OIL PRICE SHOCKS AND SECTOR RETURNS IN THE STOCK EXCHANGE OF THAILAND

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ABSTRACT

Title of Dissertation Oil Price Shocks and Sector Returns in the Stock Exchange of Thailand

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This thesis is aimed to contribute to the literature through investigating linkages between the volatility of oil prices and Thailand stock market returns in various industries. Economic theories have established that oil price shocks could create chain reaction effects on the real economic activities. Theoretically, oil price shocks is one of the factors that impact the performance of the Thai stock market. In this thesis, the GARCH approach was employed to determine the impacts of the oil price shocks on each industrial sector listed on the Stock Exchange of Thailand (SET) and on the SET index itself. We analyzed the trend of returns on each industry index from July 2004 to September 2015 using daily data. Overall, we found significant evidence that oil price shocks can alter volatilities of the eight industry indices in terms of both direction and size.

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CHAPTER 1

INTRODUCTION

It is a common knowledge in the financial economic literature that stock prices are highly volatile in nature and are influenced by various economic factors. Several previous studies show that unexpected macroeconomic phenomena can create significant pressure on the stock markets and cause stock prices to deviate from their means. Luo, Gan, and Kao (2009) analyzed the relationship between the Chinese stock market and the development of the Chinese economy in 1990. They showed that the stock market experienced a rapid growth after the introduction of the Shanghai and Shenzhen Exchange. Similarly, for the Japanese stock market, Hamao (1988) employed a variant of the classical Fama and MacBeth (1973) approach and showed that changes in expected inflation, unanticipated changes in risk premium and unanticipated changes in the slope of term structure have significant impacts on the Japanese stock market. From a market practitioner's perspective, sufficient understanding of these economic factors is crucial for making investment decisions. Amongst well-known economic factors, crude oil stands out as a prominent factor. Many studies in the energy economics literature, such as Jones and Kaul (1996), Sadorsky (1999), Apergis and Miller (2009), and Park and Ratti (2008), have investigated how short-term effects of oil shocks can be transmitted to stock markets and showed that changes in oil prices can significantly influence stock prices captured by stock price indices. Nevertheless, none of these studies have considered the possibility of heterogeneous effects of changes in oil prices on different industrial sectors. Stock indices are generally computed as a weighted average of selected stock prices from various industries. However, some industries may rely on oil more than the others, vice versa. Therefore, the effects of changes in oil prices could be significantly different on each sector.

Thailand is one of the countries that rely significantly on oil imports. The movement in oil prices could affected the economy both directly and indirectly. The error correction model (ECM) is generally utilized and there is evidence showing that changes in oil prices have strong impacts on other macroeconomic factors, specifically in the long run. Similarly, another research investigated the impact of oil crisis on Thailand economy during 2005 to 2014 using vector error correction (VEC) models and found that fluctuations in oil prices are major sources of the volatility in the country's gross domestic product. In addition, recent research found a significant relationship between the Securities Exchange of Thailand (SET) index and oil prices with cointegration. Still, like other previous studies, they do not consider the heterogeneous impacts of changes in oil prices on different market sectors.

This study aims to contribute to the literature in several aspects. First, we extend the analysis of the effects of changes in oil prices on the Thai stock market from the aggregated market level to the disaggregated sector level. In particular, we employed Thai stock indices associated with Agro and Food, Consumer Products, Financials, Industrials, Property and Construction, Resources, Services, and Technology industries. This allows us to inspect which industry is more sensitive to changes in oil prices. Second, we investigate both the long-term and short-term relationships between oil prices and stock prices in different industries. Third, we limit our study on the Securities Exchange of Thailand. This allows us to evaluate the sensitivity of the Thai stock market, and in turn, Thai economy, to changes in the world oil prices. Our findings would benefit oil users, producers, investors, and policy makers who seek to understand more about how changes in oil prices may affect the performance of the stock index in the industry that they are currently participating.

The remainder of this paper is organized as follows. Chapter 2 describes the concepts, theories, and literature related to this study. Chapter 3 presents the research methodology employed for this study in details. Chapter 4 reports and discusses the empirical results of all models in different sectors. Finally, Chapter 5 provides the conclusions drawn from this study

1.1 Research Objectives

This study aims to investigate both short-term and long-term effects of changes in the world oil prices on a stock market at the disaggregated sector level. The main objectives of this study are the followings:

By analyzing the effects at the disaggregated sector level, this allows us to inspect which industry is more sensitive to changes in oil prices. Some industries may be heavily dependent on oil, while the others may not have any relationship with the oil market at all. Thus, the effects of changes in oil prices could be significantly different on each sector.

In order to perform a comprehensive analysis on the effects of changes in oil price change on the stock market, we investigate both the long-term and short-term relationships between oil prices and stock prices in different industries. This would provide policy makers and other market participants a complete picture of how important changes in oil prices are to the stock market.

1.2 Scope of the Study

This study focuses on the long-term and short-term relationships between changes in oil prices in the world market and performance of stock indices corresponding to various market sectors in Thailand. In particular, we employed Thai stock indices associated with Agro and Food, Consumer Products, Financials, Industrials, Property and Construction, Resources, Services, and Technology industries. The indices are obtained from and maintained by the Stock Exchange of Thailand. Sectors associated with each industry are shown in the following table:

Table 1.1 SET Industry Group and Sector Classification Structure (8 Industry Groups and 28 Sectors)

Industry Group	Sector	Sector Symbol Abbr.
Agro & Food Industry [AGRO]	Agribusiness	AGRI
	Food & Beverage	FOOD
Consumer Products [CONSUMP]	Fashion	FASHION
	Home & Office Products	HOME
	Personal Products & Pharmaceuticals	PERSON
Financials [FINCIAL]	Banking	BANK
	Finance & Securities	FIN
	Insurance	INSUR
Industrials [INDUS]	Automotive	AUTO
	Industrial Materials & Machinery	IMM
	Packaging	PKG
	Paper & Printing Materials	PAPER
	Petrochemicals & Chemicals	PETRO
	Steel	STEEL
Property & Construction [PROPCON]	Construction Materials	CONMAT
	Construction Services	CONS
	Property Development	PROP
	Property Fund & REITs	PF&REIT
Resources [RESOURC]	Energy & Utilities	ENERG
	Mining	MINE

Table 1.1 (Continued)

Industry Group	**Sector**	**Sector Symbol Abbr.**
Services [SERVICE]	Commerce	COMM
	Health Care Services	HELTH
	Media & Publishing	MEDIA
	Professional Services	PROF
	Tourism & Leisure	TOURISM
	Transportation & Logistics	TRANS
Technology [TECH]	Electronic Components	ETRON
	Information & Communication Technology	ICT

Source: Stock Exchange of Thailand, 2018

1.3 Sources of Data

The data used in this study are obtained from the Securities Exchange of Thailand and the U.S. Energy Information Administration (EIA). The frequency of the data is monthly spanning from July 2004 to September 2015.

CHAPTER 2

CONCEPTS, THEORIES, AND RELATED LITERATURE

In this study, we study the documents, textbooks, articles, journals, theories and related research. The following sections cover details and explanations of all relevant concepts for this study.

2.1 Theoretical Issues

1) Production Theory

A production function is a function that captures the relationship between quantities of inputs used and product produced. Potential inputs consist of land, capital, labor, raw materials and tools used in the production of goods. The production function showed the productivity that can be produced by integrating the existing inputs.

2) Cobb-Douglas production function

A Cobb-Douglas function could be expressed in the following way.

$$Q = AL^{\alpha}K^{\beta}\#(1)$$

where

Q is the number of outputs

L is the number of labor inputs.

K is the number of capital inputs.

A is the technological advancement coefficient.

α is the proportion of wages in total costs.

β is the ratio of the cost of capital to the total cost.

The function requires the following conditions to be satisfied:

All production inputs must be greater than zero. If one of the inputs is not available, then no output can be produced.

Both inputs cannot be completely replaced.

The exponent on the variables of each factor represents the proportion of the cost of that factor to the total cost of production.

The technological advancement coefficient is often equal to one, so that the Cobb-Douglas function can be written as

$$Q = AL^{\alpha}K^{\beta}\#(2)$$

Note that if the technology advances, then A will be greater than one. Moreover, the special feature of Cobb-Douglas production function is that the exponents are not required to be equal to one. The sum of the exponents is analyzed as follows:

If the sum is equal to 1, it shows that the production is in Constant Returns to Scale, which means that if all inputs of 1% in the same proportion are added to the production process, the total output will increase by 1%.

If the sum is greater than 1, the production is in the Increasing Returns to Scale, which means that if all 1% inputs are added in the same proportion into the production process, the total output increases by more than 1%.

If the sum is less than 1, the production is in the Decreasing Returns to Scale, which means that if all 1% inputs are added in the same proportion into the production process, the total output increases by less than 1%.

According to Nicholson (1978), technical progress represents the growth rate of productivity over time. Hence, the production function can be written as.

$$Q = A(t)f(K, L)\#(3)$$

Where$K$ is the factor of capital, and L is the factor of labor, and$A(t)$can be considered as a residual term that contributes to the production. All of these factors are used to produce$Q$. A constant change of$A$ represents the technical progress.In this study, A is defined as the energy factor andcan be expressed as a function of time. The differential equations corresponding to equation (3) yield many insights about the production function:

$$\frac{dQ}{dt} = \frac{dA}{dt} \cdot \frac{Q}{A} + \frac{Q}{f(K,L)} \cdot \left(\frac{\partial f}{\partial K} \cdot \frac{dK}{dt} + \frac{\partial f}{\partial L} \cdot \frac{dL}{dt}\right) \#(4)$$

$$\frac{\frac{dQ}{dt}}{Q} = \frac{\frac{dA}{dt}}{A} + \frac{\partial f}{\partial K} \cdot \frac{K}{f(K,L)} \cdot \frac{\frac{dK}{dt}}{K} + \frac{\partial f}{\partial L} \cdot \frac{L}{f(K,L)} \cdot \frac{\frac{dL}{dt}}{L} \#(5)$$

$$g_Q = g_A + \frac{\partial f}{\partial K} \cdot \frac{K}{f(K,L)} \cdot g_K + \frac{\partial f}{\partial L} \cdot \frac{L}{f(K,L)} \cdot g_L \#(6)$$

where

$\frac{\partial f}{\partial K} \cdot \frac{K}{f(K,L)} = \frac{\partial Q}{\partial K} \cdot \frac{K}{Q} = E_{Q,K}$=Productivity Flexibility corresponding to K

$\frac{\partial f}{\partial L} \cdot \frac{L}{f(K,L)} = \frac{\partial Q}{\partial L} \cdot \frac{L}{Q} = E_{Q,L}$=Productivity Flexibility corresponding to L

Therefore, we have that

$$g_Q = g_A + E_{Q,K} g_K + E_{Q,L} g_L \#(7)$$

Equation (7) illustrates how the growth rate of production, g_Q, can be decomposed into the growth rates of capital, labor, and technology. Solow (1956) describes the technology growth, g_A, as the residual growth or Solow residual. In this study, we apply this concept from an energy economist's point of view.

3) Economic Growth Theory

Economic Growth Theory is the theory that describes the determinants or components of the process of economic growth.

4) Solow's Economic Growth Theory

Solow's economic growth theory (1956) incorporated the average production function, the average saving function, the relationship between investment and savings, the relationship of depreciation, the rate of population increase on investment, and the relationship between savings and the growth of capital to labor. The concept of steady-state growth improved upon the growth theory of Harrod and

Domar. However, Solow's Theory was an analysis of the whole system of economics, not the financial sector. It was called Solow's One Sector, Non-monetary Growth Model. The key assumptions of the model were as follows by.

The economy has a single product (one goods economy).

The production equation is a "well behaved" production function, which means that capital and labor are completely substitutable.

The production equation is constant returns to scale, which means production will increase at the same proportion as the increase in inputs. Assume that the output (Q) is produced by capital (K) and labor (L), with the relation of production as follows.

$$Q = K^{\alpha} L^{\beta}$$

Future is assumed to be forecasted accurately (perfect foresight).

The rate of population increase or increase of labor is constant and determined from the exogenous population variable.

Full employment of capital and labor is assumed.

No technical progress.

Based on these assumptions, the growth of the Cobb-Douglas production function can be shown as:

$$Q = K^{\alpha} L^{\beta} \#(8)$$

By taking the natural logarithm to the production function, we obtain

$$\log Q = \alpha \log K + \beta logL \#(9)$$

Next, we differentiate Equation (9) with respect to time, then we have

$$\frac{dlogQ}{dt} = \alpha \frac{dlogK}{dt} + \beta \frac{dlogL}{dt} \#(10)$$

where

$$\frac{dlogQ}{dt} = \frac{1}{Q} \cdot \frac{dQ}{dt} \Rightarrow \frac{dQ}{dt} = \dot{Q} = \Delta Q$$

Thus,

$$\frac{dlogQ}{dt} = \frac{\dot{Q}}{Q} = \frac{\Delta Q}{Q} \#(11)$$

In the same way,

$$\frac{dlogK}{dt} = \frac{\dot{K}}{K} = \frac{\Delta K}{K} \#(12)$$

$$\frac{dlogL}{dt} = \frac{\dot{L}}{L} = \frac{\Delta L}{L} \#(13)$$

Combining (11) – (13), then we have

$$\frac{\dot{Q}}{Q} = \alpha \frac{\dot{K}}{K} + \beta \frac{\dot{L}}{L}$$

$$\Rightarrow \frac{\Delta Q}{Q} = \alpha \frac{\Delta K}{K} + \beta \frac{\Delta L}{L} \#(14)$$

5) Energy and Production Concepts

From the variables of the growth rate of output due to other factors, Economists often call the relationship between inputs used in production processes and productivity that production function and call the engineering function as process functions. In this study, the key element of the process is energy, which is used in the following three ways.

Temperature adjustments are used to keep the environment in good working order by warming up or cooling down.

The energy used in processing causes the transformation of raw materials from one form to another.

It is a source of energy to the workers.

6) Energy in Production Function

The role of energy in production is threefold: heating, processing and working. Previously, production functions were based only on labor factors and capital factors.

$$Q = f(K, L)$$

With more resources other than capital and labor, the production function can be extended as the following in order to incorporate raw materials (M) (M) and energy (E).

$$Q = f(K, L, M, E)$$

In this function, the capital is the money paid to land, rights, machinery and plant. Machines and factories are built using pre-production processes, which requires labor, knowledge, raw materials and energy. In turn, the Solow Residual is likely to come from the energy factor, which is another important primary factor in the total production function that should be included in the Solow's growth model. Note that g_A, which represents a power factor, is not the only factor in the production function. In addition to energy consumption for production activities, over time, there are technologies and innovations that contribute to the consumption of energy for production. It is also noteworthy that, due to the source of economic growth, Solow's concept is based on long-term economic growth.

2.2 The History of the Oil Market

It is crucial to make distinction among an oil supplying country, an oil-consuming country, and if the suppliers participate in the OPEC as a member. On May 31, 2016, there were total 12 member in the organization that was founded in 1960 in order to control the oil market to coordinate oil supplying countries as regards of mineral contract structures (Carollo, 2011). Until the Yom Kippur war's 1973 occurrence, larger American oil companies had an exclusive authority over the market. Afterward, Israel-supporting countries were boycotted by Saudi Arabia's decision in taking control of crude oil price. Saudi Arabia decided to quote price by their own Arabian Light Oil. While the OPEC formation controlled over the oil market, the price of crude oil skyrocketed from $2 to $12-15 per barrel during the Middle East Crisis. Due to this situation, in 1974, the IEA (International Energy Agency) was founded by oil-consuming counties to serve two main commitments. Supposing boycott, the country members in IEA had to help each other and share the national oil information including demand, supply, stocks, and transport. Norway, at that time, was a larger competitor in the oil market.

In 1979, Iran revolution, Saddam Hussein took complete authority in Iraq leading to the Iran-Iraq war in 1980. As a result, the oil market was affected in a response of price spiked followed by supply shock. When the spike ended, the IEA became useful for the first time as the oil-consuming countries decided to raise their oil stocks ranging from 30-50 days up to 180 days of consumption. Thanks to the countries with zero influence on oil manufacturing, they analyzed the collected data and proved that the costs of the oil storage was inconsistent and redundant. As a result, the governments and the oil companies were assisted to be informed that all of them bought the excessively unnecessary quantity of oil which increased the price dramatically. At the end of the Iran-Iraq war, the oil supply situation returned into the normal state.

In 1982, all oil companies worldwide end their oil purchases from producing countries and especially the OPEC counties with very high-priced oil that was where new era of the oil market began. The OPEC faced challenges despite having been leading the cartel in 1973. The problems related to the strategy of quote the oil price in consistence with demand occurred as a result of the shock in demand. Initially, the OPEC forced the customers to purchase oil including the quantity in the previous year by signing the part of the contract because they could sustain the production level from the record level 1981. On the other hand, they had to sell more than necessary quantity of oil for spot prices in the market including independent traders making two markets with the price that was different by $10 per barrel. During the special meeting, they made a decision to cut the oil price and produced new quotas; however, the oil price trended went downhill as detected due to the nuclear power station establishment and natural gas into electricity conversion.

Many non-OPEC countries began producing, specifically ones in the North Sea Region becoming a key role in the world's political and economic balance. Margaret Thatcher, the ex-Prime Minister of the United Kingdom had been worried of the OPEC's overwhelming power as she denied any cooperation and discussion with OPEC countries related to the price regulation. The ex-U.S President, Ronald Reagan, as well as Margaret Thatcher desired the oil price free of the any political influence and excluded from the OPEC cartel. The OPEC began to lose its influence for its failure to identify the political structures and the appropriate demand.

Ahmed Yamani, the Saudi Arabian Minister of Oil brought over all the producers and the refiners around the world unknown to pump excess oil and finished goods into the market in a response to the situation considered getting loose of price war. Because the market was unable to respond to the supply shock which the crude oil price dropped, Royal Dutch Shell US suggested an alternative of fixing the price from the North Sea in a free market, called as the "15-day Brent Contract" in July 1986. The exchange of the price of crude oil was actually performed as an "exchange" for the first time that limited to only a number of professionals to operate and define the daily prices. Although it was highly restricted and exclusive to North Europe, it became a part of London's financial district a home to the HQs of the world's biggest trading companies.

However, any turmoil in the Middle East continent or the OPEC cartel decision could lead to the London trader expectation that kept fluctuating by the crude oil price. By the time Yamani was behind of the price war, the "15-day Brent Contract" fell in the worst scenario that the price of crude oil plummeted from $30 to $11 per barrel. It led to a big shock among the free market of crude oil support. Although the traders in London could withstand few-dollar fluctuation per day, some had tremendous difficulty losing their capital and eventually filed for their bankruptcy.

Oil-producing countries also began to be affected from low oil price causing many to decrease investment and budget. Many witnessed by the law of the free market was ineffective in the oil price where the spot price costed lower than marginal cost of the production. There was no interfere in the equilibrium between the global economy and the politics. In 1987, the meeting among the OPEC and the non-OPEC country governments was held as they mutually agreed with the oil price was unable to follow the laws of the free market. In December 1987, Saudi Arabia approved by signing the agreement making the fixed oil price at $28 per barrel. The production levels were controlled by the program designed by the OPEC countries. Simultaneously, the physical Brent market was on a step in entering into the financial market. Due to 1986 turmoil in London Financial district, many companies went bankrupt proving that 15-day contract failed to suffice both the economic and the financial system. Although major oil companies attempted to create pure obligation market, they faced failure. The financial sector continued to solve followed by the IPE's launched The Brent Future Contract in July 1988. It was a remarkable solution praised for the free market in opposed to the OPEC cartel initiatives.

The OPEC made a decision to abandon the Arabian Light Oil price and made the new benchmark Brent in December 1988. To simply say, all oil from the Gulf region would be priced by the Brent Crude Oil definition.

The difference between the Brent and the former Arabian oil was called OSP in order to maintain the national pride despite an evident cease in publishing the crude oil price of the Arabian oil. It was appraised by the market for entering into a new era of the world. Unknown to the true intention of the Arabians, they used the Brent market as a tool to declare a new price war. However, everything turned upside down as both the Arabians and the OPEC had a huge misunderstanding of launching a price war in the political condition at the time. As a result of their sudden loss in the foundation, it became a rival of the IEA. Consequently, many oil producing countries then used same-priced benchmark, therefore, they automatically became a part of the same cartel. The market then turned into the free market that Mrs. Thatcher and traders in London had always wanted since there was no agreement on control in pricing and production volume.

The producers could produce oil to their desired quantity due to non-existence of the agreements on production. Afterward, they could sell their crude oil with other in the market. In 1986, the market reacted as the price of Brent dropped to $9 per barrel causing a criticism for its failure to control the production level to the OPEC from those who previously praised it for the Brent adaptation for pricing the crude. In other words, they agreed for the free market condition but, at the same time, wanted the OPEC to cut their production level. At the end of the Iran-Iraq war, both sides fell into the financial crisis and wanted to have a control over partial oil market. Many countries taking market shares during the war were invited to provide both Iran and Iraq sharing; however, they both got rejected resulting in the excessive oil production into the oil market from them. The problem was needed to solve the excessive production making producers who could differ the production as a crucial part but failed at the end of the attempt of searching one falling into the criteria. The OPEC was indifferent for what had occurred after the benchmark adaptation of Brent Crude oil. The political conflict as well as the military issue in the Persian Gulf solved this problem. Therefore, the stability in the oil market made the price staying around $20-$25 until 1998 when many countries started expanding their production. Iraq's oil export after being banned by UN for a long time was the cause as well. The oil price began to plummet to $9 per barrel considered as the lowest price in 2 decades, in 1999 (Carollo, 2011).

The first profitable oil field was found on the Norwegian Continental Shelf in 1969 in which the extraction initiated in June 1971 marking as the beginning of an era of numerous large findings such as Ekofisk, Oseberg, Gullfaks, Troll, and Statfjord (Ministry of Petroleum and Energy, 2016). There fields were still treated as an important part of the petroleum development sector in Norway. Consequently, the establishment of oil companies were introduced for the oil production on Norwegian land for the future welfare foundation. Statoil and Norsk Hydro were two of the most significant drivers in the Norwegian petroleum sector that its merge. Additionally, Statoil merged with Norsk Hydro oil and gas sector in 2007. Since the year of 1971, the petroleum sector significantly became important. By 2000, Norway became the 3^{rd} largest export of oil and gas as its production peaked (Ryggvik, 2014). In 2014, the oil production dropped, the gas production had potential to grow. In the other words, the petroleum sector was responsible for 52% of the national total export.

