moderately towards the positive direction in the first 4 phases. After that, the volatility amplitude increases and gradually levels off in the subsequent 6 periods. The impulse response of the WTI to the ASXEN is rather similar to the impulse response of the ASXEN to the WTI, but with an intensified undulation frequency.

According to the variance decomposition as presented in Table IX, in the first period, the WTI cannot explain any variation of the ASXEN. Nevertheless, in the following period, 0.0726% of the variation of the ASXEN is attributed to the WTI. As the period increases, such explanation power improves, and eventually reaches 41.5906% in the last period. By contrast, the ASXEN is responsible for 20.2876% of the variation of the WTI in the first period. Even though the figure falls in the second phase, it rises to 82.3453% at the end. Consequently, the WTI can only explain a relatively low proportion of the variation of the ASXEN, while the ASXEN can explain an extremely high percentage of the variation of the WTI.

TABLE IX VARIANCE DECOMPOSITION ON ASXEN AND WTI IN VECM MODEL

Variance Decomposition of ASXEN				Variance Decomposition of WTI			
Period	S.E.	ASXEN	WTI	Period	S.E.	ASXEN	WTI
1	208.2862	100.0000	0.000000	1	1.707092	0.202876	99.79712
2	303.1339	99.99927	0.000726	2	2.341731	0.137412	99.86259
3	376.4223	99.98725	0.012748	3	2.82693	0.293475	99.70653
4	430.1221	99.98143	0.018571	4	3.241854	0.345527	99.65447
5	477.9072	99.87882	0.121179	5	3.663015	0.694678	99.30532
6	521.1178	99.78997	0.210033	6	3.982292	0.733479	99.26652
7	561.3511	99.71875	0.281255	7	4.282301	0.776827	99.22317
8	598.4671	99.66977	0.330231	8	4.560712	0.788175	99.21182
9	633.3971	99.62125	0.378753	9	4.825745	0.816235	99.18377
10	666.0269	99.58409	0.415906	10	5.068614	0.823454	99.17655

Given that there is a long-term equilibrium relation, the ECM (Error Correction Model) is utilized to delve into the speed of adjustment when one variable deviates from its normal trend, in which an Engle-Granger (E-G) two-step approach is applied. After examining the co-integration relationship of the variable groups, the ECM model is established between the variables that do not satisfy a two-way Granger causality. This paper employs the least square method (OLS) to estimate the co-integration parameter. As a non-equilibrium error term, the residual is substituted into the ECM model, whose coefficient thereby denotes how the short-term tendency moves into the long-term tendency.

In the ECM model, the long-run and short-run relation between variables are displayed by equation (6) and (7), respectively.

$$y_t = \alpha_0 + \alpha_1 x_t + \mu_t \tag{6}$$

$$y_t = \beta_0 + \beta_1 x_t + \beta_2 x_{t-1} + \xi_t \tag{7}$$

Through proper transformation, ECM model is represented by the following equation:

$$\Delta y_t = \beta_1 \Delta x_t - \lambda(y_{t-1} - \alpha_0 - \alpha_1 x_{t-1}) + \xi_t = \beta_1 \Delta x_t - \lambda ecm_{t-1} + \xi_t, \tag{8}$$

where $\lambda = 1 - \mu$, $\alpha_0 = \beta_0/(1-\mu)$, $\alpha_1 = (\beta_1 + \beta_2)/(1-\mu)$, $ecm_{t-1} = y_t - \alpha_0 - \alpha_1 x_{t-1}$.

Thus, the paper develops the ECM model for variables that do not have two-way Granger causality relation, and Table X shows the results.