Since the beginning of the production in 1971 to the mid-1990s, the amount of debt and the public consumption was paid by the revenues of the large portion of the petroleum. In the early 2000s, most the revenues was used to contribute the foundation of the Government Pension Fund Global. “Handlingsregelen” (the sustainability rule) introduced by Stoltenberg-government to restrict the government from spending more than 4% of the yearly return fund (Ryggvik, 2014) that followed the economical cyclical changes. The government, therefore, could spend no more than 4% during “bad times” but less in “good time.” At the end of June 2016, Norway became one of the most financially independent countries in Europe thanks to more than 7,400 billion NOK of the fund value.

2.3 Oil Price Shock Definition

According to Kilian and Park (2009), the magnitude of the oil price shock was related to one standard deviational change. By removing the percentage change in the sample of the oil price, one deviation equaled to 10.61%. We encountered 62 out of the 240 observational cases in the sample in which the oil price had changed either positively or negatively or as 10.61% from one month to another. According to the sample, the first huge oil shock happened in 1998 for 3 consecutive months.

Considering as the major threatening trigger, in UN-prohibited Iraq, it a rise in its supplies by 1 million barrels per day within tendency to increase its production in the future. In 1990, despite no noticeable external shock, the price considerably surged from $17.98 to $28.24. As well-explained by the report by the Petroleum Industry Research Foundation, an increased in the oil demand and price was due to accumulative situations of low stocks, firmer environmental rules, and technical characteristics (Kanovsky, 2003) plus with Europe's cold climate and the world's economic that grew rapidly than anticipated. Ari (2008) stated the price peak in June 2008 was trended as it was driven by investment bank and hedge fund speculations. Moreover, the oil price was predicted to rise by $250 per barrel based on analyses published by MERRIL LUNCH and other banks (Carollo, 2011). Again, during the 2008 financial crisis, the following oil shock consecutively as occurred where the oil priced plunged from $139 in June to $42 in December although the demand clearly did not show any sign of sudden plummet. President George W. Bush no longer banned offshore drilling (Eggen & Mufson, 2008) resulting in the plummeted price where the supply could be increased but many speculators wished to terminate their long positions. In the next month, Lehman Brother ceased its operation due to the bankruptcy on 15th of September 2008 as well as the explosion of the financial market turmoil took place.

2.4 The Concept of Passing the Volatility of Oil Prices on the Overall Economy

2.4.1 Engine Oil Market

Although movements in the oil market is different from the movements of other types of changes in other commodities, oil is the commodity that can be treated as a global currency. The relationship of supply and demand of oil is affected by several factors. The nature of the oil market can be categorized into the followings:

1) Integration of producers and consumers of oil

Both manufacturers and buyers of used fuel bundles and founded an organization by oil producers as well as organizations of the country for oil production and for export, or the "OPEC" (Organization of Petroleum Exporting Countries: OPEC). the purpose of the integration policy approach to the production and distribution of oil between member States is moving in the same direction as the manufacturers are able to define. The price is right and ability to control the balance of the oil market. As part of the integration of other producers who are not members of OPEC called. "The OPEC group" composed of Russia. Countries in the former Soviet Union Including some countries in Africa and Latin America. And in most of the industrialized countries, a major oil consumer in the world as well as the Organization for Economic Cooperation and Development. (Organization for Economic Co-operation and Development: OECD).

2) Political and Security

The political situation is related to the oil market. The effect is caused by the political unrest in oil producing countries. For example, oil price crisis in 1973 when the Arab oil-producing countries. Egypt and Syria have been reunited. "Organization of the United Arab oil producers export products" (Organization of Arab Petroleum Exporting Countries: OAPEC), while it has negotiated an agreement to curl cut oil production as well as the ban on oil exports. The United States and other countries for their support for the Israeli army during the war, "Yom Kippur", resulting in global oil prices rose.

3) Expectations and concerns of psychology

The problem of expectations and concerns of both buyers and sellers of oil, which is often caused by the situation in real time or by analyzing events and unrest in the oil market potential in the future. These factors are related to the production data. Oil reserves are published in real time to forecast economic conditions. Concerning, over the political unrest and the global trading. Including war or threat of war. This could lead to speculative investors in oil global market. The impact on the oil market in the future. If concerns over unrest is high. It could cause the price of oil on world markets has inevitably fluctuate.

4) Trading oil in US dollars

Oil trades through US dollars. The currency fluctuations that directly affect the price of oil. And the international reserves the country's oil exporters and importers worldwide.

2.4.2 Engine Oil

In this section we list out of the factors that affect prices as well as prices of other types of oil prices to reflect costs, the costs and conditions. In every part of the marketing process. Since starting production, refining, transportation and distribution to consumers by a number of factors that have a direct impact on oil prices. Those factors are the followings:

1) General factors

In general, the factors that affect the dynamics of oil prices are supply and demand. Demand-Supply is the same as its other consumer supply and demand of oil each type varies according to conditions and events when the supply and demand imbalance, it will affect the price, such as on demand. Other factors that can affect supply and demand balance in the oil market include lack of economic growth, weather, policy, capacity of oil producers, and oil reserves of the world's major consumers. Furthermore, the development of and demand for alternative energy, or even the war and terrorism are also significant factors.

2) Factors and subjective feelings of buyers, sellers in the oil market

Typically, the oil market is unique and often affected by the news, especially negative news that happened over the market. Opinions of buyers and sellers in the oil market is a key factor affecting oil price changes given the news.

3) Factor data and statistics

Buyers, sellers, and investors in the oil market must receive information and news about changes in the fundamentals of the oil market. Typically, reported average oil price for the analysis and consideration of current oil prices significantly affect oil trading decisions and may send an indirect impact on oil prices as well. In the oil futures markets, where trading volume of oil will exceed the amount of oil that exists in the market at that time, most transactions are for speculation.

2.4.3 Factors affecting the price of crude oil in the current crisis.

Baffes and Kshirsagar (2015) discussed the current oil price crisis by identifying periods of crisis during 2014 to 2015. They found that oil prices fell suddenly by 51%, which illustrates the volatility and vulnerability of current oil prices.

The incidentis what we call the oil price slump. Due to the price war between OPEC (Organization of the Petroleum Exporting Countries: OPEC) with the United States, South America and Russia became major oil producers. The United States had the technology to discover oil from shale layers (Shale Oil). As being shown in Table 2.1, the amount of oil around the world are too numerous and result in a decline in oil prices during the year 2014-2015. This was a consequence of the decision by OPEC to maintain oil production capacity.

Table 2.1 Ranks of countries discovered resources of oil shale

Rank	Country	Billion barrels
1	Russia	75
2	USA	58
3	China	32
4	Argentina	27
5	Libya	26
6	Venezuela	13
7	Mexico	13
8	Pakistan	9
9	Canada	9
10	Indonesia	8
	Total worldwide	**345**

Source: U.S. Energy Information Administration and USGC, 2017

2.5 The Concept of the Impact of Oil Prices on the Economy

2.5.1 Direct Impact of Volatile Oil Prices

The impact of volatile oil prices on the 3 main areas of consumption, investment, and industrial production. The extent affected by fluctuations in oil prices are based on two factors: the volatility caused by fluctuations in oil prices and positive attitude to the economic uncertainty.

1) Impact on consumption

The decrease in the supply of consumers under conditions of fluctuating oil prices. The future income and employment. The confidence of consumers falling under such conditions (Sadorsky, 1999) allow consumers to adjust their spending more carefully added. And that modifying behavior savings more (Baskaya, Giovanni, Kalemli-Özcan, & Peydro, 2017), such behavior confirms the forecast increase in savings by the reduction of the average user, consumer spending (Carroll, Hall, & Zeldes, 1992) as well as the uncertainty of the economy ought to result in the reduction of consumption. During a long period. The volatility is the ratio of unemployed to pressure from the consumer sector.

2) Impact on investment sector

The investment is a response to consumer demand. The demand is also expected to increase. The impact of volatile oil prices on consumption, the overall impact significantly on the decision to invest. Due to the uncertainties related to the ability to make a profit from the investment in a volatile environment, energy. The risk of increased profitability. Fear risks affecting the weight of the investment portfolio invested in the future.

3) Impact on industrial production

Industrial production is falling in response to the volatility of oil prices (Bredin & Hyde, 2004), but the importance of oil as a factor in the process manufacturing industry. Or it means that the volatility of oil prices affects the growth of the manufacturing sector (Jo, 2012), although the duration of the investment and the planned level of production will vary. The factors of investment are expected in the consumption and profits. Is typical of the production. The decline in production from the volatility of the oil price increase is a response to expectations of a decline and the rise of the uncertainty of the consumption.

However, unlike an association of negative international investment sector and the volatility of oil prices in the short period of time (Henriques &

Sadorsky, 2011) in the manufacturing industry may be fixed in the short term, though uncertainties arising from price fluctuations. Reflecting differences in risk management in the production of goods along the common mechanism that was used to make the investment in the manufacturing industry. In contrast, if the industry continues to produce at the same level as what the company will do is to increase the level of price increases to compensate for the uncertainty of the cost of production.

2.5.2 Indirect Effects of Oil Prices

The indirect impact of volatile oil prices on consumers, investors and manufacturers. The indirect effects that affect and influence the level of inflation as well as unemployment rates (Castillo, 2010) by the inflation rate and the unemployment rate will rise from the indirect effects in a short period and also in the medium and long-term periods as a result of fluctuations in oil prices. The relationship between inflation, unemployment rates, and the volatility of oil prices could be controlled by monetary policy in the event of deflation and inflation.

1) Inflation and monetary policy

Inflation is the nature of the product quality in the manufacturing industry of the increasing prices under uncertainty of production costs. The rise of inflation during 1970 can explain most of the increase in the volatility of oil prices that occurred over a period of more than a decade. By controlling the monetary policy in order to maintain the level of production under conditions of fluctuating oil prices. Inflation, which was an important factor that affects the manufacturing sector, both positive and negative. In conditions where energy prices are rising expectations related to inflation and industrial production should be in the negative due to the increase in traffic once the fuel has affected the cost of production increases. Changes in inflation will affect monetary policy. Changes in inflation will affect monetary policy. By fluctuations in oil prices are factors that need to set monetary policy by lowering interest rates to stimulate economic growth or increasing interest rates to restrict inflation to rise. By pressure from inflation and other economic (Castillo, 2010).

2) Unemployment

The increase in the unemployment rate, the oil price volatility will decline in the industrial production sector and the overall economy, according to the volatility of oil prices (Elder & Serletis, 2010) in the volatility of oil prices high. There was an increase in the unemployment rate increased because the labor sector in the short term and in the medium term is in anticipation of the reconstruction level. The product training over the need to replace the other (Davis & Haltiwanger, 2001).

The increase in the unemployment rate affects the risk of a price increase to its participation in the industrial sector to gross domestic product and the country's labor laws. The volatility of oil prices compared these hands Monmouth leads to higher rates of unemployment in the economy. The legal structure of the labor market, with a focus on the extent to which industrial production and consumption under adverse oil price volatility is interpreted as a high unemployment rate.

2.5.3 Impact of Oil Prices on the Economy of the Country

Thailand's GDP growth rate, inflation, changes in exchange rates and the US dollar during the year 1991-2015 shows that during the year 2000 onwards, the price of crude oil is likely to affect the economy. The effect of fluctuations in oil prices on an economy of Thailand. It was found that the relationship between the volatility of oil prices on the economy of Thailand is the only variable in the short term. Likewise, the oil prices as the cost of production in many industries and showed that the price of oil is a major factor affecting the economy and commodity prices, the level of prices will depend on the cost of raw materials used in production, the price of oil held in these costs.

2.5.4 Impact of Oil Prices on Thailand's Financial Markets

Statistically, Thailand is a crude oil importer. About 85% of domestic production, the cost of production has been affected by the volatility in oil price. The political crisis and the impact on the investments of the investors in Thailand showed that world oil prices affect responded negatively to every industry. However, foreign exchange rates and the gold price resulted in response to changes in different directions, according to an industry group.

2.6 Econometric Concepts

Since this study aims to analyze the impact of energy consumption and economic factors on the economic growth of the country. Most econometric models in this study are built based on the trends of the time or a unit root. It is noteworthy to point out that estimated regression equation that contains the variables which are not static or with random trend, the de-trend or estimation techniques with the traditional method of least squares (Ordinary Least Squares: OLS) often leads to results that are not reasonable. That is, spurious regression issue where the coefficients of the regression are statistically significant but invalid may occur.

While the Durbin-Watson statistics may be low, the relationship between variables may be misleading. In addition, the estimated standard error can be unreliable and inefficient. In order to avoid such problems, differencing is one of the conventional solutions. The sensitive information may be missing, thus making the use of econometric techniques to a new trend.

2.6.1 Test of Stationary

Estimation of systems of equations that contain variables to look into the statistics, time series. Generally, based on the trends and features that have changed over time, the correlations between the periods are non-stationary. When the model applied in the analysis may result in inefficient and distortion due to the fact that at the present time, based on the value that is in the past, resulting in changes over time. To test the variants obtained from the time series data that are stationary or not.

2.6.2 Unit Root Test

Unit root test or the relationship of the data is commonly used today often applied to the study, there were not a lot of information. And the empirical analysis in developing countries is how to test the Dickey and Fuller.

A unit root test can be determined by each data set with the relationship.

$$X_t = \rho X_{t-1} + e_t \#(15)$$

where

X_t and X_{t-1} arethe variable time series data at time *t* and *t-1*.

e_t is the random error

ρ is an autocorrelation coefficient

The corresponding hypothesis testing is

$$H_0: \rho = 1$$
$$H_1: -1 < \rho < 1$$

If H_0 is accepted, this means that $X_t$has a unit root or non-stationary. On the other hand, if H_1 is accepted, then there is no unit root.

Alternatively, the test can be rewritten as the followings:

$$\rho = 1 + \theta$$

Where θ is the coefficient has values between -1 and 0. Then equation (15) can be rewritten as:

$$X_t = (1 + \theta)X_{t-1} + e_t$$
$$\Rightarrow X_t - X_{t-1} = \theta X_{t-1} + e_t$$
$$\Rightarrow \Delta X_t = \theta X_{t-1} + e_t \#(16)$$

Hence, the corresponding hypothesis testing is

$$H_0: \theta = 0$$
$$H_1: \theta < 0$$

Similar to before, if H_0 is accepted, this means that $X_t$has a unit root or non-stationary. On the other hand, if H_1 is accepted, then there is no unit root.

Since the time series data at time *t* is related to the data at time *t-1*, then the method of Dickey-Fuller uses three regression equations to test whether a root unit is available or not. The tree equations are as follows.

Case 1: No Intercept

$$\Delta X_t = \theta X_{t-1} + e_t \#(17)$$

Case 2: Intercept

$$\Delta X_t = \alpha + \theta X_{t-1} + e_t \#(18)$$

Case 3: Intercept and Trend

$$\Delta X_t = \alpha + t + \theta X_{t-1} + e_t\#(19)$$

The assumption of Dickey-Fuller's test is the same as above. Augmented Dickey-Fuller Test : ADF has been used. It can be done by adding an autoregressive processes to equation (17) to (19). Because the number of lagged difference terms to be introduced into the equation must be sufficient to make the terms of the errors are in the form of serially independent and make the equation as follows.

Case 1: No Intercept

$$\Delta X_t = \theta X_{t-1} + \sum_{i=1}^{p} \phi_i \Delta X_{t-i} + e_t\#(20)$$

Case 2: Intercept

$$\Delta X_t = \alpha + \theta X_{t-1} + \sum_{i=1}^{p} \phi_i \Delta X_{t-i} + e_t\#(21)$$

Case 3: Intercept and Trend

$$\Delta X_t = \alpha + \beta t + \theta X_{t-1} + \sum_{i=1}^{p} \phi_i \Delta X_{t-i} + e_t\#(22)$$

These equations are a test of the hypothesis as described above. The ADF test statistic has a asymptotic distribution similar to the DF statistic so it can use the same crisis value.

2.6.3 Cointegration and Cointegration Test

Whether stochastic or deterministic, may lead to spurious regression, the t-statistics that are not standard distributions, or other statistics, may be inexplicable.

The goodness of fit is too high and, in general, regression results are difficult to assess. However, if two variables are nonstationary, they may be higher in time. Both variables may be assumed to have the integration of the same order and if the difference between the two variables is unlikely to increase or decrease, it is possible that the difference (or linear combination of the two variables) may be stationary. This is a concept of cointegration: if there is a long run relationship between two (or more) variables that are nonstationary, then the deviation out of long run path will be stationary. In such cases, the variables we consider are called cointegration. Consequently, the cointegration of two variables is as follows: if $X_t$and Y_t are time series, $X_t$and Y_t are called cointegrated of order (d, b), denoted by $X_t, Y_t \sim CI(d, b)$. If $X_t$and Y_t are an integer of order (d) denoted by the symbol I (d), and there must be a linear combination of these two variables and assume that $\alpha X_t + \beta Y_y$ must be an integrated of order $(d - b)$ where $d > b > 0$. The vector $[\alpha, \beta]$ is called the cointegrating vector. For example, if both$X_t$and Y_t are I (1) and error term ϵ_t of linear regression in both variables is stationary process, Hence cointegration regression is a technique for estimating long-term equilibrium relationships between nonstationary series. The deviation from this long-term equilibrium path is stationary.

Nevertheless, ifX_t is $n \times$ 1vector of series $X_{1t}, X_{2t}, \dots, X_{nt}$and if each$X_{it}$is I (d), then $i = 1, \dots, n$, and there is an α, which is $n \times$ 1vector that makes $X'\alpha \sim I$ $(d - b)$, so it is $X_t'\alpha \sim CI$ $(d - b)$.

For an empirical econometric case, the most interesting case is in the case where the series is transformed and the cointegrating vector is stationary:n the case of $d = b$ and cointegrating coefficients can be obtained using the parameters in the longitudinal relationship equation between the variables in the model.

For cointegration, residuals from the regression equation are used to obtain cointegration.

$$\Delta \hat{e}_t = \gamma \hat{e}_{t-1} + \nu_t \#(23)$$

The t-statistic was derived from the ratio of $\hat{\gamma}/SE(\hat{\gamma})$to compare with the MacKinnon critical values. The null hypothesis of no cointegration is $H_0 : \gamma = 0$ and if the statistic t is significant, it will reject the null hypothesis or the nonstationary variable in the equation as cointegrated.

If the residual of the equation (23) is not white noise, we will use Augmented Dickey-Fuller (ADF) test instead of the equation (23). Assume that the ν_t of the equation (23) has a serial relation. We will use the following equation.

$$\Delta\,\hat{e}_t = \gamma\hat{e}_{t-1} + \sum_{i=1}^{p} a_i\Delta\hat{e}_{t-1} + \nu_t\#(24)$$

If$-2 < \gamma < 0$, it can be concluded that the residue is stationary and X_t, Y_t is $CI\,(1,1)$. Note that the equations (23) and (24) have no intercept term because $\hat{e}_t$ is the residue of the regression equation.

2.6.4 Ordinary Least Squares Method: OLS

The Ordinary Least Squares Method: OLS is the best linear approximation of analytic equations by the Gauss-Markov Theorem. The OLS method, in addition to the non-bias estimation method, is also the least variable method. So the OLS method is called "BLUE" or "Best Linear Unbiased Estimator". In estimating linear equations using the OLS method, the following assumptions can be made:

The Y and X variables must be linearly related to one-way Causation, namely, one-way relationships or independent variables (X) that describe the dependent variables (Y) or Y cannot describe X.

The variable X must know the fixed value or no distribution.

The Y variable must be a random variable.

The error or residual must have the following characteristics:

$$U_i \sim NormalDistribution$$
$$E(U_i) = 0$$
$$Var(U_i) = \sigma^2$$
$$Cov(U_i, U_j) = Cov(U_j, U_i) = 0$$

These conditions imply that the error term must consist of normal distribution, independence, zero mean and constant variance.

The number of observations (n) must always be greater than the number of parameters expected.

Ultimately, we are solving the following optimization problem:

$$\min \sum \epsilon_i^2 = \min \sum (Y_i - \beta_0 - \beta_1 X_i)^2 \#(25)$$

From equation (25), we can see that $\epsilon_i = f(\beta_0, \beta_1)$. Therefore, the first order conditions corresponding to the equation are:

$$\left.\begin{aligned} \frac{\partial \sum \epsilon_i^2}{\partial \beta_0} = \frac{\partial \sum (Y_i - \beta_0 - \beta_1 X_i)^2}{\partial \beta_0} = 0 \\ \frac{\partial \sum \epsilon_i^2}{\partial \beta_1} = \frac{\partial \sum (Y_i - \beta_0 - \beta_1 X_i)^2}{\partial \beta_1} = 0 \end{aligned}\right\} \text{Normal equations}$$

The first normal equation yields

$$2 \sum (Y_i - \beta_0 - \beta_1 X_i)(-1) = 0$$
$$\Rightarrow (-2) \sum (Y_i - \beta_0 - \beta_1 X_i) = 0 \#(26)$$

The second normal equation yields

$$2 \sum (Y_i - \beta_0 - \beta_1 X_i)(-X_i) = 0$$
$$\Rightarrow (-2) \sum (Y_i - \beta_0 - \beta_1 X_i)(X_i) = 0 \#(27)$$

Consider the following properties:
If $Y = f(X_1, X_2)$, a partial value of Y relative to X_1 is

$$\frac{\partial Y}{\partial X_1} = n[f(X_1, X_2)]^{n-1} \frac{\partial f}{\partial X_1}$$

$\sum aX_i = a \sum X_i$ where a is a constant.

Note that since X_i is not a constant, equation (27) is not equal to $(-2X_i) \sum (Y_i - \beta_0 - \beta_1 X_i)$.

$\sum a = na$ where a is a constant.

$$\sum (X_i + Y_i) = \sum X_i + \sum Y_i$$

Dividing equation (26) and (27) by -2, we obtain

$$\sum (Y_i - \beta_0 - \beta_1 X_i) = 0 \#(28)$$

$$\sum (Y_i - \beta_0 - \beta_1 X_i)\, X_i = 0 \#(29)$$

From equation (28), we then have

$$\sum Y_i = n\beta_0 + \beta_1 \sum X_i \#(30)$$

And from equation (29), we have

$$\sum X_i Y_i = \beta_0 \sum X_i + \beta_1 \sum X_i^2 \#(31)$$

Next, we multiply both sides of equation (30) by $\sum X_i$. This yields

$$\sum Y_i \sum X_i = n\beta_0 \sum X_i + \beta_1 \left(\sum X_i\right)^2 \#(32)$$

Then we multiply both sides of equation (31) by n and obtain

$$n \sum X_i Y_i = n\beta_0 \sum X_i + n\beta_1 \sum X_i^2 \#(33)$$

Subtract equation (33) with equation (32), then we have

$$n \sum X_i Y_i - \sum Y_i \sum X_i = n\beta_1 \sum X_i^2 - \beta_1 \left(\sum X_i\right)^2$$

$$\Rightarrow n \sum X_i Y_i - \sum Y_i \sum X_i = \beta_1 \left\{ n \sum X_i^2 - \left(\sum X_i\right)^2 \right\}$$

$$\Rightarrow \beta_1 = \frac{n \sum X_i Y_i - \sum Y_i \sum X_i}{n \sum X_i^2 - (\sum X_i)^2} \#(34)$$

Next, we divide equation (30) by n and obtain

$$\frac{\sum Y_i}{n} = \frac{n\beta_0}{n} + \frac{\beta_1 \sum X_i}{n}$$

$$\Rightarrow \bar{Y} = \beta_0 + \beta_1 \bar{X}$$

Hence, we have

$$\beta_0 = \bar{Y} - \beta_1 \bar{X} \#(35)$$

2.6.5 Vector Error Correction Models (VECM)

A VECM model is built to be used with Series of data. Nonstationary Cointegrated which have occurred in the VECM model with the inclusion relationships. The combination with each other" in the equation. To limit / define the long-term behavior of the endogenous variable back into the relationship shared together. While it may fluctuate in the short term occurs (Short-run Adjustment Dynamics). As for the term of the joint together or Cointegration. It may be that the term of the Error Correction due to deviations from the equilibrium in the long term (Long-run Equilibrium) are gradually adapting to the changes in the short term through the Series each of the variables that occur. Error-Correction Model: ECM is thus a link between short-term and long-term variable. It is used to analyze the adjustment of the variable short-term to long-term equilibrium. From the form of equation Unrestricted VAR: VAR(p)

Given a VAR(p) of $I(1)$ x's (ignoring consts and determ trends)

$$X_t = \Phi_1 X_{t-1} + \cdots + \Phi_p X_{t-p} + \epsilon_t$$

There exists an error correction representation of the following form:

$$\Delta X_t = \Pi X_{t-1} + \sum_{i=1}^{p-1} \Phi_i^* \Delta X_{t-i} + \epsilon_t$$

where

$$\boldsymbol{\Phi_j^*} = -\sum_{i=j+1}^{p} \boldsymbol{\Phi_i}, \quad \boldsymbol{j = 1, \ldots, p-1}$$

$$\boldsymbol{\Pi} = -(\boldsymbol{I} - \boldsymbol{\Phi_1} - \cdots - \boldsymbol{\Phi_p}) = -\boldsymbol{\Phi(1)}$$

The characteristic polynomial is then

$$\boldsymbol{I} - \boldsymbol{\Phi_1 Z} - \cdots - \boldsymbol{\Phi_p Z^p} = \boldsymbol{\Phi(Z)}$$

2.6.6 Causality Testing

Before constructing a model, it is important to examine relationships, either long-run or short-run, between variables in the model. It would be inefficient and time-consuming to include variables that are irrelevant to each other into a model. Not to mention that the estimated model could be misleading. For instance, using population age to explain volatility in oil prices would not make senses. Typically, relationships between variables can be detected by testing for cointegration. The most well-known statistics test for this is called “Granger causality test”. This statistics test determines whether changes in one variable can lead to changes in other variables. Conventionally, we interpret the test for two variables, X and Y as: “X Granger causes Y”. This tells us that the past values of X have the power to predict the current value of Y. Hence, it is reasonable to model Y by using X. In other words, this is how we validate our decision to incorporating X into a mode that explains Y.

In the case of a simple VAR model:

$$y_t = \beta_1 y_{t-1} + \beta_2 y_{t-2} + \cdots + \beta_k y_{t-k} + \alpha_1 x_{t-1} + \alpha_2 x_{t-2} + \cdots + \alpha_q x_{t-q} + u_t$$

Suppose that all X are statistically significant as “X Granger causes Y”. Following Brooks (2008), under the case that X Granger causes Y but not vice versa, then this phenomenon is called “unidirectional causality”. On the other hand, if the causality happens both ways, then the phenomenon is called “bidirectional causality”. To test for a Granger causality, restrictions are then imposed on the VAR model. The restrictions are:

H_0: $\alpha_1 = \cdots = \alpha_q = 0$ "X does not Granger cause Y"

H_1: At least one of $\alpha \neq 0$ "X Granger causes Y"

2.7 Empirical Literature

This section of literature review focuses on several aspects of spillover effects of oil price shocks. Specifically, we delved deep into previous studies focusing on dynamic relations between oil and stock markets.

In energy literature, a number of papers have focused on the effect of oil price shocks on the returns of the oil and gas sector. Nevertheless, their results are controversial. While several studies point out that oil price shocks can positively affect stock returns, quite a few studies show the otherwise. Numerous studies found evidence supporting positive relation between the oil and stock markets (Sadorsky, 2001;
Boyer & Filion, 2007; El-Sharif, Brown, Burton, & Nixon, 2005; Ramos & Veiga, 2011). These studies focused mainly on analyzing the impacts of oil price shocks on stock returns at the aggregate stock market level. In contrast to those studies, Nandha & Faff (2008) pointed out that surging in oil prices negatively impact all sectors but the oil and gas sectors. In addition, Nandha and Faff (2008), McSweeney and Worthington (2008) found that oil price shocks adversely affected banking and transport sectors.

Most papers utilized the GARCH models to capture oil price shocks volatility. Surprisingly, only a few papers address the effect of oil price volatility on the volatility of the stock returns. That is, in terms of stock returns, they do not investigate their volatility thoroughly. Practically, volatility spillover from the oil market to the stock markets is expected. In fact, Sadorsky (2003); Hammoudeh, Dibooglu, and Aleisa (2004); Elyasiani, Mansur, and Odusami(2011) analyzed the markets in the US and found consistent results that the oil-intensive sectors were vulnerable to increase in volatility in oil prices.

Other than the direct effects of changes in oil prices on the stock markets, we also look at the studies investigating other possible links between the oil markets and the economy as a whole. Dramatic increase in oil prices can drastically reduce consumer spending and in turn, contributes to the economic downturn (Hamilton, 2008; Kilian, 2008; Alquist & Kilian, 2010). That is, surge in oil price could significantly dry up consumer discretionary income. As a result, consumers and investors alike would be less willing to spend on other stuffs. This effect is strong on how consumers make their decisions for final goods and services.

Furthermore, inflation is also linked to changes in oil prices. Kilian (2009) pointed out how the effects of oil price shocks were passed through inflation and in turn stock markets. Interestingly, changes in crude oil prices could dramatically affect the consumer price index. Lastly, oil price shocks can lead to negative effects on international trades (Jimenez-Rodriguez & Sanchez, 2005). On the other hand, Jo (2012) showed that oil prices increase could potentially benefit oil exporting countries.

As we can see in this section, several past studies primarily focused on the relation of oil price shocks to the economy at the aggregate level. Unfortunately, this may hide diverse reactions at sector level. Technically speaking, industries differ in how vulnerable their production to oil price shocks. In this paper, we will fill in the gap in the literature by performing a thorough analysis on a variety of industries.

CHAPTER 3

RESEARCH METHODOLOGY

To investigate both the long-term and short-term relationships between changes in oil prices and stock prices in different industries in Thailand, several time series statistics and parametric models are employed for this study. Oil and stock price series are collected at monthly time intervals, hence there exist correlations among observations at different months. This is one of the classic issues in time series analysis, called "autocorrelation", which must be dealt with first before we start constructing our models. In this chapter, we first thoroughly list out and explain relevant statistical tests, such as unit root tests, information criterion statistics, and a test for conditional heteroscedasticity. Then we further explain the parametric models used in this study starting from the autoregressive integrated moving average process (ARIMA) model, the autoregressive conditional heteroskedasticity (ARCH) model, and, lastly, the generalized autoregressive conditional heteroskedasticity (GARCH) model.

3.1 Unit Root Tests

It is common for financial time series, such as oil prices and stock prices, to exhibit non-stationarity in the mean or trending behavior. Hence, it is necessary to first determine the most appropriate form of trend in the data. If the data are actually trending, then some form of trend removal is required. The most common de-trending procedures are first differencing and time-trend regression. In general, first differencing is appropriate for $I(1)$ time series, while time-trend regression is appropriate for $I(0)$ time series. To determine if data should be first differenced or regressed on a deterministic function, unit root tests can be used on the data.

Following Dickey and Fuller (1981) and Said and Dickey (1984), we use the Dickey-Fuller (DF) test and the augmented Dickey-Fuller (ADF) test as our main unit root tests. The DF test tests the null hypothesis that a unit root is present in an autoregressive model against the alternative hypothesis of stationarity. Similarly, the ADF test tests the null hypothesis that a time series is $I(1)$ against the alternative hypothesis that the time series is $I(0)$ assuming that the data has an ARMA structure.

3.1.1 Dickey-Fuller (DF) Test

Suppose that the data can be modeled as a simple AR(1) model:

$$y_t = \rho y_{t-1} + u_t \#(1)$$

where y_t is the variable of interest, t is the time index, ρ is a coefficient, and u_t is the error term. The model is non-stationary or has a unit root if $\rho = 1$. Equation (1) can be rewritten as

$$\Delta y_t = (\rho - 1) y_{t-1} + u_t = \delta y_{t-1} + u_t \#(2)$$

where Δ is the first difference operator. Thus the model has a unit root if $\delta = 0$.
Theoretically, there are three main versions of the test:
Test for a unit root:

$$\Delta y_t = \delta y_{t-1} + u_t \#(3)$$

Test for a unit root with drift:

$$\Delta y_t = a_0 + \delta y_{t-1} + u_t \#(4)$$

Test for a unit root with drift and deterministic time trend:

$$\Delta y_t = a_0 + a_1 t + \delta y_{t-1} + u_t \#(5)$$

The hypotheses to be tested are

$$H_0: \delta = 0$$
$$H_1: \delta \neq 0$$

3.1.2 Augmented Dickey-Fuller (ADF) Test

Extending further from the DF test, Said and Dickey (1984) augment "the basic autoregressive unit root test to accommodate general ARMA(p, q) models with unknown orders and the test is referred to as the augmented Dickey-Fuller (ADF) test".

The ADF test tests the null hypothesis that a time series is $I(1)$ against the alternative hypothesis that the time series is $I(0)$ assuming that the data has an ARMA structure.

The ADF test is based on estimating the test regression

$$y_t = \beta' \mathbf{D}_t + \phi y_{t-1} + \sum_{j=1}^{p} \psi_j \, \Delta y_{t-j} + \epsilon_t \#(6)$$

where$\mathbf{D}_t$ is a vector of deterministic terms (constant, trend etc.). The p lagged difference terms, Δy_{t-j}, are used to approximate the ARMA structure of the errors, and the value of p is set so that the error ϵ_t is serially uncorrelated. The error term is assumed to be homoskedastic. Under the null hypothesis, $\phi = 1$. Equation (6) can be rewritten as

$$\Delta y_t = \beta' \mathbf{D}_t + \pi y_{t-1} + \sum_{j=1}^{p} \psi_j \, \Delta y_{t-j} + \epsilon_t \#(7)$$

where $\pi = \phi - 1$. Under the null hypothesis, $\pi = 0$, which implies that Δy_t is $I(0)$.

3.2 Diagnostic Checking

After checking for stationarity and choosing the appropriate de-trending procedure for model fitting, it is necessary to determine whether the chosen model is appropriate or not. It is typical to fit data with more than one models. Hence, we also need to determine which model is the best amongst all alternatives.

3.2.1 Information Criteria

In order to determine which model is the best choice for our data, information criterion statistics are used. Conceptually, information criterion statistics are a combination of number of parameters, the sample size, and the sum of squared errors of the model. Thus, the lower the value of the statistics compared to values for other models means that the model associated to that statistics outperforms the others.

In this study, the information criterion statistics we use are Akaike's Information Criterion (AIC) and Schwartz's Bayesian Criterion (SBC), which is also called Bayesian Information Criterion (BIC). The formulas associated with these statistics are the followings:

$$AIC = n \ln SSE - n \ln n + 2p \#(8)$$

$$SBC = n \ln SSE - n \ln n + p \ln n \#(9)$$

where$n$ is the sample size, p is the number of coefficients in the model. Note that the main difference between AIC and SBC is the multiplier of p in the SBC formula. In other words, SBC actually penalizes the model with a higher number of variables more than the model with a fewer number of variables. As a result, SBC tends to choose a more parsimonious model. On the other hand, AIC tends to choose a model with more variables, or overfit models. Nevertheless, both statistics are consistent. When comparing two different models, the model with the lower value of the information criterion statistics is the best.

3.3 Models

In this study, we employ several time series models, such as ARIMA models, ARCH models, GARCH models, and GARCH-M models. In this section, we explain the concepts and how to construct those models in details.

3.3.1 ARIMA Model

An autoregressive integrated moving average (ARIMA) model is a generalized version of an autoregressive moving average (ARMA) model. In general, the model can be made stationary by applying first differencing. The model separates the signal from noises and then the signal is used to forecast into the future. The AR part of the model captures the motion of the variable of interest, which is regressed on its own lagged terms, while the MA part assumes a linear combination of error terms. Lastly, the I part of the model shows whether the data has applied differencing between the current values and the previous values or not.

Suppose y represents the d^{th} difference of Y such that for $= 1, y_t = Y_t - Y_{t-1}$. Thus, we can write a general form of an ARIMA model as:

$$\hat{y}_t = \alpha + \beta_1 y_{t-1} + \cdots + \beta_p y_{t-p} - \gamma_1 e_{t-1} - \cdots - \gamma_q e_{t-q} \#(10)$$

Whereα is an intercept term, $\beta_1, \ldots, \beta_p$ are the autoregressive coefficients, $\gamma_1, \ldots, \gamma_q$ are the moving average coefficients, and $\{e_t\}$ are white noise time series.

If the process contains no autoregressive terms, then the model is called an integrated moving average IMA(d, q) model. On the other hand, if moving average terms do not exist, then the model is denoted as ARI(p, d). In order to identify an appropriate ARIMA model for a variable of interest, we may start by choosing the right order of differencing, $d,$ in order to make the series stationary. We may also apply a variance-stabilizing transformation such as taking logs. Nevertheless, the stationary series may still have autocorrelated errors suggesting that some number of AR terms, p, or MA terms, q, should be incorporated into the model.

3.3.2 ARCH Model

An autoregressive conditionally heteroscedastic (ARCH) model is a model for variance of the current error term as a function of past error terms. It is appropriate when the error variance follows an autoregressive model. Generally, the model is used to capture changes in variance, especially short periods of increased variation.

Suppose e_t denote the error terms, which can be decomposed into a stochastic term z_t and a time-dependent standard deviation σ_t.

$$e_t = \sigma_t z_t \#(11)$$

wherez_t is assumed to be a strong white noise process. Thus, σ_t^2 can be modeled as

$$\sigma_t^2 = \alpha_0 + \alpha_1 e_{t-1}^2 + \cdots + \alpha_q e_{t-q}^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i e_{t-i}^2 \#(12)$$

where$\alpha_0 > 0$ and $\alpha_i \geq 0, i > 0$. These conditions are assumed to avoid negative variance.

Theoretically, we can test for the ARCH effect following the three steps proposed by Engle (1982) below:

We first estimate the variable of interest, y_t, as an AR(q) process:

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \cdots + \alpha_q y_{t-q} + e_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i y_{t-i} + e_t \#(13)$$

Then, we calculate the squares of the error terms obtained from step 1 and regress on their lagged values:

$$\hat{e}_t^2 = \hat{\alpha}_0 + \sum_{i=0}^{q} \hat{\alpha}_i \hat{e}_{t-i}^2 \#(14)$$

Finally, we perform a hypothesis testing with the null hypothesis that there is no ARCH components, which mean $\alpha_i = 0$for $i = 1, \ldots, q$. The alternative hypothesis is ARCH components exist.

3.3.3 GARCH Model

A generalized autoregressive conditionally heteroscedastic (GARCH) model is a generalized version of the ARCH model where the error variance is assumed to follow an ARMA model. That is, the error variance is modeled using values of the past squared observations and past variances. Therefore, equation (12) can be rewritten as:

$$\sigma_t^2 = \alpha_0 + \alpha_1 e_{t-1}^2 + \cdots + \alpha_q e_{t-q}^2 + \beta_1 \sigma_{t-1}^2 + \cdots + \beta_p \sigma_{t-p}^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i e_{t-i}^2 + \sum_{i=1}^{p} \beta_i \sigma_t^2 \#(15)$$

3.3.4 BEKK-GARCH(p,q) Model

Another version of the GARCH model used in this study is the BEKK-model (Baba, Engle, Kraft & Kroner, 1990). The advantage of this model over the other versions of the GARCH model is that it captures a more thorough dynamic structure of the data. The general form of the model is the following:

$$\Sigma_t = \beta'\beta + \sum_{j=1}^{J} \sum_{i=1}^{I} \gamma'_{ij} \epsilon_{t-i} \epsilon'_{t-i} \gamma_{ij} + \sum\nolimits_{j=1}^{J} \sum\nolimits_{z=1}^{Z} \Omega'_{jz} \Sigma_{t-z} \Omega_{jz} \#(16)$$

where

$\beta$is an upper coefficient matrix of constant values.

$\gamma_{ij}$is an upper coefficient matrix *i* corresponding to the vector of the *j*th lagged values of error terms.

$\Omega_{\mathrm{jz}}$is anupper coefficient matrix *j* corresponding to the *z*th lagged values of variance-covariance matrix.

$\epsilon_{t-i}$is the vector of *i*th lagged values of error terms.

$\Sigma_{t-z}$is the *z*th lagged values of the variance-covariance matrix.

Note that the coefficient matrices, in effect, restrict the vector representation of the GARCH(p,q) models. Theoretically, according to Engle and Kroner (1995), Σ_t is required to be positive definite under the sufficient condition that either β or Ω_{jz} has full rank.

CHAPTER 4

EMPIRICAL RESULTS

This thesis emphasis on the volatility relationship between returns in Thailand stock indexes and the oil market. The paper estimated ten bivariate GARCH models and twenty-eight multivariate GARCH models. The constant conditional correlation bivariate GARCH model and multivariate GARCH model are adopted here and show the results for each of the variance equations, respectively, while the results for each mean equation demonstrates in the appendix. Moreover, the thesis applied the AIC and significance of coefficient as the selection criteria.

Before going to show the results, the paper would like to define the variables appeared in each model. The $h_{1,t}$ represents the conditional variance (volatility) for oil returns at time t, whereas $h_{2,t}$ describes the volatility for specific sector index returns, and $h_{12,t}$ indicates the conditional covariance between the oil returns and specific sector index return. Also, the squared error terms $\varepsilon^2_{1,t-1}$ and $\varepsilon^2_{2,t-1}$ in each model express the effect of news, for example unexpected event or shock or innovation, originating from oil market and Thailand stock market, respectively. Those terms may be known as the direct effects (Malik & Ewing, 2009).

In this section, the result of test for stationary is presented below, after that the estimated correlation by bivariate and multivariate GARCH models is demonstrated.

4.1 Test for Stationary

The thesis applies the time series data and the first step is required for using those data is test for stationary. In order to avoiding spurious problem, the data used for this study are needed to be stationary. Looking at the results of test for stationary, the Augmented Dickey Fuller test is adopted. All variables are stationary at level, with pure random walk model, as evidenced by the significant ADF statistics. This is because the thesis focuses on the returns of them, they usually are deviated around zero. For the details of each variable are shown below.

Table 4.1 Test for Stationary results: Unit Root Test

Variables	Pre-crisis	Post-crisis
	ADF statistics	**ADF statistics**
SET index	-34.3866**	-40.0536**
SET50 index	-24.4701**	-41.0311**
Oil	-29.1621**	-37.8672**
Agriculture sector index	-33.9682**	-39.3752**
Consumption sector index	-36.0446**	-26.8665**
Finance sector index	-33.4303**	-39.9349**
Industry sector index	-32.3557**	-26.4713**
Property Construction sector index	-33.2388**	-37.7180**
Resource sector index	-33.6338**	-41.1902**
Service sector index	-34.7135**	-37.6546**
Technology sector index	-35.9081**	-41.1982**

Note: ***, **, and * indicates significance at the 1%, 5% and 10%, respectively

For the next section, the results of bivariate and multivariate GARCH models are presented here.

4.2 The results of bivariate GARCH model

Table 4.2 The results of bivariate GARCH modeloil-set index

	Pre-crisis		Post-crisis	
Panel 1	**Oil** $(h_{1,t})$	**SET index** $(h_{2,t})$	**Oil** $(h_{1,t})$	**SET index** $(h_{2,t})$
constant	1.6 x 10^{-5}	5.0 x 10^{-5}	5.9 x 10^{-6}	3.6 x 10^{-6}
	(2.15)	*(4.81)*	*(4.54)*	*(4.10)*
$\varepsilon^2_{i,t-1}$	0.0568	0.1794	0.1368	0.1458
	(3.54)	*(5.33)*	*(10.09)*	*(10.44)*
$h_{i,t-1}$	0.8965	0.5976	0.8606	0.8475
	(27.09)	*(10.25)*	*(66.64)*	*(66.01)*
$h_{1,t}\, h_{2,t}$	0.1165		0.2531	
	(3.72)		*(12.42)*	

Note: the t-statistics are in parentheses.

The results for the oil-SET index model illustrations that the volatility of oil returns is considerably impacted by its own previous volatility and news, as evidenced by the significant coefficient on $h_{1,t-1}$and $\varepsilon^2_{1,t-1}$, respectively, in pre- and post-crisis. The coefficient on $h_{1,t-1}$ is positive which indicates that an increase in the past volatility of oil return leads to more volatility in the current return on oil. Similarly, the volatility of returns in SET index is significantly affected by its own previous volatility and news, as shown by the significant coefficient on $h_{2,t-1}$and $\varepsilon^2_{2,t-1}$, respectively. The coefficient on $h_{2,t-1}$ is positive which indicates that an increase in the past volatility of SET index return leads to more volatility in the current return on SET index. Also, the estimated conditional correlation between the two returns in pre-crisis is 0.1165 points that these returns tend to move in the same directions; on other hand, an increase in the return for oil tends to be associated with a rise in the return for SET index, and vice versa. Moreover, in the post-crisis, the estimated conditional correlation between the two returns is 0.2531 points that these returns tend to move in the same directions.