TABLE X ECM MODEL

Dependent Variable	Independent Variable	Coefficient	Standard Deviation	t Statistics	Probability
DCSI 500	DWTI	5.675627	1.204134	4.713452	0.0000
	RESIDUAL(-1)	-0.004213	0.00163	-2.584471	0.0098
DCSIST	DWTI	0.862625	1.560188	0.552898	0.5804
	RESIDUAL(-1)	-0.005394	0.001829	-2.948309	0.0032
DCSIDIS	DWTI	0.195470	1.046326	0.186816	0.8518
	RESIDUAL(-1)	-0.004972	0.001651	-3.011831	0.0026
DCSIEN	DWTI	0.635924	1.139501	0.558073	0.5768
	RESIDUAL(-1)	-0.006861	0.002314	-2.964845	0.0031
DCSIMA	DWTI	0.448492	0.926522	0.48406	0.6284
	RESIDUAL(-1)	-0.005208	0.001921	-2.711663	0.0067
DCSIINDUS	DWTI	0.945084	1.223290	0.772575	0.4399
	RESIDUAL(-1)	-0.004822	0.001672	-2.883704	0.0040
DCSIUT	DWTI	0.246263	0.870041	0.283048	0.7772
	RESIDUAL(-1)	-0.005624	0.001843	-3.050671	0.0023

Referring to Table X, only the coefficient of the DWTI on the DCSI 500 is significant at the 1% level, which implies that the WTI futures price is strongly related to the Chinese composite index in the long term. All the coefficients of the error correction terms are significant at the 1% level and are negative, indicating that the stock market has the function of reserve self-correction. The absolute value of the error correction coefficient is rather small, which is below 0.006861. Thus, when stock index volatility deviates from the long-term equilibrium, the adjustment to such deviation is limited. Consequently, the error term of the WTI futures price only has restricted adjustment to the fluctuation of the stock index in the long run.

4 CONCLUSION AND POLICY IMPLICATIONS

In conclusion, this paper applies the VAR model, OLS regression, the BEKK-GARCH model, the VECM model, and the ECM model on the data from June 1st, 2008 to May 31st, 2018, in order to analyze whether the international crude oil futures price has a significant impact on the composite index and sector index between the Chinese and Australian stock markets. On the basis of these empirical findings, this paper puts forward the following suggestions for the stock market and the international crude oil futures market.

Firstly, financial institutions are supposed to perfect the supervision mechanism of the international crude oil narket. Since the volatility of crude oil has certain impacts on the stock market, it is somewhat necessary to control the price of international crude oil futures. At present, the demand for crude oil has become stable in developed countries. Meanwhile, the demand for crude oil in developing countries is at a relatively low growth rate. In terms of the supply side of petroleum, the volume of oil production is stable unless new techniques or oil fields appear. Thus, the supply and demand of crude oil attains an equilibrium. However, the phenomenon of malicious speculation is quite serious, which is detrimental to the development of the financial market. Hence, financial institutions ought to strengthen supervision on the market and the participants.

In addition, the validity of the Chinese financial market should be improved. Currently, the Chinese stock market is less sensitive to the Australian stock market, which implies that the Chinese stock market has not yet achieved weak efficiency. In the stock market of China, most individual investors have difficulty gaining effective information, and the stock price cannot adequately reflect the instant information. As a result, personnel who use the position to access inside information should be punished. Since manipulating the price of a specific stock requires capital, regulators ought to be cautious about the inflow or outflow of a large sum of money. The eradication of abnormal trading would be propitious to enhance the effectiveness of the financial market.

Furthermore, the development of the stock market should comply with the trend of macro-economy. As both the composite and sector indices of the Chinese stock market have co-integration relationship with the international crude oil futures price, it can be inferred that different financial markets would move in an analogous pattern in the long run. Thus, when the macro-economy shows an irreversible trend, intervention may be counterproductive. In the past, when the composite stock index went down, the Chinese government would implement a battery of policies and even pour money into the market. However, such actions would trigger the panic of investors. Given that the stock market has the function of self-correction, conforming to the development of the macro-economy could guide the stock market out of the doldrums.

REFERENCES

[1] Chen, NF., Roll, R, and Ross, SA. 1986, ‘Economic Forces and the Stock Market’, *Journal of Business*, vol. 59, no. 3, pp. 383-403.