Table 4.3 The results of bivariate GARCH model oil-set50 index

	Pre-crisis		Post-crisis	
Panel 2	**Oil** $(\boldsymbol{h_{1,t}})$	**SET50 index** $(\boldsymbol{h_{2,t}})$	**Oil** $(\boldsymbol{h_{1,t}})$	**SET50 index** $(\boldsymbol{h_{2,t}})$
constant	6.4 x 10^{-5}	1.3 x 10^{-4}	8.7 x 10^{-6}	5.0 x 10^{-6}
	(2.94)	*(8.89)*	*(5.34)*	*(3.89)*
$\varepsilon_{i,t-1}^2$	0.0966	0.4036	0.1721	0.1381
	(3.56)	*(9.94)*	*(10.44)*	*(9.44)*
$h_{i,t-1}$	0.8273	0.4164	0.8222	0.8512
	(18.29)	*(10.74)*	*(53.93)*	*(59.52)*
$h_{1,t}\, h_{2,t}$	0.1398		0.2393	
	(4.62)		*(11.65)*	

Note: the t-statistics are in parentheses.

From the results of the oil-SET50 index model shows indifferently from the oil-SET index model. That is the volatility of oil returns is considerably positively impacted by its own previous volatility and news in pre- and post-crisis. The volatility of returns in SET50 index is significantly positively affected by its own previous volatility and news. Additionally, the estimated conditional correlation between the two returns is 0.1398 and 0.2393 indicates that the returns on these rises or falls together.

Table 4.4 The results of bivariate GARCH model oil-agriculture

	Pre-crisis		Post-crisis	
Panel 3	**Oil** $(\boldsymbol{h_{1,t}})$	**Agriculture sector index** $(\boldsymbol{h_{2,t}})$	**Oil** $(\boldsymbol{h_{1,t}})$	**Agriculture sector index** $(\boldsymbol{h_{2,t}})$
constant	2.0 x 10^{-5}	1.2 x 10^{-5}	8.1 x 10^{-6}	1.6 x 10^{-5}
	(2.34)	*(4.41)*	*(5.16)*	*(5.91)*
$\varepsilon^2_{i,t-1}$	0.0781	0.4500	0.1710	0.1847
	(3.66)	*(12.51)*	*(10.46)*	*(9.63)*
$h_{i,t-1}$	0.8712	0.5136	0.8252	0.7454
	(24.17)	*(11.29)*	*(54.53)*	*(31.86)*
$h_{1,t}\, h_{2,t}$	-0.0743		0.1567	
	(-2.08)		*(7.60)*	

Note: the t-statistics are in parentheses.

From the oil-agriculture model, thevolatility ofboth the oil returns and the agricultural sector index returns is positively considerably impacted by its own past volatility and news, seen by the significant coefficient on $h_{1,t-1}$, $\varepsilon^2_{1,t-1}$, $h_{2,t-1}$, and $\varepsilon^2_{2,t-1}$ respectively. The estimated conditional correlation between the two returns in pre-crisis is -0.07 points that these returns tend to move in opposite direction; namely, an increase in the return for oil tends to be associated with a decrease in the return for agricultural sector index, and vice versa. However, the estimated conditional correlation between the two returns in post-crisis is 0.1567 points that these returns tend to move in the same direction; namely, an increase in the return for oil tends to be associated with a rise in the return for agricultural sector index, and vice versa.

Table 4.5 The results of bivariate GARCH model oil-consumption

	Pre-crisis		**Post-crisis**	
Panel 4	**Oil ($h_{1,t}$)**	**Consumption sector index ($h_{2,t}$)**	**Oil ($h_{1,t}$)**	**Consumption sector index ($h_{2,t}$)**
constant	2.0×10^{-5}	7.6×10^{-6}	7.4×10^{-6}	2.1×10^{-5}
	(2.33)	*(6.39)*	*(4.97)*	*(13.07)*
$\varepsilon_{i,t-1}^2$	0.0788	0.3035	0.1665	0.2854
	(3.66)	*(6.64)*	*(10.39)*	*(11.69)*
$h_{i,t-1}$	0.8702	0.6523	0.8312	0.4842
	(24.16)	*(17.32)*	*(56.20)*	*(13.47)*
$h_{1,t}\, h_{2,t}$	-0.0314		0.0834	
	(-0.79)		*(3.62)*	

Note: the t-statistics are in parentheses.

According to the result from oil-consumption model, in each volatility model its own past volatility and news (direct effect) have a significant impact on the current volatility for both two returns; oil and consumption sector index. Although, there is no effect between volatility of oil returns and the sector index returns in pre-crisis, as evidenced by the insignificant coefficient on $h_{1,t}h_{2,t}$. However, there is a positive correlation between volatility of oil returns and the sector index returns in post-crisis, with 0.0834, these two returns rise and fall together.

Table 4.6 The results of bivariate GARCH model oil-financial

	Pre-crisis		**Post-crisis**	
Panel 5	**Oil** $(\boldsymbol{h_{1,t}})$	**Finance sector index** $(\boldsymbol{h_{2,t}})$	**Oil** $(\boldsymbol{h_{1,t}})$	**Finance sector index** $(\boldsymbol{h_{2,t}})$
constant	2.0×10^{-5}	2.3×10^{-4}	8.5×10^{-6}	9.4×10^{-6}
	(2.34)	*(5.18)*	*(5.29)*	*(3.98)*
$\varepsilon_{i,t-1}^{2}$	0.0797	0.1723	0.1698	0.1473
	(3.68)	*(4.60)*	*(10.39)*	*(9.52)*
$h_{i,t-1}$	0.8697	0.0580	0.8246	0.8330
	(24.19)	*(0.32)*	*(54.32)*	*(51.78)*
$h_{1,t}\, h_{2,t}$	-0.0543		0.1772	
	(-1.51)		*(8.33)*	

Note: the t-statistics are in parentheses.

The oil-financial model illustrations an indifferent from previous model. This is to say its own previous volatility and news have a significant effect on the current volatility for oil and financial sector index returns. Surprisingly, there is no a considerable correlation between two returns in pre-crisis, reflecting from an insignificant coefficient on $h_{1,t}h_{2,t}$. Although, it is significantly positively correlated between the volatility returns for oil and financial sector index in post-crisis, with 0.1772 means that an increase in volatility of the returns for oil tends to be associated with a grow in the return for financial sector index, and vice versa.

Table 4.7 The results of bivariate GARCH model oil-industry

	Pre-crisis		Post-crisis	
Panel 6	**Oil ($h_{1,t}$)**	**Industry sector index ($h_{2,t}$)**	**Oil ($h_{1,t}$)**	**Industry sector index ($h_{2,t}$)**
constant	2.0×10^{-5}	3.0×10^{-4}	8.4×10^{-6}	1.0×10^{-5}
	(2.32)	*(5.53)*	*(5.36)*	*(4.44)*
$\varepsilon_{i,t-1}^2$	0.0785	0.1593	0.1680	0.1399
	(3.70)	*(5.57)*	*(10.46)*	*(9.18)*
$h_{i,t-1}$	0.8734	0.6968	0.8262	0.8404
	(25.09)	*(14.06)*	*(55.13)*	*(49.57)*
$h_{1,t}\, h_{2,t}$	-0.1033		0.2166	
	(-2.84)		*(10.13)*	

Note: the t-statistics are in parentheses.

In terms of the oil-industry sector model, the result shows that the current volatility of oil returns and industry sector index returns are affected by its own past volatility and news. However, the estimated conditional correlation between the two returns in pre-crisis is -0.1033 points that these returns tend to move in opposite direction; namely, an increase in the return for oil tends to be associated with a decrease in the return for industry sector index, and vice versa. While the estimated conditional correlation between the two returns in post-crisis is 0.2166 points that these returns tend to move in the same direction; namely, an increase in the return for oil tends to be associated with a decrease in the return for industry sector index, and vice versa.

Table 4.8 The results of bivariate GARCH model oil-property

	Pre-crisis		**Post-crisis**	
Panel 7	**Oil** ($\boldsymbol{h_{1,t}}$)	**Property Construction sector index** ($\boldsymbol{h_{2,t}}$)	**Oil** ($\boldsymbol{h_{1,t}}$)	**Property Construction sector index** ($\boldsymbol{h_{2,t}}$)
constant	2.0 x 10^{-5}	5.8 x 10^{-5}	8.2 x 10^{-6}	3.6 x 10^{-6}
	(2.35)	*(5.53)*	*(4.93)*	*(4.94)*
$\varepsilon_{i,t-1}^{2}$	0.0804	0.3315	0.1777	0.1148
	(3.72)	*(6.64)*	*(10.51)*	*(9.59)*
$h_{i,t-1}$	0.8699	0.4641	0.8197	0.8709
	(24.42)	*(7.41)*	*(53.96)*	*(73.77)*
$h_{1,t}\, h_{2,t}$	-0.0659		0.1684	
	(-1.84)		*(8.00)*	

Note: the t-statistics are in parentheses.

Due to the oil-property construction model express that the current volatility of the return for oil and property construction sector index are significantly affected by its own previous volatility and news. In case of the correlation between two returns, it witnessed a negative correlation in pre-crisis, with -0.0659, which indicates that the returns for oil and property construction sector index move considerably in the opposite way. Moreover, it witnessed a positive correlation in post-crisis, with 0.1684, which indicates that the returns for oil and property construction sector index move considerably in the same way.

Table 4.9 The results of bivariate GARCH model oil-resource

	Pre-crisis		Post-crisis	
Panel 8	**Oil** ($\boldsymbol{h_{1,t}}$)	**Resource sector index** ($\boldsymbol{h_{2,t}}$)	**Oil** ($\boldsymbol{h_{1,t}}$)	**Resource sector index** ($\boldsymbol{h_{2,t}}$)
constant	2.0 x 10^{-5}	8.0 x 10^{-5}	8.9 x 10^{-6}	8.8 x 10^{-6}
	(2.32)	*(9.15)*	*(5.37)*	*(4.39)*
$\varepsilon_{i,t-1}^{2}$	0.0785	0.2677	0.1754	0.1150
	(3.68)	*(5.61)*	*(10.45)*	*(9.36)*
$h_{i,t-1}$	0.8708	0.5512	0.8219	0.8675
	(24.07)	*(11.46)*	*(53.75)*	*(65.87)*
$h_{1,t}\,h_{2,t}$	-0.0210		0.2548	
	(-0.57)		*(12.55)*	

Note: the t-statistics are in parentheses.

With regard to the oil-resource sector model, the volatility of the return for oil and resource sector index are significantly affected by its own previous volatility and news. There was no relationship between these returns in pre-crisis, as seen by the insignificant coefficient on $h_{1,t}h_{2,t}$. Although there is a significantly positive correlation between the volatility of returns for oil and resource sector index in post-crisis, with 0.2548 means that these two returns rise and fall together.

Table 4.10 The results of bivariate GARCH model oil-service

	Pre-crisis		**Post-crisis**	
Panel 9	**Oil ($h_{1,t}$)**	**Service sector index ($h_{2,t}$)**	**Oil ($h_{1,t}$)**	**Service sector index ($h_{2,t}$)**
constant	2.0×10^{-5}	3.9×10^{-5}	7.7×10^{-6}	8.1×10^{-6}
	(2.35)	*(9.33)*	*(5.06)*	*(5.33)*
$\varepsilon_{i,t-1}^2$	0.0787	0.3634	0.1658	0.1478
	(3.68)	*(5.48)*	*(10.37)*	*(10.69)*
$h_{i,t-1}$	0.8709	0.3665	0.8304	0.8124
	(24.35)	*(6.47)*	*(55.98)*	*(48.89)*
$h_{1,t}\, h_{2,t}$	-0.0363		0.1711	
	(-0.97)		*(7.93)*	

Note: the t-statistics are in parentheses.

According to the oil-service sector model, the volatility of the return for oil and service sector index sector were significantly impacted by its own previous volatility and news. There was no relationship between these returns in pre-crisis, as seen by the insignificant coefficient on $h_{1,t}h_{2,t}$ since its t-statistics is lower than critical t. While there is a significantly positive correlation between the volatility of returns for oil and resource sector index in post-crisis, with 0.1711 means that these two returns rise and fall together.

Table 4.11 The results of bivariate GARCH model oil-technology

	Pre-crisis		Post-crisis	
Panel 10	**Oil** $(h_{1,t})$	**Technology sector index** $(h_{2,t})$	**Oil** $(h_{1,t})$	**Technology sector index** $(h_{2,t})$
constant	2.0 x 10^{-5}	2.1 x 10^{-5}	7.6 x 10^{-6}	4.1 x 10^{-5}
	(2.35)	*(4.21)*	*(5.09)*	*(6.20)*
$\varepsilon_{i,t-1}^{2}$	0.0796	0.1265	0.1668	0.2105
	(3.71)	*(4.34)*	*(10.37)*	*(8.43)*
$h_{i,t-1}$	0.8701	0.3172	0.8310	0.6732
	(24.34)	*(2.06)*	*(55.83)*	*(18.40)*
$h_{1,t}\, h_{2,t}$	-0.0588		0.1611	
	(-1.59)		*(6.85)*	

Note: the t-statistics are in parentheses.

For the oil-technology sector model, the volatility of the return for oil and technology sector index sector are significantly influenced by its own previous volatility and news. There was no relationship between these returns in pre-crisis, as seen by the insignificant coefficient on $h_{1,t}h_{2,t}$ since its t-statistics is lower than critical t. However, there is a significantly positive correlation between the volatility of returns for oil and resource sector index in post-crisis, with 0.1711 means that these two returns rise and fall together.

4.3 Multivariate GARCH model

Table 4.12 The results of multivariate GARCH model oil-agriculture-consumption

	Pre-crisis			Post-crisis		
Panel 1	**Oil** $(\boldsymbol{h_{1,t}})$	**Agriculture** $(\boldsymbol{h_{2,t}})$	**Consumption** $(\boldsymbol{h_{3,t}})$	**Oil** $(\boldsymbol{h_{1,t}})$	**Agriculture** $(\boldsymbol{h_{2,t}})$	**Consumption** $(\boldsymbol{h_{3,t}})$
constant	5.5 x 10^{-6} *(1.99)*	9.1 x 10^{-6} *(4.81)*	5.1 x 10^{-6} *(6.34)*	1.7 x 10^{-6} *(4.12)*	6.6 x 10^{-6} *(5.73)*	1.9 x 10^{-5} *(12.40)*
$\varepsilon_{i,t-1}^{2}$	0.0302 *(3.74)*	0.1415 *(4.86)*	0.1462 *(6.25)*	0.0654 *(8.84)*	0.0837 *(7.80)*	0.2238 *(12.42)*
$h_{i,t-1}$	0.9497 *(65.38)*	0.7453 *(16.50)*	0.7206 *(21.80)*	0.9327 *(131.30)*	0.8677 *(58.45)*	0.4710 *(12.35)*
$h_{1,t}\, h_{2,t}$	0.0705 *(2.26)*			0.1833 *(8.92)*		
$h_{1,t}\, h_{3,t}$	0.0841 *(2.69)*			0.1202 *(4.95)*		
$h_{2,t}\, h_{3,t}$	0.4229 *(26.54)*			0.3915 *(21.32)*		
Log Likelihood		10724.92			16676.96	
AIC		-19.8957			-18.7567	

Note: the t-statistics are in parentheses.

The output above results for the MGARCH of oil-Agriculture-Consumption sector index returns model in pre- and post-crisis. Overall, there is a sufficient evidence to conclude that the relationship among the three returns volatility in pre- and post-crisis is consistent. This is to say, in the period of pre-crisis, the volatility of the return oil returns, agriculture and consumption sector index returns are significantly impacted by its own previous volatility and news, as evidenced by the significant coefficient on $h_{1,t-1}$ and $\varepsilon_{1,t-1}^{2}$, respectively. The coefficient on $h_{1,t-1}$ is positive which indicates that an increase in the past volatility of its return leads to more volatility in its current return on three sectors with different magnitude. Also, the estimated conditional correlation between the volatility of oil and agriculture sector index returns represented by $h_{1,t}\,h_{2,t}$ is 0.0705 points that these volatility returns tend to move in the same directions; on other hand, an increase in the return for oil tends to be associated with a rise in the return for agriculture sector index, and vice versa. Similarly, the estimated conditional correlation between the volatility of oil and consumption sector index returns represented by $h_{1,t}\,h_{3,t}$ is 0.0841 indicates that these two returns rise and fall together. Moreover, the estimated conditional correlation between the volatility of agriculture and consumption sector index returns represented by $h_{2,t}\,h_{3,t}$ is 0.4229 indicates that these two sectors index returns move together.

Turning to the period of post-crisis, the returns volatility for three sectors is indifferent with the pre-crisis. However, the correlation between oil returns and two certain sectors index returns is increased. The estimated conditional correlation between the volatility of oil and agriculture sector index returns rise to 0.1833 and the estimated conditional correlation between the volatility of oil and consumption sector index returns grow to 0.1202. It can imply that these two sectors index returns tend to more associated with oil returns.

Table 4.13 The results of multivariate GARCH model oil-agriculture-finance

	Pre-crisis			Post-crisis		
Panel 2	**Oil** $(h_{1,t})$	**Agriculture** $(h_{2,t})$	**Finance** $(h_{3,t})$	**Oil** $(h_{1,t})$	**Agriculture** $(h_{2,t})$	**Finance** $(h_{3,t})$
constant	5.8 x 10^{-6}	9.6 x 10^{-6}	0.0839	1.8 x 10^{-6}	9.6 x 10^{-6}	8.3 x 10^{-6}
	(1.99)	*(6.35)*	*(6.28)*	*(4.37)*	*(6.40)*	*(5.04)*
$\varepsilon_{i,t-1}^2$	0.0303	0.2197	0.3082	0.0647	0.0860	0.0892
	(3.69)	*(7.06)*	*(6.54)*	*(8.79)*	*(7.59)*	*(9.02)*
$h_{i,t-1}$	0.9482	0.6819	0.3568	0.9325	0.8409	0.8734
	(61.08)	*(19.37)*	*(5.35)*	*(130.58)*	*(49.35)*	*(61.49)*
$h_{1,t}\,h_{2,t}$	0.0701			0.1840		
	(2.21)			*(8.95)*		
$h_{1,t}\,h_{3,t}$	-0.0219			0.0285		
	(-0.67)			*(10.79)*		
$h_{2,t}\,h_{3,t}$	-0.0005			0.6080		
	(-0.01)			*(44.18)*		
Log Likelihood		5881.02			15774.03	
AIC		-10.8941			-17.7399	

Note: the t-statistics are in parentheses.

The oil-agriculture-finance sector model, the volatility of the return for each is significantly influenced by its own previous volatility and news. There is a significantly positive correlation between the volatility of returns for oil and agriculture sector index, with 0.0701 and 0.1840 in pre- and post-crisis respectively. Nevertheless, the volatility of returns for oil and finance sector index are positively correlated, with 0.0285 in post-crisis only.

Table 4.14 The results of multivariate GARCH model oil-agriculture-industry

	Pre-crisis			Post-crisis		
Panel 3	**Oil ($h_{1,t}$)**	**Agriculture ($h_{2,t}$)**	**Industry ($h_{3,t}$)**	**Oil ($h_{1,t}$)**	**Agriculture ($h_{2,t}$)**	**Industry ($h_{3,t}$)**
constant	5.5 x 10^{-6} *(1.99)*	9.2 x 10^{-6} *(4.87)*	1.3 x 10^{-5} *(5.38)*	1.9 x 10^{-6} *(4.49)*	1.1 x 10^{-5} *(6.40)*	9.1 x 10^{-6} *(5.40)*
$\varepsilon_{i,t-1}^{2}$	0.0298 *(3.71)*	0.1385 *(4.86)*	0.1035 *(6.68)*	0.0639 *(8.78)*	0.0944 *(7.79)*	0.0999 *(8.39)*
$h_{i,t-1}$	0.9500 *(65.48)*	0.7448 *(16.85)*	0.8229 *(32.66)*	0.9330 *(131.39)*	0.8248 *(42.95)*	0.8632 *(54.75)*
$h_{1,t}\,h_{2,t}$	0.0702 *(2.24)*			0.1846 *(9.02)*		
$h_{1,t}\,h_{3,t}$	0.1083 *(3.43)*			0.2577 *(11.89)*		
$h_{2,t}\,h_{3,t}$	0.5179 *(32.35)*			0.5758 *(41.94)*		
Log Likelihood		9924.01			15669.69	
AIC		-18.4071			-17.6224	

Note: the t-statistics are in parentheses.

According to the oil-agriculture-industry sector model, the volatility of the return for each is significantly impacted by its own previous volatility and news. There is a significantly positive correlation between the volatility of returns for oil and agriculture sector index, with 0.0702 and 0.1846 in pre- and post-crisis respectively, consistent with the previous model. Moreover, the volatility of oil returns and industry sector index returns are positively correlated, with 0.1083 and 0.2577 in pre- and post-crisis respectively.

Table 4.15 The results of multivariate GARCH model oil-agriculture-property

	Pre-crisis			Post-crisis		
Panel 4	**Oil** ($h_{1,t}$)	**Agriculture** ($h_{2,t}$)	**Prop Con** ($h_{3,t}$)	**Oil** ($h_{1,t}$)	**Agriculture** ($h_{2,t}$)	**Prop Con** ($h_{3,t}$)
constant	5.6 x 10^{-6}	1.0 x 10^{-6}	3.4 x 10^{-5}	1.8 x 10^{-6}	7.9 x 10^{-6}	4.5 x 10^{-6}
	(1.99)	*(4.40)*	*(5.69)*	*(4.19)*	*(6.95)*	*(6.27)*
$\varepsilon^2_{i,t-1}$	0.0299	0.1142	0.1545	0.0660	0.0728	0.0745
	(3.68)	*(4.79)*	*(4.42)*	*(8.90)*	*(7.26)*	*(8.69)*
$h_{i,t-1}$	0.9497	0.7482	0.6715	0.9319	0.8663	0.8967
	(64.64)	*(15.32)*	*(12.19)*	*(131.18)*	*(53.81)*	*(86.99)*
$h_{1,t}\, h_{2,t}$	0.0705			0.1834		
	(2.26)			*(8.88)*		
$h_{1,t}\, h_{3,t}$	0.1045			0.2237		
	(3.38)			*(11.11)*		
$h_{2,t}\, h_{3,t}$	0.5982			0.6589		
	(40.16)			*(56.47)*		
Log Likelihood		9952.32			16159.76	
AIC		-18.4597			-18.17427	

Note: the t-statistics are in parentheses.

With regard to oil-agriculture-property construction sector model, the volatility of the return for each is significantly affected by its own previous volatility and news. There is a significantly positive correlation between the volatility of returns for oil and agriculture sector index, with 0.0705 and 0.1834 in pre- and post-crisis respectively, consistent with the previous model. Furthermore, the volatility of oil returns and property construction sector index returns are positively correlated, with 0.1045 and 0.2237 in pre- and post-crisis respectively.

Table 4.16 The results of multivariate GARCH model oil-agriculture-resource

	Pre-crisis			Post-crisis		
Panel 5	**Oil** $(\boldsymbol{h_{1,t}})$	**Agriculture** $(\boldsymbol{h_{2,t}})$	**Resource** $(\boldsymbol{h_{3,t}})$	**Oil** $(\boldsymbol{h_{1,t}})$	**Agriculture** $(\boldsymbol{h_{2,t}})$	**Resource** $(\boldsymbol{h_{3,t}})$
constant	5.2 x 10^{-6} *(1.99)*	1.0 x 10^{-5} *(4.75)*	3.7 x 10^{-5} *(4.42)*	1.9 x 10^{-6} *(4.49)*	7.9 x 10^{-6} *(6.18)*	7.5 x 10^{-6} *(5.49)*
$\varepsilon^2_{i,t-1}$	0.0299 *(3.75)*	0.1290 *(5.01)*	0.1392 *(4.26)*	0.0635 *(8.75)*	0.0775 *(7.64)*	0.0779 *(8.05)*
$h_{i,t-1}$	0.9512 *(69.33)*	0.7392 *(16.10)*	0.7315 *(13.50)*	0.9329 *(131.33)*	0.8620 *(55.24)*	0.8912 *(68.75)*
$h_{1,t}\,h_{2,t}$	0.0706 *(2.26)*			0.1878 *(9.07)*		
$h_{1,t}\,h_{3,t}$	0.1678 *(5.43)*			0.3017 *(15.75)*		
$h_{2,t}\,h_{3,t}$	0.5329 *(31.84)*			0.5696 *(42.83)*		
Log Likelihood		9711.97			15665.08	
AIC		-18.0129			-17.6172	

Note: the t-statistics are in parentheses.

Due to the oil-agriculture-resource sector model, the volatility of the return for each is significantly influenced by its own previous volatility and news. There is a significantly positive correlation between the volatility of returns for oil and agriculture sector index, with 0.0706 and 0.1878 in pre- and post-crisis respectively, consistent with the previous model. Similarly, the volatility of oil returns and resource sector index returns are positively correlated, with 0.1678 and 0.3017 in pre- and post-crisis respectively.

Table 4.17 The results of multivariate GARCH model oil-agriculture-service

	Pre-crisis			Post-crisis		
Panel 6	**Oil** $(\boldsymbol{h_{1,t}})$	**Agriculture** $(\boldsymbol{h_{2,t}})$	**Service** $(\boldsymbol{h_{3,t}})$	**Oil** $(\boldsymbol{h_{1,t}})$	**Agriculture** $(\boldsymbol{h_{2,t}})$	**Service** $(\boldsymbol{h_{3,t}})$
constant	5.8 x 10^{-6} *(1.97)*	1.0 x 10^{-5} *(4.28)*	1.1 x 10^{-5} *(4.49)*	1.7 x 10^{-6} *(4.26)*	8.5 x 10^{-6} *(5.86)*	7.4 x 10^{-6} *(6.06)*
$\varepsilon_{i,t-1}^2$	0.0305 *(3.67)*	0.0976 *(4.33)*	0.0961 *(4.62)*	0.0654 *(8.85)*	0.0669 *(6.98)*	0.0914 *(9.13)*
$h_{i,t-1}$	0.9482 *(61.22)*	0.7626 *(15.69)*	0.7917 *(19.43)*	0.9324 *(132.35)*	0.8675 *(51.62)*	0.8453 *(48.45)*
$h_{1,t}\,h_{2,t}$	0.0707 *(2.29)*			0.1831 *(8.99)*		
$h_{1,t}\,h_{3,t}$	0.0688 *(2.07)*			0.1866 *(9.45)*		
$h_{2,t}\,h_{3,t}$	0.6069 *(42.39)*			0.6784 *(58.05)*		
Log Likelihood		10306.47			16446.25	
AIC		-19.1179			-18.4969	

Note: the t-statistics are in parentheses.

Turning to the oil-agriculture-service sector model, the volatility of the return for each is significantly impacted by its own previous volatility and news. There is a significantly positive correlation between the volatility of returns for oil and service sector index, with 0.0688 and 0.1866 in pre- and post-crisis respectively, means that these two returns rise and fall together. In addition to, the volatility of oil returns and agriculture sector index returns are still positive.

Table 4.18 The results of multivariate GARCH model oil-agriculture-technology

	Pre-crisis			Post-crisis		
Panel 7	**Oil ($h_{1,t}$)**	**Agriculture ($h_{2,t}$)**	**Technology ($h_{3,t}$)**	**Oil ($h_{1,t}$)**	**Agriculture ($h_{2,t}$)**	**Technology ($h_{3,t}$)**
constant	5.7 x 10^{-6} *(1.99)*	8.2 x 10^{-6} *(4.33)*	1.2 x 10^{-4} *(3.64)*	1.8 x 10^{-6} *(4.27)*	8.5 x 10^{-6} *(6.03)*	3.0 x 10^{-5} *(6.36)*
$\varepsilon_{i,t-1}^2$	0.0298 *(3.67)*	0.1079 *(4.73)*	0.0843 *(3.58)*	0.0666 *(8.84)*	0.0897 *(7.60)*	0.13299 *(7.55)*
$h_{i,t-1}$	0.9493 *(63.53)*	0.7841 *(18.73)*	0.4861 *(3.71)*	0.9314 *(129.89)*	0.8467 *(48.35)*	0.7258 *(21.13)*
$h_{1,t}\, h_{2,t}$	0.0706 *(2.25)*			0.1833 *(8.91)*		
$h_{1,t}\, h_{3,t}$	0.0878 *(2.64)*			0.1445 *(6.14)*		
$h_{2,t}\, h_{3,t}$	0.5348 *(31.66)*			0.4849 *(28.95)*		
Log Likelihood		9650.14			15619.60	
AIC		-17.8980			-17.5659	

Note: the t-statistics are in parentheses.

For the oil-agriculture-technology sector model, the volatility of the return for each is significantly affected by its own previous volatility and news. There is a significantly positive correlation between the volatility of returns for oil and technology sector index, with 0.0878 and 0.1445 in pre- and post-crisis respectively, means that these two returns rise and fall together. Also, the volatility of oil returns and agriculture sector index returns are still positive, with the consistent magnitude from the previous model.

Table 4.19 The results of multivariate GARCH model oil-consumption-finance

	Pre-crisis			Post-crisis		
Panel 8	**Oil** $(\boldsymbol{h_{1,t}})$	**Consumption** $(\boldsymbol{h_{2,t}})$	**Finance** $(\boldsymbol{h_{3,t}})$	**Oil** $(\boldsymbol{h_{1,t}})$	**Consumption** $(\boldsymbol{h_{2,t}})$	**Finance** $(\boldsymbol{h_{3,t}})$
constant	5.3 x 10^{-6} *(1.98)*	6.3 x 10^{-6} *(7.05)*	1.0 x 10^{-4} *(4.37)*	1.8 x 10^{-6} *(4.24)*	2.1 x 10^{-5} *(13.37)*	4.2 x 10^{-6} *(4.51)*
$\varepsilon_{i,t-1}^{2}$	0.0301 *(3.74)*	0.1332 *(5.97)*	0.1228 *(3.41)*	0.0639 *(8.82)*	0.2286 *(12.78)*	0.0772 *(8.93)*
$h_{i,t-1}$	0.9501 *(67.33)*	0.6924 *(20.13)*	0.4313 *(3.55)*	0.9334 *(133.42)*	0.4457 *(11.96)*	0.9052 *(92.83)*
$h_{1,t}\, h_{2,t}$	0.0858 *(2.25)*			0.1201 *(4.85)*		
$h_{1,t}\, h_{3,t}$	0.1099 *(2.64)*			0.2047 *(10.46)*		
$h_{2,t}\, h_{3,t}$	0.4884 *(31.66)*			0.4047 *(22.65)*		
Log Likelihood		10107.52			16251.81	
AIC		-18.7482			-18.2779	

Note: the t-statistics are in parentheses.

From the result of the oil-consumption-finance sector model, the volatility of the return for each is significantly influenced by its own previous volatility and news. There is a significantly positive correlation between the volatility of returns for oil and consumption sector index, with 0.0858 and 0.1201 in pre- and post-crisis respectively, means that these two returns rise and fall together. Similarly, the volatility of returns for oil and finance sector index are still positive, 0.1099 and 0.2047 in pre- and post-crisis respectively.

Table 4.20 The results of multivariate GARCH model oil-consumption-industry

	Pre-crisis			Post-crisis		
Panel 9	**Oil ($h_{1,t}$)**	**Consumption ($h_{2,t}$)**	**Industry ($h_{3,t}$)**	**Oil ($h_{1,t}$)**	**Consumption ($h_{2,t}$)**	**Industry ($h_{3,t}$)**
constant	5.3 x 10^{-6} *(1.98)*	5.3 x 10^{-6} *(7.02)*	1.8 x 10^{-5} *(5.24)*	1.8 x 10^{-6} *(4.35)*	1.9 x 10^{-5} *(12.13)*	5.1 x 10^{-6} *(4.29)*
$\varepsilon^2_{i,t-1}$	0.0298 *(3.76)*	0.1414 *(6.03)*	0.1346 *(6.19)*	0.0635 *(8.79)*	0.2238 *(12.01)*	0.0922 *(8.54)*
$h_{i,t-1}$	0.9509 *(68.11)*	0.7179 *(23.03)*	0.7661 *(22.17)*	0.9336 *(132.92)*	0.4757 *(12.36)*	0.8898 *(75.06)*
$h_{1,t}\, h_{2,t}$	0.0845 *(2.68)*			0.1221 *(5.09)*		
$h_{1,t}\, h_{3,t}$	0.1101 *(3.46)*			0.2562 *(11.99)*		
$h_{2,t}\, h_{3,t}$	0.4307 *(23.69)*			0.3897 *(24.56)*		
Log Likelihood		10255.47			16189.19	
AIC		-19.0232			-18.2074	

Note: the t-statistics are in parentheses.

According to the oil-consumption-industry sector model, the volatility of the return for each is significantly impacted by its own previous volatility and news. There is a significantly positive correlation between the volatility of returns for oil and consumption sector index, with 0.0845 and 0.1221 in pre- and post-crisis respectively, consistent with the previous model. Likewise, the volatility of returns for oil and industry sector index are still positive, 0.1101 and 0.2562 in pre- and post-crisis respectively.

Table 4.21 The results of multivariate GARCH model oil-consumption-property

	Pre-crisis			Post-crisis		
Panel 10	**Oil** $(\boldsymbol{h_{1,t}})$	**Consumption** $(\boldsymbol{h_{2,t}})$	**Prop Con** $(\boldsymbol{h_{3,t}})$	**Oil** $(\boldsymbol{h_{1,t}})$	**Consumption** $(\boldsymbol{h_{2,t}})$	**Prop Con** $(\boldsymbol{h_{3,t}})$
constant	5.4 x 10^{-6} *(1.99)*	5.9 x 10^{-6} *(6.86)*	3.9 x 10^{-5} *(6.31)*	1.7 x 10^{-6} *(4.14)*	1.8 x 10^{-5} *(11.73)*	2.5 x 10^{-6} *(5.15)*
$\varepsilon_{i,t-1}^{2}$	0.0299 *(3.73)*	0.1405 *(6.18)*	0.1828 *(4.45)*	0.0659 *(8.91)*	0.1963 *(12.06)*	0.0706 *(8.77)*
$h_{i,t-1}$	0.9504 *(67.02)*	0.6988 *(20.75)*	0.6186 *(10.79)*	0.9322 *(132.13)*	0.5077 *(13.26)*	0.9148 *(108.99)*
$h_{1,t}\, h_{2,t}$	0.0852 *(2.70)*			0.1191 *(4.89)*		
$h_{1,t}\, h_{3,t}$	0.1069 *(3.43)*			0.2227 *(10.96)*		
$h_{2,t}\, h_{3,t}$	0.5075 *(30.02)*			0.4749 *(28.49)*		
Log Likelihood		10264.06			16612.07	
AIC		-19.0392			-18.6836	

Note: the t-statistics are in parentheses.

With regard to the oil-consumption-property construction sector model, the volatility of the return for each is significantly influenced by its own previous volatility and news. There is a significantly positive correlation between the volatility of returns for oil and consumption sector index, with 0.0852 and 0.1191 in pre- and post-crisis respectively, consistent with the previous model. Additionally, the volatility of returns for oil and property construction sector index are still positive, 0.1069 and 0.2227 in pre- and post-crisis respectively.

Table 4.22 The results of multivariate GARCH model oil-consumption-resource

	Pre-crisis			Post-crisis		
Panel 11	**Oil** ($\boldsymbol{h_{1,t}}$)	**Consumption** ($\boldsymbol{h_{2,t}}$)	**Resource** ($\boldsymbol{h_{3,t}}$)	**Oil** ($\boldsymbol{h_{1,t}}$)	**Consumption** ($\boldsymbol{h_{2,t}}$)	**Resource** ($\boldsymbol{h_{3,t}}$)
constant	5.2 x 10^{-6} *(1.99)*	5.2 x 10^{-6} *(6.73)*	3.6 x 10^{-5} *(4.20)*	1.9 x 10^{-6} *(4.37)*	2.0 x 10^{-5} *(12.56)*	4.9 x 10^{-6} *(5.18)*
$\varepsilon_{i,t-1}^2$	0.0302 *(3.78)*	0.1404 *(5.95)*	0.1483 *(4.08)*	0.0634 *(8.76)*	0.2163 *(11.94)*	0.0728 *(8.14)*
$h_{i,t-1}$	0.9509 *(69.22)*	0.7217 *(22.23)*	0.7297 *(12.86)*	0.9332 *(133.05)*	0.4639 *(11.99)*	0.9084 *(90.29)*
$h_{1,t}\,h_{2,t}$	0.0841 *(2.66)*			0.1252 *(5.09)*		
$h_{1,t}\,h_{3,t}$	0.1678 *(5.41)*			0.2994 *(15.46)*		
$h_{2,t}\,h_{3,t}$	0.4201 *(21.66)*			0.4036 *(25.11)*		
Log Likelihood		10024.92			16204.07	
AIC		-18.5946			-18.2241	

Note: the t-statistics are in parentheses.

Due to the oil-consumption-resource sector model, the volatility of the return for each is significantly impacted by its own previous volatility and news. There is a significantly positive correlation between the volatility of returns for oil and consumption sector index, with 0.0841 and 0.1252 in pre- and post-crisis respectively, consistent with the previous model. Similarly, the volatility of returns for oil and resource sector index are still positive, 0.1678 and 0.2994 in pre- and post-crisis respectively.

Table 4.23 The results of multivariate GARCH model oil-consumption-service

	Pre-crisis			Post-crisis		
Panel 12	**Oil** ($h_{1,t}$)	**Consumption** ($h_{2,t}$)	**Service** ($h_{3,t}$)	**Oil** ($h_{1,t}$)	**Consumption** ($h_{2,t}$)	**Service** ($h_{3,t}$)
constant	5.5 x 10^{-6}	5.3 x 10^{-6}	1.3 x 10^{-5}	1.7 x 10^{-6}	2.0 x 10^{-6}	5.9 x 10^{-5}
	(1.97)	*(6.06)*	*(4.54)*	*(4.14)*	*(12.28)*	*(5.81)*
$\varepsilon_{i,t-1}^2$	0.0302	0.1238	0.1235	0.0652	0.2198	0.1011
	(3.69)	*(5.83)*	*(4.71)*	*(8.86)*	*(12.42)*	*(8.52)*
$h_{i,t-1}$	0.9499	0.7307	0.7481	0.9329	0.4545	0.8507
	(64.69)	*(21.23)*	*(15.39)*	*(132.99)*	*(11.53)*	*(51.65)*
$h_{1,t}\, h_{2,t}$	0.0848			0.1196		
	(2.71)			*(4.96)*		
$h_{1,t}\, h_{3,t}$	0.0689			0.1867		
	(2.06)			*(9.39)*		
$h_{2,t}\, h_{3,t}$	0.5099			0.4459		
	(28.92)			*(25.45)*		
Log Likelihood		10613.83			16831.07	
AIC		-19.6893			-18.9302	

Note: the t-statistics are in parentheses.

For the oil-consumption-service sector model, the volatility of the return for each is significantly affected by its own previous volatility and news. There is a significantly positive correlation between the volatility of returns for oil and consumption sector index, with 0.0848 and 0.1196 in pre- and post-crisis respectively, consistent with the previous model. Also, the volatility of returns for oil and service sector index are still positive, 0.0689 and 0.1867 in pre- and post-crisis respectively.

Table 4.24 The results of multivariate GARCH model oil-consumption-technology

	Pre-crisis			Post-crisis		
Panel 13	**Oil** $(\boldsymbol{h_{1,t}})$	**Consumption** $(\boldsymbol{h_{2,t}})$	**Technology** $(\boldsymbol{h_{3,t}})$	**Oil** $(\boldsymbol{h_{1,t}})$	**Consumption** $(\boldsymbol{h_{2,t}})$	**Technology** $(\boldsymbol{h_{3,t}})$
constant	5.4 x 10^{-6} *(1.99)*	5.1 x 10^{-6} *(6.06)*	1.4 x 10^{-4} *(4.54)*	1.7 x 10^{-6} *(4.21)*	1.9 x 10^{-5} *(12.86)*	1.1 x 10^{-5} *(4.41)*
$\varepsilon_{i,t-1}^{2}$	0.0297 *(3.72)*	0.1269 *(5.59)*	0.0945 *(3.27)*	0.0662 *(8.86)*	0.2297 *(12.59)*	0.0788 *(6.86)*
$h_{i,t-1}$	0.9506 *(66.53)*	0.7349 *(21.15)*	0.3975 *(2.68)*	0.9321 *(131.77)*	0.4584 *(12.22)*	0.8689 *(41.62)*
$h_{1,t}\,h_{2,t}$	0.0846 *(2.69)*			0.1189 *(4.89)*		
$h_{1,t}\,h_{3,t}$	0.0893 *(2.67)*			0.1445 *(6.19)*		
$h_{2,t}\,h_{3,t}$	0.4314 *(24.11)*			0.3386 *(16.60)*		
Log Likelihood		9969.61			16208.53	
AIC		-18.4918			-18.2292	

Note: the t-statistics are in parentheses.

The oil-consumption-technology sector model, the volatility of the return for each is significantly affected by its own previous volatility and news. There is a significantly positive correlation between the volatility of returns for oil and consumption sector index, with 0.0846 and 0.1189 in pre- and post-crisis respectively, consistent with the previous model. Additionally, the volatility of returns for oil and Technology sector index are still positive, 0.0893 and 0.1445 in pre- and post-crisis respectively.

Table 4.25 The results of multivariate GARCH model oil-finance-industry

	Pre-crisis	Post-crisis

Panel 14	Oil ($\boldsymbol{h_{1,t}}$)	Finance ($\boldsymbol{h_{2,t}}$)	Industry ($\boldsymbol{h_{3,t}}$)	Oil ($\boldsymbol{h_{1,t}}$)	Finance ($\boldsymbol{h_{2,t}}$)	Industry ($\boldsymbol{h_{3,t}}$)
constant	5.4 x 10^{-6} *(1.98)*	8.5 x 10^{-5} *(6.10)*	2.3 x 10^{-5} *(6.21)*	1.9 x 10^{-6} *(4.44)*	9.8 x 10^{-6} *(5.48)*	1.1 x 10^{-5} *(6.25)*
$\varepsilon^2_{i,t-1}$	0.0297 *(3.72)*	0.1184 *(4.38)*	0.1524 *(6.91)*	0.0637 *(8.79)*	0.0984 *(9.91)*	0.1074 *(8.91)*
$h_{i,t-1}$	0.9506 *(66.66)*	0.5179 *(6.95)*	0.7207 *(21.24)*	0.9330 *(132.09)*	0.8582 *(59.93)*	0.8461 *(56.29)*
$h_{1,t}\, h_{2,t}$	0.1089 *(3.33)*			0.2108 *(10.97)*		
$h_{1,t}\, h_{3,t}$	0.1084 *(3.45)*			0.2582 *(12.06)*		
$h_{2,t}\, h_{3,t}$	0.6943 *(59.72)*			0.6404 *(51.33)*		
Log Likelihood		9453.015			15332.63	
AIC		-17.5316			-17.2428	

Note: the t-statistics are in parentheses.

According to the oil-finance-industry sector model, the volatility of the return for each is significantly influenced by its own previous volatility and news. There is a significantly positive correlation between the volatility of returns for oil and finance sector index, with 0.1089 and 0.2108 in pre- and post-crisis respectively, consistent with the previous model. While, the volatility of returns for oil and industry sector index are still positive, 0.1084 and 0.2582 in pre- and post-crisis respectively.

Table 4.26 The results of multivariate GARCH model oil-finance-property

	Pre-crisis			Post-crisis		
Panel 15	**Oil** $(h_{1,t})$	**Finance** $(h_{2,t})$	**Prop Con** $(h_{3,t})$	**Oil** $(h_{1,t})$	**Finance** $(h_{2,t})$	**Prop Con** $(h_{3,t})$
constant	5.4 x 10^{-6}	9.2 x 10^{-5}	3.9 x 10^{-5}	1.8 x 10^{-6}	1.2 x 10^{-5}	6.1 x 10^{-6}
	(1.98)	*(7.40)*	*(6.29)*	*(4.24)*	*(6.08)*	*(7.07)*
$\varepsilon_{i,t-1}^2$	0.0300	0.1429	0.1427	0.0652	0.0773	0.0689
	(3.67)	*(5.89)*	*(5.22)*	*(8.83)*	*(9.45)*	*(8.91)*
$h_{i,t-1}$	0.9500	0.4728	0.6481	0.9322	0.8679	0.8906
	(65.47)	*(7.21)*	*(13.09)*	*(132.09)*	*(61.83)*	*(84.36)*
$h_{1,t}\,h_{2,t}$	0.1099			0.2104		
	(3.40)			*(10.88)*		
$h_{1,t}\,h_{3,t}$	0.1055			0.2245		
	(3.44)			*(11.14)*		
$h_{2,t}\,h_{3,t}$	0.8379			0.7739		
	(121.89)			*(92.81)*		
Log Likelihood		9704.68			16001.99	
AIC		-17.9994			-17.9966	

Note: the t-statistics are in parentheses.