[2] Dai, DD. 2014, *A Study on the Impact of International Crude Oil Futures Price on the Sector Index in the Chinese Stock Market*, Inner Mongolia University, Inner Mongolia.

[3] Fried, ER. and Schultze, CL. 1975, ‘Higher Oil Prices and the World Economy: The Adjustment Problem’, *Brookings Institution*, vol. 40, no. 6, pp. 355-367.

[4] Hamao, Y., Masulis, R., and Ng, V. 1990, ‘Correlations in Price Changes and Volatility Across International Stock Markets’, *Review of Financial Studies*, vol. 3, no. 2, pp. 281-307.

[5] Hamilton, JD. 1996, ‘This Is What Happened to the Oil Price–Macroeconomy Relationship’, *Journal of Monetary Economics*, vol. 38, no. 2, pp. 215-220.

[6] Hamilton, JD. 2011, ‘Oil Price Shocks’, *Nber Reporter*, vol. 21, no. 99, pp. 449-469.

[7] Hooker, MA. 2002, ‘Are Oil Shocks Inflationary? Asymmetric and Nonlinear Specifications versus Changes in Regime’, *Journal of Money*, vol. 34, no. 2, pp. 540-561.

[8] Huang, RD., Masulis, RW., and Stoll, HR. 1996, 'Energy Shocks and Financial Markets', *Journal of Futures Markets*, vol.16, no. 1, pp. 1-27.

[9] Jin, HF. and Jin, H. 2010, 'Impact of the International Oil Price on the Chinese Stock Market: Empirical Analysis Based on Industry Data', *Financial Research*, no. 2, pp. 173-187.

[10] Lao, JN. 2008, 'Does the Oil Price Affect the Shanghai Composite Index? An Empirical Analysis Based on the Data from 2000 to 2007', *World Economic Outlook*, no. 5, pp. 71-76.

[11] LeBlance, M. and Chinn, MD. 2004, 'Do High Oil Prices Presage Inflation? The Evidence from G-5 Countries', *Business Economics*, vol. 39, no. 2, pp. 38-48.

[12] Maghyereh, A. 2004, 'Oil Price Shocks and Emerging Stock Markets: A Generalized VAR Approach', *International Journal of Applied Econometrics and Quantitative Studies*, vol. 1, no. 2, pp. 27-40.

[13] Qi, QY. and Zhu, HL. 2011, 'Econometric Analysis of the Relationship Between the International Oil Price and the Stock Market Between the Chinese and U.S. Stock Markets', *Securities Market*, no. 7, pp. 82-87.

[14] Rasche, RH. and Tatom, JA. 2005, 'Energy Resources and Potential GNP', *Federal Reserve Bank of St Louis Review*, vol. 59, pp. 10-24.

[15] Sadorsky, P. 1999, 'Oil Price Shocks and Stock Market Activity', *Energy Economics*, vol. 21, no. 5, pp. 449-469.

[16] Sadorsky, P. 2001, 'Risk Factors in Stock Returns of Canadian Oil and Gas Companies', *Energy Economics*, vol. 23, no. 1, pp. 17-28.

[17] Zhang, H. 2013, *A Comparative Study on the Impact of Crude Oil Price Volatility on Stock Price: Taken from Different Industries and Time Periods*, Zhejiang Science and Technology University, Zhejiang.

[18] Zhang, X. and Wang, JY. 2010, 'An International Comparison of the Impact of Crude Oil Price on the Stock Market', *Price Theory and Practice*, no. 1, pp. 75-76.

[19] Zhu, CY. 2015, *A Study on the Spillover Effect in Crude Oil Futures Market, Exchange Rate Market and Stock Market*, Ocean University of China, Qingdao.

[20] Zhuge, SQ. and Hao, XC. 2009, 'Shock of Domestic and Foreign Crude Oil Price and the Chinese Stock Market', *China's Prices*, no. 6, pp. 41-44.