Turning to the oil-finance-property construction sector model, the volatility of the return for each is significantly affected by its own previous volatility and news. There is a significantly positive correlation between the volatility of returns for oil and finance sector index, with 0.1099 and 0.2104 in pre- and post-crisis respectively, consistent with the previous model. In addition to, the volatility of returns for oil and property construction sector index are still positive, 0.1055 and 0.2245 in pre- and post-crisis respectively.

Table 4.27 The results of multivariate GARCH model oil-finance-resource

	Pre-crisis			Post-crisis		
Panel 16	Oil ($h_{1,t}$)	Finance ($h_{2,t}$)	Resource ($h_{3,t}$)	Oil ($h_{1,t}$)	Finance ($h_{2,t}$)	Resource ($h_{3,t}$)
constant	5.2 x 10^{-6} *(2.01)*	1.3 x 10^{-4} *(5.59)*	5.0 x 10^{-5} *(5.68)*	2.0 x 10^{-6} *(4.52)*	1.1 x 10^{-5} *(5.69)*	1.1 x 10^{-5} *(6.65)*
$\varepsilon_{i,t-1}^2$	0.0301 *(3.77)*	0.1491 *(4.18)*	0.1739 *(4.99)*	0.0638 *(8.77)*	0.0863 *(8.98)*	0.0817 *(4.99)*
$h_{i,t-1}$	0.9509 *(69.30)*	0.3059 *(2.65)*	0.6508 *(12.12)*	0.9325 *(131.54)*	0.8635 *(56.29)*	0.8732 *(62.89)*
$h_{1,t}\,h_{2,t}$	0.1099 *(3.34)*			0.2138 *(11.15)*		
$h_{1,t}\,h_{3,t}$	0.1677 *(5.45)*			0.3048 *(16.21)*		
$h_{2,t}\,h_{3,t}$	0.7161 *(66.29)*			0.6932 *(65.39)*		
Log Likelihood		9259.87			15441.70	
AIC		-17.1726			-17.3657	

Note: the t-statistics are in parentheses.

From result of the oil-finance-resource sector model, the volatility of the return for each is significantly impacted by its own previous volatility and news. There is a significantly positive correlation between the volatility of returns for oil and finance sector index, with 0.1099 and 0.2138 in pre- and post-crisis respectively, consistent with the previous model. Also, the volatility of returns for oil and resource sector index are still positive, 0.1677 and 0.3048 in pre- and post-crisis respectively.

Table 4.28 The results of multivariate GARCH model oil-finance-service

	Pre-crisis			Post-crisis		
Panel 17	**Oil** $(\boldsymbol{h_{1,t}})$	**Finance** $(\boldsymbol{h_{2,t}})$	**Service** $(\boldsymbol{h_{3,t}})$	**Oil** $(\boldsymbol{h_{1,t}})$	**Finance** $(\boldsymbol{h_{2,t}})$	**Service** $(\boldsymbol{h_{3,t}})$
constant	5.4 x 10^{-6} *(1.97)*	7.9 x 10^{-5} *(4.36)*	1.7 x 10^{-5} *(5.68)*	1.8 x 10^{-6} *(4.34)*	7.8 x 10^{-6} *(5.67)*	7.7 x 10^{-6} *(6.39)*
$\varepsilon^2_{i,t-1}$	0.0298 *(3.72)*	0.0981 *(4.04)*	0.1262 *(5.53)*	0.0645 *(8.72)*	0.0735 *(9.44)*	0.0888 *(9.06)*
$h_{i,t-1}$	0.9505 *(66.13)*	0.5596 *(6.02)*	0.6981 *(15.17)*	0.9328 *(131.98)*	0.8900 *(77.42)*	0.8448 *(49.01)*
$h_{1,t}\,h_{2,t}$	0.1088 *(3.36)*			0.2087 *(10.78)*		
$h_{1,t}\,h_{3,t}$	0.0698 *(2.12)*			0.1879 *(9.45)*		
$h_{2,t}\,h_{3,t}$	0.7838 *(88.44)*			0.6914 *(61.76)*		
Log Likelihood		9918.86			9918.86	
AIC		-18.3975			-18.3975	

Note: the t-statistics are in parentheses.

In term of the oil-finance-service sector model, the volatility of the return for each is significantly affected by its own previous volatility and news. There is a significantly positive correlation between the volatility of returns for oil and finance sector index, with 0.1088 and 0.2087 in pre- and post-crisis respectively, consistent with the previous model. Additionally, the volatility of returns for oil and service sector index are still positive, 0.0698 and 0.1879 in pre- and post-crisis respectively.

Table 4.29 The results of multivariate GARCH model oil-finance-technology

	Pre-crisis			Post-crisis		
Panel 18	**Oil** $(\boldsymbol{h_{1,t}})$	**Finance** $(\boldsymbol{h_{2,t}})$	**Technology** $(\boldsymbol{h_{3,t}})$	**Oil** $(\boldsymbol{h_{1,t}})$	**Finance** $(\boldsymbol{h_{2,t}})$	**Technology** $(\boldsymbol{h_{3,t}})$
constant	5.4 x 10^{-6} *(1.97)*	1.1 x 10^{-4} *(5.39)*	1.7 x 10^{-4} *(5.04)*	1.8 x 10^{-6} *(4.3)*	6.6 x 10^{-6} *(5.48)*	1.9 x 10^{-5} *(5.48)*
$\varepsilon^2_{i,t-1}$	0.0299 *(3.70)*	0.1269 *(4.35)*	0.1070 *(3.72)*	0.0649 *(8.76)*	0.0798 *(9.39)*	0.0898 *(6.82)*
$h_{i,t-1}$	0.9502 *(65.86)*	0.4133 *(4.07)*	0.2844 *(2.20)*	0.9323 *(131.58)*	0.8907 *(83.09)*	0.8149 *(29.80)*
$h_{1,t}\,h_{2,t}$	0.1100 *(3.35)*			0.2080 *(10.74)*		
$h_{1,t}\,h_{3,t}$	0.0892 *(2.66)*			0.1459 *(6.22)*		
$h_{2,t}\,h_{3,t}$	0.7163 *(69.04)*			0.5467 *(35.89)*		
Log Likelihood		9202.13			15255.83	
AIC		-17.0653			-17.15634	

Note: the t-statistics are in parentheses.

For the oil-finance-technology sector model, the volatility of the return for each is significantly influenced by its own previous volatility and news. There is a significantly positive correlation between the volatility of returns for oil and finance sector index, with 0.1100 and 0.2080 in pre- and post-crisis respectively, consistent with the previous model. Furthermore, the volatility of returns for oil and technology sector index are still positive, 0.0892 and 0.1459 in pre- and post-crisis respectively.

Table 4.30 The results of multivariate GARCH model oil-industry-property

	Pre-crisis			Post-crisis		
Panel 19	**Oil** $(h_{1,t})$	**Industry** $(h_{2,t})$	**Prop Con** $(h_{3,t})$	**Oil** $(h_{1,t})$	**Industry** $(h_{2,t})$	**Prop Con** $(h_{3,t})$
constant	5.4 x 10^{-6}	2.2 x 10^{-5}	3.8 x 10^{-5}	1.9 x 10^{-6}	1.1 x 10^{-5}	5.4 x 10^{-6}
	(1.99)	*(6.06)*	*(6.74)*	*(4.37)*	*(6.35)*	*(6.23)*
$\varepsilon^2_{i,t-1}$	0.02978	0.1299	0.1275	0.0642	0.0942	0.0849
	(3.73)	*(6.43)*	*(3.99)*	*(8.79)*	*(8.77)*	*(8.93)*
$h_{i,t-1}$	0.9504	0.7447	0.6665	0.9328	0.8591	0.8809
	(66.83)	*(22.32)*	*(12.85)*	*(132.35)*	*(59.41)*	*(76.86)*
$h_{1,t}\,h_{2,t}$	0.1092			0.2584		
	(3.44)			*(11.95)*		
$h_{1,t}\,h_{3,t}$	0.1056			0.2251		
	(3.38)			*(11.28)*		
$h_{2,t}\,h_{3,t}$	0.7251			0.7021		
	(68.58)			*(64.63)*		
Log Likelihood		9640.31			15753.92	
AIC		-17.8797			-17.7173	

Note: the t-statistics are in parentheses.

Turning to the oil-industry-property construction sector model, the volatility of the return for each is significantly impacted by its own previous volatility and news. There is a significantly positive correlation between the volatility of returns for oil and industry sector index, with 0.1092 and 0.2584 in pre- and post-crisis respectively, consistent with the previous model. While, the volatility of returns for oil and property construction sector index are still positive, 0.1056 and 0.2251 in pre- and post-crisis respectively.

Table 4.31 The results of multivariate GARCH model oil-industry-resource

	Pre-crisis			Post-crisis		
Panel 20	**Oil** ($h_{1,t}$)	**Industry** ($h_{2,t}$)	**Resource** ($h_{3,t}$)	**Oil** ($h_{1,t}$)	**Industry** ($h_{2,t}$)	**Resource** ($h_{3,t}$)
constant	5.2 x 10^{-6} *(2.00)*	1.7 x 10^{-5} *(5.46)*	4.2 x 10^{-5} *(4.30)*	1.9 x 10^{-6} *(4.48)*	8.7 x 10^{-6} *(6.19)*	7.7 x 10^{-6} *(6.71)*
$\varepsilon_{i,t-1}^{2}$	0.0301 *(3.78)*	0.1118 *(6.64)*	0.1372 *(4.08)*	0.0631 *(8.78)*	0.0853 *(8.96)*	0.0779 *(9.23)*
$h_{i,t-1}$	0.9508 *(69.05)*	0.7952 *(27.19)*	0.7116 *(11.43)*	0.9332 *(132.71)*	0.8781 *(71.91)*	0.8902 *(82.25)*
$h_{1,t}\,h_{2,t}$	0.1077 *(3.45)*			0.2616 *(12.15)*		
$h_{1,t}\,h_{3,t}$	0.1672 *(5.40)*			0.3018 *(15.81)*		
$h_{2,t}\,h_{3,t}$	0.6693 *(53.43)*			0.7253 *(73.14)*		
Log Likelihood		9376.07			15462.27	
AIC		-17.3886			-17.3888	

Note: the t-statistics are in parentheses.

In term of the oil-industry-resource sector model, the volatility of the return for each is significantly affected by its own previous volatility and news. There is a significantly positive correlation between the volatility of returns for oil and industry sector index, with 0.1077 and 0.2616 in pre- and post-crisis respectively, consistent with the previous model. Similarly, the volatility of returns for oil and resource sector index are still positive, 0.1672 and 0.3018 in pre- and post-crisis respectively.

Table 4.32 The results of multivariate GARCH model oil-industry-service

	Pre-crisis			Post-crisis		
Panel 21	**Oil** $(\boldsymbol{h_{1,t}})$	**Industry** $(\boldsymbol{h_{2,t}})$	**Service** $(\boldsymbol{h_{3,t}})$	**Oil** $(\boldsymbol{h_{1,t}})$	**Industry** $(\boldsymbol{h_{2,t}})$	**Service** $(\boldsymbol{h_{3,t}})$
constant	5.4 x 10^{-6} *(1.96)*	1.7 x 10^{-5} *(5.21)*	1.2 x 10^{-5} *(5.44)*	1.9 x 10^{-6} *(4.43)*	8.8 x 10^{-5} *(5.86)*	8.1 x 10^{-6} *(6.38)*
$\varepsilon_{i,t-1}^2$	0.0295 *(3.69)*	0.1211 *(6.54)*	0.0954 *(5.01)*	0.0638 *(8.74)*	0.0922 *(8.55)*	0.1073 *(9.23)*
$h_{i,t-1}$	0.9507 *(65.63)*	0.7862 *(26.62)*	0.7848 *(21.94)*	0.9332 *(132.22)*	0.8711 *(64.09)*	0.8254 *(44.65)*
$h_{1,t}\, h_{2,t}$	0.1084 *(3.42)*			0.2584 *(12.02)*		
$h_{1,t}\, h_{3,t}$	0.0683 *(2.04)*			0.1877 *(9.41)*		
$h_{2,t}\, h_{3,t}$	0.7133 *(59.23)*			0.6198 *(48.27)*		
Log Likelihood		9972.71			15844.89	
AIC		-18.4976			-18.8197	

Note: the t-statistics are in parentheses.

Due to the oil-industry-service sector model, the volatility of the return for each is significantly influenced by its own previous volatility and news. There is a significantly positive correlation between the volatility of returns for oil and industry sector index, with 0.1084 and 0.2584 in pre- and post-crisis respectively, consistent with the previous model. Likewise, the volatility of returns for oil and service sector index are still positive, 0.0683 and 0.1877 in pre- and post-crisis respectively.

Table 4.33 The results of multivariate GARCH model oil-industry-technology

	Pre-crisis			Post-crisis		
Panel 22	**Oil** $(h_{1,t})$	**Industry** $(h_{2,t})$	**Technology** $(h_{3,t})$	**Oil** $(h_{1,t})$	**Industry** $(h_{2,t})$	**Technology** $(h_{3,t})$
constant	5.8 x 10^{-6}	1.7 x 10^{-5}	1.7 x 10^{-4}	1.8 x 10^{-6}	6.9 x 10^{-6}	2.5 x 10^{-5}
	(1.99)	*(5.44)*	*(4.17)*	*(4.47)*	*(5.01)*	*(5.77)*
$\varepsilon_{i,t-1}^{2}$	0.0294	0.1165	0.0878	0.0641	0.0945	0.1182
	(3.62)	*(6.05)*	*(2.81)*	*(8.74)*	*(8.71)*	*(7.49)*
$h_{i,t-1}$	0.9493	0.7892	0.3082	0.9329	0.8785	0.7667
	(62.63)	*(26.01)*	*(1.97)*	*(131.72)*	*(67.54)*	*(24.58)*
$h_{1,t}\, h_{2,t}$	0.0963			0.2577		
	(3.06)			*(12.08)*		
$h_{1,t}\, h_{3,t}$	0.0831			0.1453		
	(2.49)			*(6.34)*		
$h_{2,t}\, h_{3,t}$	0.6539			0.4816		
	(53.87)			*(29.21)*		
Log Likelihood		9268.61			15128.06	
AIC		-17.1888			-17.0125	

Note: the t-statistics are in parentheses.

For the oil-industry-technology sector model, the volatility of the return for each is significantly affected by its own previous volatility and news. There is a significantly positive correlation between the volatility of returns for oil and industry sector index, with 0.0963 and 0.2577 in pre- and post-crisis respectively, consistent with the previous model. Additionally, the volatility of returns for oil and technology sector index are still positive, 0.0831 and 0.1453 in pre- and post-crisis respectively.

Table 4.34 The results of multivariate GARCH model oil-property-resource

	Pre-crisis			Post-crisis		
Panel 23	**Oil** $(\boldsymbol{h_{1,t}})$	**Prop Con** $(\boldsymbol{h_{2,t}})$	**Resource** $(\boldsymbol{h_{3,t}})$	**Oil** $(\boldsymbol{h_{1,t}})$	**Prop Con** $(\boldsymbol{h_{2,t}})$	**Resource** $(\boldsymbol{h_{3,t}})$
constant	5.2 x 10^{-6}	3.4 x 10^{-5}	4.5 x 10^{-5}	1.9 x 10^{-6}	4.7 x 10^{-6}	8.5 x 10^{-6}
	(2.00)	*(6.09)*	*(5.26)*	*(4.44)*	*(6.60)*	*(7.01)*
$\varepsilon_{i,t-1}^{2}$	0.0301	0.1364	0.1622	0.0637	0.0762	0.0756
	(3.77)	*(4.29)*	*(4.61)*	*(8.67)*	*(9.18)*	*(8.77)*
$h_{i,t-1}$	0.9509	0.6815	0.6815	0.9327	0.8933	0.8882
	(69.12)	*(13.39)*	*(12.29)*	*(131.75)*	*(90.30)*	*(78.28)*
$h_{1,t}\,h_{2,t}$	0.1005			0.2266		
	(3.24)			*(11.19)*		
$h_{1,t}\,h_{3,t}$	0.1676			0.3032		
	(5.42)			*(15.87)*		
$h_{2,t}\,h_{3,t}$	0.6987			0.7306		
	(62.02)			*(77.82)*		
Log Likelihood		9375.81			15833.25	
AIC		-17.3881			-17.8066	

Note: the t-statistics are in parentheses.

According to the oil-property construction-resource sector model, the volatility of the return for each is significantly impacted by its own previous volatility and news. There is a significantly positive correlation between the volatility of returns for oil and property construction sector index, with 0.1005 and 0.2266 in pre- and post-crisis respectively. Moreover, the volatility of returns for oil and resource sector index are still positive, 0.1676 and 0.3032 in pre- and post-crisis respectively.

Table 4.35 The results of multivariate GARCH model oil-property-service

	Pre-crisis			Post-crisis		
Panel 24	**Oil** $(\boldsymbol{h_{1,t}})$	**Prop Con** $(\boldsymbol{h_{2,t}})$	**Service** $(\boldsymbol{h_{3,t}})$	**Oil** $(\boldsymbol{h_{1,t}})$	**Prop Con** $(\boldsymbol{h_{2,t}})$	**Service** $(\boldsymbol{h_{3,t}})$
constant	5.5 x 10^{-6} *(1.98)*	4.0 x 10^{-5} *(4.33)*	1.6 x 10^{-5} *(5.36)*	1.7 x 10^{-6} *(4.23)*	4.8 x 10^{-6} *(6.96)*	7.7 x 10^{-6} *(6.19)*
$\varepsilon_{i,t-1}^2$	0.0296 *(3.62)*	0.0920 *(3.68)*	0.0888 *(5.03)*	0.0658 *(8.87)*	0.0656 *(8.69)*	0.0787 *(8.89)*
$h_{i,t-1}$	0.9503 *(65.03)*	0.6852 *(9.93)*	0.7396 *(16.32)*	0.9322 *(132.16)*	0.9022 *(93.38)*	0.8544 *(50.05)*
$h_{1,t}\, h_{2,t}$	0.1045 *(3.46)*			0.2235 *(11.13)*		
$h_{1,t}\, h_{3,t}$	0.0719 *(2.22)*			0.1875 *(9.51)*		
$h_{2,t}\, h_{3,t}$	0.8132 *(99.44)*			0.7684 *(95.76)*		
Log Likelihood		10119.05			16536.83	
AIC		-18.7696			-18.5989	

Note: the t-statistics are in parentheses.

Turning to the oil-property construction-service sector model, the volatility of the return for each is significantly influenced by its own previous volatility and news. There is a significantly positive correlation between the volatility of returns for oil and property construction sector index, with 0.1045 and 0.2235 in pre- and post-crisis respectively, consistent with the previous model. Furthermore, the volatility of returns for oil and service sector index are still positive, 0.0719 and 0.1875 in pre- and post-crisis respectively.

Table 4.36 The results of multivariate GARCH model oil-property-technology

	Pre-crisis			Post-crisis		
Panel 25	**Oil** $(h_{1,t})$	**Prop Con** $(h_{2,t})$	**Technology** $(h_{3,t})$	**Oil** $(h_{1,t})$	**Prop Con** $(h_{2,t})$	**Technology** $(h_{3,t})$
constant	5.5 x 10^{-6} *(2.00)*	4.0 x 10^{-5} *(5.93)*	1.4 x 10^{-4} *(4.61)*	1.7 x 10^{-6} *(4.27)*	4.3 x 10^{-6} *(5.99)*	2.2 x 10^{-5} *(5.45)*
$\varepsilon_{i,t-1}^2$	0.0298 *(3.69)*	0.1204 *(4.31)*	0.0952 *(3.51)*	0.0664 *(8.87)*	0.0735 *(8.77)*	0.0922 *(6.85)*
$h_{i,t-1}$	0.9499 *(65.32)*	0.6642 *(12.39)*	0.3841 *(3.09)*	0.9317 *(131.51)*	0.8991 *(88.91)*	0.8006 *(26.69)*
$h_{1,t}\,h_{2,t}$	0.1052 *(3.38)*			0.2241 *(11.25)*		
$h_{1,t}\,h_{3,t}$	0.0894 *(2.67)*			0.1456 *(6.24)*		
$h_{2,t}\,h_{3,t}$	0.7305 *(71.84)*			0.5898 *(43.73)*		
Log Likelihood		9363.05			15611.71	
AIC		-17.3644			-17.5571	

Note: the t-statistics are in parentheses.

With regard to the oil-property construction-technology sector model, the volatility of the return for each is significantly impacted by its own previous volatility and news. There is a significantly positive correlation between the volatility of returns for oil and property construction sector index, with 0.1052 and 0.2241 in pre- and post-crisis respectively, consistent with the previous model. Similarly, the volatility of returns for oil and technology sector index are still positive, 0.0894 and 0.1456 in pre- and post-crisis respectively.

Table 4.37 The results of multivariate GARCH model oil-resource-service

	Pre-crisis			Post-crisis		
Panel 26	**Oil ($h_{1,t}$)**	**Resource ($h_{2,t}$)**	**Service ($h_{3,t}$)**	**Oil ($h_{1,t}$)**	**Resource ($h_{2,t}$)**	**Service ($h_{3,t}$)**
constant	5.1 x 10^{-6}	5.1 x 10^{-5}	1.7 x 10^{-5}	2.0 x 10^{-6}	8.9 x 10^{-6}	7.5 x 10^{-6}
	(1.99)	*(4.87)*	*(7.09)*	*(4.47)*	*(6.34)*	*(6.36)*
$\varepsilon_{i,t-1}^2$	0.0297	0.1700	0.1416	0.0637	0.0807	0.0937
	(3.77)	*(4.49)*	*(5.23)*	*(8.61)*	*(8.55)*	*(8.75)*
$h_{i,t-1}$	0.9518	0.6513	0.6833	0.9326	0.8823	0.8422
	(70.91)	*(10.39)*	*(16.11)*	*(130.78)*	*(70.75)*	*(48.00)*
$h_{1,t}\, h_{2,t}$	0.1692			0.3038		
	(5.55)			*(15.99)*		
$h_{1,t}\, h_{3,t}$	0.0656			0.1898		
	(1.94)			*(9.39)*		
$h_{2,t}\, h_{3,t}$	0.6715			0.6377		
	(50.03)			*(54.15)*		
Log Likelihood		9690.04			15879.16	
AIC		-17.9722			-17.8583	

Note: the t-statistics are in parentheses.

In term of the oil-resource-service sector model, the volatility of the return for each is significantly affected by its own previous volatility and news. There is a significantly positive correlation between the volatility of returns for oil and resource sector index, with 0.1692 and 0.3038 in pre- and post-crisis respectively. Also, the volatility of returns for oil and service sector index are still positive, 0.0656 and 0.1898 in pre- and post-crisis respectively.

Table 4.38 The results of multivariate GARCH model oil-resource-technology

	Pre-crisis			Post-crisis		
Panel 27	**Oil** $(\boldsymbol{h_{1,t}})$	**Resource** $(\boldsymbol{h_{2,t}})$	**Technology** $(\boldsymbol{h_{3,t}})$	**Oil** $(\boldsymbol{h_{1,t}})$	**Resource** $(\boldsymbol{h_{2,t}})$	**Technology** $(\boldsymbol{h_{3,t}})$
constant	5.2 x 10^{-6} *(2.01)*	3.9 x 10^{-5} *(4.57)*	1.5 x 10^{-4} *(4.65)*	1.9 x 10^{-6} *(4.44)*	5.3 x 10^{-6} *(5.54)*	2.0 x 10^{-5} *(5.55)*
$\varepsilon^2_{i,t-1}$	0.0302 *(3.78)*	0.1574 *(4.50)*	0.1055 *(3.73)*	0.0635 *(8.63)*	0.0719 *(8.79)*	0.1042 *(7.12)*
$h_{i,t-1}$	0.9509 *(69.49)*	0.7068 *(12.63)*	0.3358 *(2.61)*	0.9331 *(132.12)*	0.9072 *(93.76)*	0.7993 *(28.52)*
$h_{1,t}\, h_{2,t}$	0.1682 *(5.43)*			0.3008 *(15.71)*		
$h_{1,t}\, h_{3,t}$	0.0873 *(2.61)*			0.1455 *(6.19)*		
$h_{2,t}\, h_{3,t}$	0.6313 *(43.73)*			0.5059 *(31.26)*		
Log Likelihood		9690.04			1519.68	
AIC		-16.7752			-17.0481	

Note: the t-statistics are in parentheses.

From the result of the oil-resource-technology sector model, the volatility of the return for each is significantly influenced by its own previous volatility and news. There is a significantly positive correlation between the volatility of returns for oil and resource sector index, with 0.1692 and 0.3038 in pre- and post-crisis respectively. In addition to, the volatility of returns for oil and service sector index are still positive, 0.0873 and 0.1455 in pre- and post-crisis respectively.

Table 4.39 The results of multivariate GARCH model oil-service-technology

	Pre-crisis			Post-crisis		
Panel 28	**Oil** $(\boldsymbol{h_{1,t}})$	**Service** $(\boldsymbol{h_{2,t}})$	**Technology** $(\boldsymbol{h_{3,t}})$	**Oil** $(\boldsymbol{h_{1,t}})$	**Service** $(\boldsymbol{h_{2,t}})$	**Technology** $(\boldsymbol{h_{3,t}})$
constant	5.7 x 10^{-6} *(1.98)*	1.3 x 10^{-5} *(4.62)*	1.5 x 10^{-4} *(4.03)*	1.7 x 10^{-6} *(4.27)*	7.7 x 10^{-6} *(6.21)*	2.6 x 10^{-5} *(6.08)*
$\varepsilon_{i,t-1}^{2}$	0.0297 *(3.63)*	0.0940 *(4.52)*	0.0862 *(3.17)*	0.0662 *(8.89)*	0.1091 *(8.94)*	0.1082 *(7.34)*
$h_{i,t-1}$	0.9495 *(63.23)*	0.7695 *(17.04)*	0.3542 *(2.39)*	0.9318 *(131.89)*	0.8274 *(44.92)*	0.7657 *(24.57)*
$h_{1,t}\, h_{2,t}$	0.0697 *(2.09)*			0.1447 *(6.17)*		
$h_{1,t}\, h_{3,t}$	0.0896 *(2.67)*			0.1866 *(9.43)*		
$h_{2,t}\, h_{3,t}$	0.6886 *(56.42)*			0.5877 *(42.69)*		
Log Likelihood		9648.05			15858.84	
AIC		-17.8942			-17.8354	

Note: the t-statistics are in parentheses.

The oil-service-technology sector model, the volatility of the return for each is significantly impacted by its own previous volatility and news. There is a significantly positive correlation between the volatility of returns for oil and service sector index, with 0.0697 and 0.1447 in pre- and post-crisis respectively. Moreover, the volatility of returns for oil and technology sector index are still positive, 0.0697 and 0.1866 in pre- and post-crisis respectively.

4.4 The results of bivariate BEKK-GARCH model

This thesis seeks to examine the relationships between the volatility of returns in the international oil market and Thailand stock exchange. In this study, we employed the Bivariate GARCH models in estimating the relationships. There are 10 models containing the volatility of oil returns and the volatility of Thailand SET index or subsector indexes returns. The results are presented in Tables 4.40 - 4.49. The symbols used in this study include $h_{11,t}$is the volatility of oil returns at time t, $h_{11,t-1}$is the volatility of oil returns at time t-1, $h_{22,t}$presents the volatility of an index returns at time t, $h_{22,t-1}$is the volatility of an index returns at time t-1, $h_{12,t-1}$describes the conditional covariance between oil returns and an index returns, while $\varepsilon_{1,t-1}^2$and $\varepsilon_{2,t-1}^2$are the effects of news originating in the international oil market and Thailand stock exchange in order, and $\varepsilon_{1,t-1}\varepsilon_{2,t-1}$presents the shock transmission from one to another markets (i.e., from the international oil market to SET or subsector indexes).

Table 4.40 shows the results of the oil-SET models in pre- and post-crisis periods. The volatility of the international oil returns in both periods were affected by its own previous volatility and shocks, as evidenced by the significant coefficients on $\mathrm{h}_{11,t-1}$and$\varepsilon_{1,t-1}^2$, respectively. There were no sufficient evidences that the volatility and shock of SET index returns had impact on the international oil market returns.

Considering the SET index in both periods, the results displayed significantly different patterns. In the pre-crisis period, the volatility of SET index returns was determined by its own previous volatility and shocks, together with volatility originating in the international oil market, as shown by the considerable coefficients on $h_{22,t-1}$, $\varepsilon_{2,t-1}^2$, respectively. Plus, there was a positive direct impact from the volatility of the international oil returns on the volatility of SET index returns, as seen the significant coefficient on$h_{12,t-1}$.Conversely, in the post-crisis, the volatility of SET index returns was not affected by its own previous volatility and shocks only, but by the previous volatility of the international oil market returns and shocks also. Additionally, the positive direct effect of the volatility of the international oil returns existed. This might be the case that the firms that make up for SET index are dominant by energy and petrochemical firms. Their profits are obviously closed to the oil price movement, and thus high volatile and shock increase those companies' performance volatile.

Table 4.40 The results of bivariate BEKK model oil-set index

	pre-crisis		**post-crisis**	
	Oil $(h_{11,t})$	**SET index** $(h_{22,t})$	**Oil** $(h_{11,t})$	**SET index** $(h_{22,t})$
constant	0.0000	0.0000***	0.0000***	0.0000***
p-value	0.0285	0.0000	0.0000	0.0000
$h_{11,t-1}$	0.9490***	0.0250	0.9420***	0.0520***
p-value	0.0000	0.3125	0.0000	0.0004
$h_{12,t-1}$	0.0050	0.0900***	0.0020	0.0950***
p-value	0.4413	0.0000	0.4179	0.0000
$h_{22,t-1}$	0.0000	0.6700***	0.0050	0.8780***
p-value	0.8415	0.0000	1.0000	0.0000
$\varepsilon^2_{1,t-1}$	0.0300***	0.0000	0.0550***	0.0000***
p-value	0.0002	0.1615	0.0000	0.0028
$\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	0.0000	-0.0180	0.0010	0.0270***
p-value	0.5093	1.8098	0.8650	0.0001
$\varepsilon^2_{2,t-1}$	0.0010	0.1290***	0.0000	0.1100***
p-value	0.8729	0.0001	1.0000	0.0000

Oil returns, consistent with the oil-SET index model. For the post-crisis, differently, SET50 index returns volatility was not affected by its own past volatility and shock only, but by the volatility and shock of the international oil market also. Additionally, high volatile in the international oil returns triggered more volatile in SET50 index returns significantly, as evidenced by the coefficient $h_{12,t-1}$. The reasonable explanation it is exactly the same for SET index, but the magnitudes for SET50 index are greater than SET index. That is, the firms built for SET50 index are 50 biggest and the most liquidity firms, they are concentrated in few industries such as resources, bank, and telecommunication.

Table 4.41 The results of bivariate BEKK model oil-set50 index

	pre-crisis		post-crisis	
	Oil $(h_{11,t})$	**SET50 index** $(h_{22,t})$	**Oil** $(h_{11,t})$	**SET50 index** $(h_{22,t})$
constant	0.0000**	0.0000***	0.0000***	0.0000***
p-value	0.0293	0.0000	0.0000	0.0000
$h_{11,t-1}$	0.9490***	0.0350	0.9420***	0.0620***
p-value	0.0000	0.2077	0.0000	0.0001
$h_{12,t-1}$	0.0000	0.0890***	0.0090	0.0950***
p-value	0.3524	0.0000	0.3271	0.0000
$h_{22,t-1}$	0.0020	0.6750***	0.0000	0.8900***
p-value	0.4839	0.0000	0.9761	0.0000
$\varepsilon^2_{1,t-1}$	0.0300***	0.0000	0.0550***	0.0000***
p-value	0.0002	0.1416	0.0000	0.0033
$\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	0.0020	-0.0180	0.0020	0.0290***
p-value	0.8259	1.8064	0.9045	0.0000
$\varepsilon^2_{2,t-1}$	0.0000	0.1170***	0.0030	0.1000***
p-value	0.3222	0.0001	0.3681	0.0000

In terms of the oil-agricultural business sector modelin Table 4.42, the findings support the fact that the volatility of the international oil returns was determined by its own past volatility and shock as seen from the former models.

The volatility of agricultural business index returns in pre-crisis showed that it was influenced by its own previous volatility and shock only, as evidenced by the considerable coefficients on $h_{22,t-1}$and $\varepsilon^2_{2,t-1}$, respectively. However, the volatility of agricultural business index returns in the post-crisis was not affected by its own past volatility and shock only, but by the international oil returns volatility and its shocks also. Furthermore, there was a prevalence of positive effect of the international oil volatility spillover to the agricultural business sector index. This is to say high volatility created in the international oil market increased considerably the volatility in agricultural business index returns. This might be the case that the characteristics of the firms make up the sector are normally tied to the oil price movement. For instance, palm oil or sugarcane, when the oil prices are stayed at high level, the consumers consider the use bio-diesel for transportation. But if the oil prices are declined, they turn to use fossil fuel. The performance for firms related to palm oil naturally are volatile. In the meantime, in the post-crisis, the oil price stayed high level, and it triggered the demand for bio-diesel, and thus increased more volatile in this sector performance.

Table 4.42 The results of bivariate BEKK model oil-agriculture

	pre-crisis		post-crisis	
	Oil ($h_{11,t}$)	**Agri** ($h_{22,t}$)	**Oil** ($h_{11,t}$)	**Agri** ($h_{22,t}$)
constant	0.0000**	0.0000***	0.0000***	0.0000***
p-value	0.0404	0.0000	0.0000	0.0000
$h_{11,t-1}$	0.9410***	-0.0030	0.9360***	0.0370***
p-value	0.0000	1.1585	0.0000	0.0085
$h_{12,t-1}$	0.0040	-0.2780	0.0030	0.9180***
p-value	0.9124	1.4177	0.3320	0.0000
$h_{22,t-1}$	0.0000	0.7330***	0.0080	0.8560***
p-value	0.8026	0.0000	1.0000	0.0000
$\varepsilon^2_{1,t-1}$	0.0310***	0.0000	0.0610***	0.0000***
p-value	0.0006	0.1074	0.0000	0.0093
$\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	0.0060	0.0580	0.0000	0.0370***
p-value	0.4715	0.2501	0.6527	0.0010
$\varepsilon^2_{2,t-1}$	0.0000	0.1730***	0.0000	0.1000
p-value	1.0000	0.0000	0.3789	0.0000

In Table 4.43 presents the oil-consumer product sector model, the results revealed the fact that the volatility of the international oil returns was affected by only its own previous volatility and shock as similar to the previous models. The impact of the volatility of consumer product sector index was insignificant. Yet, the volatilities of consumer product sector index in pre- and post-crisis are different.

In the pre-crisis, the volatility of consumer product sector index return was determined by its own previous volatilities and shocks, as seen the significant

$h_{22,t-1}$, and $\varepsilon^2_{2,t-1}$, respectively. Additionally, there is a sufficient evidence that the conditional covariance between the international oil returns and the sector index returns was strongly positive, as evidenced the considerable coefficient on $h_{12,t-1}$. In the post-crisis, the volatilities of consumer product sector index return were not impacted by its own past volatilities and shocks only, but by the volatilities of the international oil returns also. Similarly, the conditional covariance was consistent with the pre-crisis.

It should be noted that the sector index is made up with fashion, home and office products, personal products, and pharmaceuticals companies. High volatilities in oil returns could imply high volatilities in demand for those products, and thus affect the companies' performance.

Table 4.43 The results of bivariate BEKK model oil-consumption

	pre-crisis		**post-crisis**	
	Oil ($\boldsymbol{h_{11,t}}$)	**Cons** ($\boldsymbol{h_{22,t}}$)	**Oil** ($\boldsymbol{h_{11,t}}$)	**Cons** ($\boldsymbol{h_{22,t}}$)
constant	0.0000**	0.0000***	0.0000***	0.0000***
p-value	0.0285	0.0000	0.0000	0.0000
$\boldsymbol{h_{11,t-1}}$	0.9490***	-0.0070	0.9380***	0.0410***
p-value	0.0000	1.5035	0.0000	0.0000
$\boldsymbol{h_{12,t-1}}$	0.0000	0.0980***	0.0000	0.0950***
p-value	0.4839	0.0000	0.9362	0.0000
$\boldsymbol{h_{22,t-1}}$	0.0020	0.7360***	0.0010	0.4690***
p-value	0.5485	0.0000	0.9362	0.0000
$\boldsymbol{\varepsilon^2_{1,t-1}}$	0.0300***	0.0000	0.0610***	0.0000
p-value	0.0001	0.1211	0.0000	0.3843
$\boldsymbol{\varepsilon_{1,t-1}\varepsilon_{2,t-1}}$	0.0000	-0.0120	0.0000	0.0100
p-value	0.7414	1.8990	1.0000	0.3125
$\boldsymbol{\varepsilon^2_{2,t-1}}$	0.0100	0.1430	0.0000	0.2500***
p-value	0.7414	0.0000	1.0000	0.0000

The results of oil-financial sector index model are presented in Table 4.44. The volatilities of the international oil returns are consistent with the prior models, that is, it was affected by its own past volatility and shock in both pre- and post-crisis. There was no significant impact of the volatility and shock of financial sector index on the volatility of the international oil market.

While, the volatilities of the financial sector index return were affected by its own past volatilities and shocks, as seen the significant coefficients on $h_{22,t-1}$, and $\varepsilon_{2,t-1}^2$ in both pre- and post-crisis, respectively. Also, the volatilities of the sector index were positively affected by the volatility and unexpected events of the international oil market, as experienced the significant coefficients on $h_{12,t-1}$and $\varepsilon_{1,t-1}\varepsilon_{2,t-1}$, in both pre- and post-crisis, respectively. It might be the case that once high volatility in the international oil market could imply instability of macroeconomics indicators, for example inflation, interest rate, or output, and those affected the financial businesses. A spike in oil price usually comes with inflation, central bank who seeks for price stability might consider raising the benchmark rate and it ultimately has an impact on bank assets, especially long-term loans, as well as its performance.

Table 4.44 The results of bivariate BEKK model oil-financial

	pre-crisis		post-crisis	
	Oil ($h_{11,t}$)	**fin** ($h_{22,t}$)	**Oil** ($h_{11,t}$)	**fin** ($h_{22,t}$)
constant	0.0000**	0.0000***	0.0000***	0.0000***
p-value	0.0300	0.0021	0.0000	0.0000
$h_{11,t-1}$	0.9480***	-0.0350	0.9410***	0.0250
p-value	0.0000	1.7580	0.0000	0.1499
$h_{12,t-1}$	0.0000	0.0930***	0.0000	0.0950***
p-value	0.5093	0.0000	0.9601	0.0000
$h_{22,t-1}$	0.0030	0.8170***	0.0010	0.8820***
p-value	0.5485	0.0000	0.3789	0.0000
$\varepsilon_{1,t-1}^{2}$	0.0320***	0.0000*	0.0560***	0.0000**
p-value	0.0001	0.0643	0.0000	0.0366
$\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	0.0010	0.0290	0.0000	0.0270***
p-value	0.3222	1.9774	0.8026	0.0001
$\varepsilon_{2,t-1}^{2}$	0.0030	0.0500***	0.0000	0.1000***
p-value	0.9124	0.0000	0.7414	0.0000

For the oil-industrials sector index model is presented in Table 4.45. The volatility of the international oil returns was significantly influenced by its own past volatility and shock, consistent with the previous models. There were any effects of industrials sector index return volatility and shock on the international oil market volatility and shock.

By looking at the volatility of industrials sector index returns differs in pre- and post-crisis, the results offer differently. That is, in pre-crisis, the volatility was affected by its own past volatility and shocks. Additionally, the volatility of the international oil market was positively spread to the volatility of industrials sector index. While, in post-crisis, the sector index volatility was not determined by its own past volatility and shock only, but by the past volatility and return of the international oil market also. Overall, the volatility of the international oil market and the unexpected circumstance increased the volatility of the sector index significantly. Given the nature of firms make up this sector (e.g., automotive, industrial materials and machine, petrochemicals and chemicals), those are demanders and users of oil and petroleum-base product. Oil price may affect firm's profitability since there are evidences support that the sector index return was positively affected.

Table 4.45 The results of bivariate BEKK model oil-industry

	pre-crisis		post-crisis	
	Oil $(h_{11,t})$	**fin** $(h_{22,t})$	**Oil** $(h_{11,t})$	**fin** $(h_{22,t})$
constant	0.0000**	0.0000***	0.0000***	0.0000***
p-value	0.0300	0.0000	0.0000	0.0000
$h_{11,t-1}$	0.9490***	-0.0080	0.9410***	0.0870***
p-value	0.0000	1.2434	0.0000	0.0000
$h_{12,t-1}$	0.0000	0.0770**	0.0050	0.0930***
p-value	0.9362	0.0434	0.9124	0.0000
$h_{22,t-1}$	0.0020	0.7750***	0.0040	0.8770***
p-value	0.9920	0.0000	0.5353	0.0000
$\varepsilon^2_{1,t-1}$	0.0290***	0.0000	0.0560***	0.0000**
p-value	0.0002	0.5619	0.0000	0.0139
$\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	0.0000	-0.0140	0.0000	0.0420***
p-value	0.3789	1.4039	0.7263	0.0000
$\varepsilon^2_{2,t-1}$	0.0000	0.1240***	0.0000	0.1060***
p-value	0.7414	0.0000	0.4413	0.0000

Table 4.46 presents the results of the oil-property construction sector model. The results of the international oil return volatility are consistent with the previous models. That is, it was considerably affected by its own past volatility and shock only. There are no any effects of the property construction sector index on the volatility of the international oil returns.

For the volatilities of property construction sector index return are obviously different in pre- and post-crisis. In pre-crisis, its volatility was positively affected by its own past volatility and shock together with the past conditional covariance with the international oil market. While, in the post-crisis, it was influenced by its own past volatility and shock plus the past volatility and shock of the international oil market.

Firms made up this sector are major demanders and users for oil products. Oil prices could impact the firm’s performance certainty. That is, an increase in volatility of international oil raise more volatile the sector index return.

Table 4.46 The results of bivariate BEKK model oil-property

	pre-crisis		post-crisis	
	Oil $(h_{11,t})$	**Prop** $(h_{22,t})$	**Oil** $(h_{11,t})$	**Prop** $(h_{22,t})$
constant	0.0000**	0.0000***	0.0000***	0.0000***
p-value	0.0300	0.0000	0.0000	0.0000
$h_{11,t-1}$	0.9490***	-0.0080	0.9410***	0.0870***
p-value	0.0000	1.2434	0.0000	0.0000
$h_{12,t-1}$	0.0010	0.0770	0.0000	0.0930***
p-value	0.8259	0.0434	0.6965	0.0000
$h_{22,t-1}$	0.0000	0.7750***	0.0010	0.8770***
p-value	1.0000	0.0000	0.8259	0.0000
$\varepsilon^2_{1,t-1}$	0.0290***	0.0000	0.0560***	0.0000**
p-value	0.0002	0.5619	0.0000	0.0139
$\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	0.0020	-0.0140	0.0000	0.0420***
p-value	0.9124	1.4039	0.8729	0.0000
$\varepsilon^2_{2,t-1}$	0.0080	0.1240***	0.0000	0.1060***
p-value	1.0000	0.0000	0.4354	0.0000

The results of oil-resources sector model are displayed in Table 4.47. The results of the international oil market reveal that its returns are in line with another models. Its return volatility was positively affected by its own past volatility and shock in both periods. Also, there are no impacts of the property construction sector index model

For the volatilities of resource sector index return in both periods are different. In pre-crisis, the volatility of the sector index returns was determined by its own past volatility and shock couple with by the past volatility of the international oil returns. And the volatility of the international oil returns increased the volatility of the sector index returns. In the post-crisis, the volatility of the sector index return was not affected by its own past volatility and shock only, but by the past volatility and shock of the international oil market. It appears the fact that those effects are positively related to the volatility of the sector index. Obviously, the firms make up this sector have oil-related activities, for instance energy, utilities, and mining. Products' prices are related to oil price and thus high volatile in oil price rises the volatility of the product prices. Certainly, oil prices may affect the firms' performances.

Table 4.47 The results of bivariate BEKK model oil-resource

	pre-crisis		**post-crisis**	
	Oil ($h_{11,t}$)	**Res** ($h_{22,t}$)	**Oil** ($h_{11,t}$)	**Res** ($h_{22,t}$)
constant	0.0000**	0.0000***	0.0000***	0.0000***
p-value	0.0226	0.0000	0.0000	0.0000
$h_{11,t-1}$	0.9480***	0.1580***	0.9450***	0.1630***
p-value	0.0000	0.0000	0.0000	0.0000
$h_{12,t-1}$	0.0000	0.0890***	0.0080	0.0950***
p-value	0.5892	0.0000	0.5823	0.0000
$h_{22,t-1}$	0.0010	0.6860***	0.0000	0.8970***
p-value	0.9522	0.0000	0.3576	0.0000
$\varepsilon^2_{1,t-1}$	0.0300***	0.0000	0.0520***	0.0000***
p-value	0.0002	0.2460	0.0000	0.0028
$\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	0.0000	-0.0210	0.0030	0.0290***
p-value	0.8966	1.8293	0.4473	0.0000
$\varepsilon^2_{2,t-1}$	0.0050	0.1850***	0.0080	0.0870***
p-value	0.9761	0.0000	0.9840	0.0000

The results of the oil-service sector index model are presented in Table 4.48. Similarly, the results of the volatility of the international oil returns are consistent with another models. That is, the volatility of the international oil returns was affected by its own past volatility and shock only. The effects of the service sector index are insignificant in pre- and post-crisis.

Turning to the volatility of the service sector index returns, the results offers that there are divergence patterns for both periods. In pre-crisis, it was determined significantly by its own past volatility and shock. Also, high volatility in the international oil market transmits directly positively to the volatility of service sector index returns, as seen the coefficient on $h_{12,t-1}$. While, in post-crisis, the volatility of service sector index returns was affected considerably by its own past volatility and shock. Additionally, the international oil market sent directly to the service sector index return through intense the sector volatility together with indirectly through the positive unexpected events, reflected by the significant coefficients on $h_{12,t-1}$and $\varepsilon_{1,t-1}\varepsilon_{2,t-1}$, respectively. This is because the firms' nature of this sector are users for oil and related products, particularly transportation. High oil volatility could increase the volatility of those firms' performance.

Table 4.48 The results of bivariate BEKK model oil-service

	pre-crisis		post-crisis	
	Oil ($h_{11,t}$)	**Serv** ($h_{22,t}$)	**Oil** ($h_{11,t}$)	**Serv** ($h_{22,t}$)
constant	0.0000**	0.0000***	0.0000***	0.0000***
p-value	0.0357	0.0000	0.0000	0.0000
$h_{11,t-1}$	0.9460***	-0.0340	0.9390***	0.0040
p-value	0.0000	1.9312	0.0000	0.7718
$h_{12,t-1}$	0.0080	0.0880***	0.0000	0.0960***
p-value	0.4413	0.0000	1.0000	0.0000
$h_{22,t-1}$	0.0020	0.7550***	0.0010	0.8320***
p-value	0.5353	0.0000	0.9442	0.0000
$\varepsilon^2_{1,t-1}$	0.0320***	0.0000	0.0590***	0.0000**
p-value	0.0002	0.2713	0.0000	0.0414
$\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	0.0020	-0.0270	0.0030	0.0140***
p-value	0.3222	1.8584	0.9045	0.0198
$\varepsilon^2_{2,t-1}$	0.0010	0.1250***	0.0070	0.1270***
p-value	0.4413	0.0000	0.9124	0.0000

The results of the oil-technology sector index model are demonstrated in Table 4.49. The results of the volatility of the international oil returns are consistent with another models. That is, the volatility of the international oil returns was affected by its own past volatility and shock only. The effects of technology sector index are insignificant on the volatility of the international oil market in pre- and post-crisis.

For the volatility of the technology sector index returns, there are different patterns for both periods. In pre-crisis, it was determined significantly by its own past volatility and shock. Also, high volatility in the international oil market transmits directly positively to the volatility of technology sector index returns, as seen the coefficient on $h_{12,t-1}$. While, in post-crisis, the volatility of technology sector index returns was affected considerably by its own past volatility and shock. Additionally, the international oil market sent directly to the technology sector index return through intense the sector volatility together with indirectly through the positively unexpected events, reflected by the significant coefficients on $h_{12,t-1}$and $\varepsilon_{1,t-1}\varepsilon_{2,t-1}$, respectively. It might be the case that when the oil prices are more volatile it might affect the demand for investment in technology because firms might allocate the budget to handle the high cost. It thus has an impact on the technology profitability.

Table 4.49 The results of bivariate BEKK model oil-technology

	pre-crisis		**post-crisis**	
	Oil $(\boldsymbol{h_{11,t}})$	**Tech** $(\boldsymbol{h_{22,t}})$	**Oil** $(\boldsymbol{h_{11,t}})$	**Tech** $(\boldsymbol{h_{22,t}})$
constant	0.0000**	0.0001***	0.0000***	0.0000***
p-value	0.0300	0.0000	0.0000	0.0000
$\boldsymbol{h_{11,t-1}}$	0.9460***	-0.0570	0.9340***	-0.0240
p-value	0.0000	1.9265	0.0000	1.8529
$\boldsymbol{h_{12,t-1}}$	0.0040	0.0760***	0.0030	0.0840***
p-value	0.9283	0.0011	0.9840	0.0000
$\boldsymbol{h_{22,t-1}}$	0.0000	0.5160***	0.0080	0.7950***
p-value	1.0000	0.0000	0.9124	0.0000
$\boldsymbol{\varepsilon^2_{1,t-1}}$	0.0300***	0.0000	0.0640***	0.0000
p-value	0.0004	0.4122	0.0000	0.1971
$\boldsymbol{\varepsilon_{1,t-1}\varepsilon_{2,t-1}}$	0.0050	0.0170	0.0000	0.0350**
p-value	0.9601	0.5157	0.8259	0.0444
$\boldsymbol{\varepsilon^2_{2,t-1}}$	0.0000	0.0770***	0.0000	0.1220***
p-value	0.9124	0.0000	0.8572	0.0000

To sum up, the results of bivariate GARCH model, the volatility of the international oil market was affected by its own previous volatility and shock only. Also, there are sufficient evidences that the effects of the Thailand sector indexes were insignificant on the volatility of the international oil market. While, the volatility of Thailand stock index and sector indexes were influenced by the its own past volatilities and shocks coupled with the past volatilities and shocks of the international oil markets positively. Moreover, the volatility of the international oil market was transmitted positively directly to the volatility of Thailand stock market index and the sector indexes, particularly in post-crisis. Together, the unexpected events emerged in the international oil market sent positive impact on Thailand stock index volatility and the sector indexes volatility.

However, the current thesis would like to introduce with the multivariate GARCH model answering the designated research question since the findings with this method has been limited empirically evidences in the existing literature and in Thailand context. The results obtaining with this method are reported in the section 4.5.

4.5 The results of multivariate BEKK-GARCH model

The estimated spillover effects of the international oil market to Thailand sector indexes are demonstrated in this section. In Table 4.50 and 4.51 offer the estimated results obtaining from the multivariate BEKK-GARCH model in pre- and post-crisis, respectively.

To begin with in pre-crisis, the results of multivariate BEKK-GARCH are reported in Table 4.52. Overall, there are significant evidences to conclude that the volatility of the international oil returns was transmitted positively to the volatility of each sector index returns, as seen the significant coefficients on $h_{1i,t-1}$. Additionally, the shock emerged from the international oil market increased the volatility of sector index returns in Thailand, as evidenced the considerable coefficients on $\varepsilon_{1,t-1}\varepsilon_{i,t-1}$. The top three riskiest sectors are financial, industrials and service sector indexes. That is, the volatility of financial sector index returns is the riskiest it was reflected by the considerable coefficient on $h_{14,t-1}$or 0.0854. The volatility of industrials sector index returns comes after, with the significant coefficient of 0.0845. While, the volatility of the service sector index returns witnesses the third, with the significant coefficient of 0.0823.Moreover, the top three volatile sector indexes from hitting shock in the international oil market include agricultural business, technology, and property construction sector indexes. For the agricultural business sector index returns, its volatility was risker once the unexpected events emerged in the international oil market, with 0.071, the highest coefficient among the sectors. It might be the case that the demand for agricultural products is mixed and it depends on the oil price level and trend. On the one hand, if the oil prices are going up the demand for agricultural product will increase also because there is growth in demand for bio-diesel. On the other hand, when the oil prices are dropped people turn to use fossil fuel, and thus the demand for bio-diesel will slowdown. While, the volatility of technology and property construction sectors index returns come after. Those sectors witnessed more volatile when there is an emergence of the unexpected news in the international oil market (positive sign of estimated parameters). For technology sector, it might be the case that when there is shock in oil price the demand for investment might be postponed due to uncertainty in cost. Similarly, the demand for construction or housing could be delayed when consumers are facing inflation because of the deceleration of purchasing power.

Table 4.50 The results of multivariate BEKK model pre-crisis

	Oil	**Agr**	**Cons**	**Fin**	**Indus**	**PopC**	**Res**	**Serv**	**Tech**
	$h_{11,t}$	$h_{22,t}$	$h_{33,t}$	$h_{44,t}$	$h_{55,t}$	$h_{66,t}$	$h_{77,t}$	$h_{88,t}$	$h_{99,t}$
constant	0.0000*	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0001***
	0.0629	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$\boldsymbol{h_{1i,t-1}}$	0.9446***	0.0770***	0.0811***	0.0854***	0.0845***	0.0725***	0.0805***	0.0823***	0.0725***
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$\boldsymbol{h_{2i,t-1}}$		0.7500***	0.0741***	0.0790***	0.0762***	0.0690***	0.0722***	0.0755***	0.0601***
		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$\boldsymbol{h_{3i,t-1}}$			0.7511***	0.0785***	0.0762***	0.0690***	0.0720***	0.0754***	0.0591***
			0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$\boldsymbol{h_{4i,t-1}}$				0.8348***	0.0813***	0.0738	0.0774***	0.0802***	0.0647***
				0.0000	0.0000***	0.0000***	0.0000	0.0000	0.0000
$\boldsymbol{h_{5i,t-1}}$					0.7939***	0.0714***	0.0750***	0.0779***	0.0625***
					0.0000	0.0000	0.0000	0.0000	0.0000
$\boldsymbol{h_{6i,t-1}}$						0.6458***	0.0675***	0.0704***	0.0554***
						0.0000	0.0000	0.0000	0.0000
$\boldsymbol{h_{7i,t-1}}$							0.7147***	0.0739***	0.0587***
							0.0000	0.0000	0.0000
$\boldsymbol{h_{8i,t-1}}$								0.7722***	0.0616***
								0.0000	0.0000
$\boldsymbol{h_{9i,t-1}}$									0.4752***
									0.0000

Table 4.50 (Continued)

	Oil	**Agr**	**Cons**	**Fin**	**Indus**	**PopC**	**Res**	**Serv**	**Tech**
	$h_{11,t}$	$h_{22,t}$	$h_{33,t}$	$h_{44,t}$	$h_{55,t}$	$h_{66,t}$	$h_{77,t}$	$h_{88,t}$	$h_{99,t}$
$\varepsilon_{1,t-1}\varepsilon_{i,t-1}$	0.0322***	0.0710**	0.0340	0.0279*	0.0245	0.0357	0.0331	0.0317*	0.0387*
	0.0015	0.0147	0.2187	0.0658	0.2801	0.1211	0.1527	0.0989	0.0854
$\varepsilon_{2,t-1}\varepsilon_{i,t-1}$		0.1670***	0.1516***	0.0845***	0.1366***	0.1675***	0.1638***	0.1378***	0.1157***
		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$\varepsilon_{3,t-1}\varepsilon_{i,t-1}$			0.1401***	0.0778***	0.1236***	0.1514***	0.1503***	0.1250***	0.1050***
			0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$\varepsilon_{4,t-1}\varepsilon_{i,t-1}$				0.0450***	0.0713***	0.0852***	0.0852***	0.0707***	0.0591***
				0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$\varepsilon_{5,t-1}\varepsilon_{i,t-1}$					0.1176***	0.1387***	0.1365***	0.1138***	0.0966***
					0.0000	0.0000	0.0000	0.0000	0.0000
$\varepsilon_{6,t-1}\varepsilon_{i,t-1}$						0.1684***	0.1663***	0.1382***	0.1157***
						0.0000	0.0000	0.0000	0.0000
$\varepsilon_{7,t-1}\varepsilon_{i,t-1}$							0.1668***	0.1367***	0.1144***
							0.0000	0.0000	0.0000
$\varepsilon_{8,t-1}\varepsilon_{i,t-1}$								0.1144***	0.0963***
								0.0000	0.0000
$\varepsilon_{9,t-1}\varepsilon_{i,t-1}$									0.0810***
									0.0002

The results of the effects of the international oil market on Thailand sector indexes in post-crisis are demonstrated in Table 4.51. Overall, there are critical changes as compared to the results in pre-crisis. The top three sector getting more volatile from direct effect of the volatility of the international oil returns include resources, consumption, and industrials sector, as evidenced the significantly highest coefficients on $h_{17,t}$, $h_{13,t}$, and$h_{15,t}$,respectively. For the resources sector, it is undoubtedly the fact that the nature of the sector is close to oil price movement and its profitability should be coincided with the movement. It makes sense about that the high volatility of the international oil market leads to accelerate volatility of the resources sector index returns. While, the volatility of consumption sector index returns and the volatility of the industrials index returns come next, respectively. For the consumption sector index return, it is obvious that when the oil prices fluctuation might come with the inflation, affecting the purchasing power deceleration significantly. People or consumers will adjust the consumption patterns maintaining the stability their utility by cutting the unnecessary spending. It will decrease the aggregate demand and thus affect turnovers of the businesses, reflecting the profitability. Similarly, for the industrial sector, this sector is demanders and users the oil and oil-related products as the raw material in producing intermediate- or finished-goods. When the oil prices are fluctuated considerably it will affect the costs of the companies inevitably. Also, the producers with lack of risk management push the costs to the consumers, it might cause the inflation and the demand slowdown.

However, by considering indirect effect of the volatility of the international oil returns, the results offer divergence picture. The indirect impacts are sent through the news or unexpected events creating in the international oil market. Top three sectors were affected in post-crisis includes the agricultural business, service, and financial sectors, respectively. For the volatility agricultural business sector index, this is because the nature of the sector is tied to the oil prices inevitably as discussed in the pre-crisis. While, the volatility of service sector index returns was affected by the shock of the volatility of the international oil returns comes after. It might be the case that a growing in tourism triggers the demand for air travel. The businesses are more sensitive to the volatility of oil prices and it might affect the companies' performance when oil prices were more fluctuation. The volatility of financials sector index returns got more volatile from the unexpected events from the international oil market at third. This is because the oil shocks could cause the macroeconomic indicators changes, it might affect the financial firms' performance through depreciation the quality of assets, especially banking sector.

Table 4.51 The results of multivariate BEKK model post-crisis

	Oil	**Agr**	**Cons**	**Fin**	**Indus**	**PopC**	**Res**	**Serv**	**Tech**
	$h_{11,t}$	$h_{22,t}$	$h_{33,t}$	$h_{44,t}$	$h_{55,t}$	$h_{66,t}$	$h_{77,t}$	$h_{88,t}$	$h_{99,t}$
constant	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000**	0.0000***	0.0000***	0.0000***
	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$h_{1i,t}$	0.9391***	0.0674***	0.0939***	0.0910***	0.0936***	0.0757***	0.0962***	0.0633***	0.0581***
	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0061	0.2263
$h_{2i,t}$		0.8238***	0.0693***	0.0826***	0.0851***	0.0833***	0.0837***	0.0819***	0.0779***
		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$h_{3i,t}$			0.7874***	0.0670***	0.0797***	0.0617***	0.0808***	0.0654***	0.0701***
			0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$h_{4i,t}$				0.8344***	0.0866***	0.0847***	0.0846***	0.0832***	0.0815***
				0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$h_{5i,t}$					0.8489***	0.0868***	0.0831***	0.0840***	0.0860***
					0.0000	0.0000	0.0000	0.0000	0.0000
$h_{6i,t}$						0.8426***	0.0849***	0.0830***	0.0853***
						0.0000	0.0000	0.0000	0.0000
$h_{7i,t}$							0.8238***	0.0844***	0.0833***
							0.0000	0.0000	0.0000
$h_{8i,t}$								0.8000***	0.0836***
								0.0000	0.0000
$h_{9i,t}$									0.8358***
									0.0000
$\varepsilon_{1,t-1}\varepsilon_{i,t-1}$	0.0568***	0.0362***	-0.0041	0.0233***	0.0135**	0.0219**	0.0118***	0.0287**	0.0206
	0.0000	0.0067	1.2961	0.0005	0.0324	0.0466	0.0080	0.0203	0.2670
$\varepsilon_{2,t-1}\varepsilon_{i,t-1}$		0.0609***	0.0570	0.0525***	0.0502**	0.0550**	0.0555***	0.0543**	0.0478
		0.0067	1.2961	0.0005	0.0324	0.0466	0.0080	0.0203	0.2670
$\varepsilon_{3,t-1}\varepsilon_{i,t-1}$			0.1045***	0.0916***	0.0489***	0.0894***	0.0578***	0.0943***	0.0549***
			0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
$\varepsilon_{4,t-1}\varepsilon_{i,t-1}$				0.0819***	0.0507***	0.0689***	0.0658***	0.0640***	0.0667***
				0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
$\varepsilon_{5,t-1}\varepsilon_{i,t-1}$					0.0689***	0.0518***	0.0696***	0.0557***	0.0436***
					0.0000	0.0000	0.0000	0.0000	0.0000
$\varepsilon_{6,t-1}\varepsilon_{i,t-1}$						0.0770***	0.0630***	0.0687***	0.0556***
						0.0000	0.0000	0.0000	0.0000
$\varepsilon_{7,t-1}\varepsilon_{i,t-1}$							0.0912***	0.0590***	0.0586***
							0.0000	0.0000	0.0000
$\varepsilon_{8,t-1}\varepsilon_{i,t-1}$								0.0799***	0.0540***
								0.0000	0.0000
$\varepsilon_{9,t-1}\varepsilon_{i,t-1}$									0.0693***
									0.0000

CHAPTER 5

CONCLUSION

The current thesis focused on the relationship between oil returns and Thai stock market returns. It aimed to investigate those relationship in narrow aspect; Thai sector index returns and global oil returns, in daily basis. The data were collected since July 2004 to September 2015 on daily basis. The adopted sample was divided into two periods; pre- and post-crisis. The pre-crisis was covered since July 2004 to May 2008, while the rest was defined for the post-crisis.

The models adopted by the thesis to study could be divided into 2 main groups. The constant conditional correlation bivariate GARCH model and multivariate GARCH model for proposing the different angle of the relationship. For the bivariate GARCH model, it has ten models. While, for the multivariate GARCH model, it has twenty-eight models.

The results of the study illustrated that there was a correlation of the volatility of oil returns and Thai stock index returns, as well as Thai stock sector returns. Especially, in the post-crisis, those correlation were more increasing statistically. For example, in bivariate GARCH model, the thesis found the strong correlation between the volatility of oil returns and SET index returns, and SET50 index returns, in both periods. Moreover, there is the sufficient evidences to conclude that there is no relationship between the volatility of oil returns and Consumption, Finance, Property construction, Resource, Service, as well as Technology sector index returns in pre-crisis. Whereas it witnessed a considerably positive correlation for those sector index returns and oil returns in post-crisis.

For the results of multivariate GARCH model, there is only one model; the oil-agriculture-finance model, showed that it has significantly no relationship between the volatility of oil returns and agriculture, and finance sector index returns, in pre-crisis. There is a positive correlation between the volatility of oil returns and Thai subsector index returns in post-crisis. On other hand, an increase in the return for the oil tends to be associated with a rise in the return for the Thai stock index, and vice versa.

Overall, the volatility of oil returns tended to be positively correlated with Thai stock index returns; in term of overall market returns and subsector index returns. The correlation is obvious in the post-crisis. This is because of highly integrated among Thai market and global market, especially commodity market

Lastly, this thesis employs the indices market return and sectors return to examine the impact of oil price shocks on Thai stock market that might useful for the investors who interest to Minimum their loss of capital, and Maximum their profits between stocks investment and the uncertainly of oil prices. On the other hand, for policy makers might use this thesis as the monitor of inflation, and using the interest rate to control the inflation during the rising of oil prices.

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APPENDIX

Mean equation: Pre-crisis

Model	
oil-SET index	$\Delta r_{1,t} = 4.3 \times 10^{-5} - 0.5694\Delta r_{1,t-1} - 0.3208\Delta r_{1,t-2}$ (0.08) (-18.66) (-10.64) $\Delta r_{2,t} = -1.1 \times 10^{-4} - 0.5804\Delta r_{2,t-1} - 0.2752\Delta r_{2,t-2}$ (-0.27) (-16.35) (-7.49)
oil-SET50 index	$\Delta r_{1,t} = 1.47 \times 10^{-4} - 0.6424\Delta r_{1,t-1}$ (0.19) (-23.26) $\Delta r_{2,t} = 1.32 \times 10^{-4} - 0.6795\Delta r_{2,t-1}$ (0.26) (-24.25)
oil-agriculture	$\Delta r_{1,t} = 9.59 \times 10^{-5} - 0.4337\Delta r_{1,t-1}$ (0.19) (-13.09) $\Delta r_{2,t} = -1.93 \times 10^{-5} - 0.4665\Delta r_{2,t-1}$ (-0.08) (-15.22)
oil-consumption	$\Delta r_{1,t} = 1.02 \times 10^{-4} - 0.4342\Delta r_{1,t-1}$ (0.17) (-13.09) $\Delta r_{2,t} = -1.69 \times 10^{-5} - 0.5229\Delta r_{2,t-1}$ (-0.08) (-14.48)
oil-finance	$\Delta r_{1,t} = 1.03 \times 10^{-4} - 0.4326\Delta r_{1,t-1}$ (0.17) (-13.06) $\Delta r_{2,t} = -5.97 \times 10^{-5} - 0.4234\Delta r_{2,t-1}$ (-0.10) (-12.34)
oil-industry	$\Delta r_{1,t} = 1.08 \times 10^{-4} - 0.4319\Delta r_{1,t-1}$ (0.18) (-13.04) $\Delta r_{2,t} = -1.53 \times 10^{-4} - 0.4672\Delta r_{2,t-1}$ (-0.36) (-13.34)
oil-prop con	$\Delta r_{1,t} = 9.75 \times 10^{-5} - 0.4319\Delta r_{1,t-1}$ (0.17) (-13.08) $\Delta r_{2,t} = -3.16 \times 10^{-5} - 0.3941\Delta r_{2,t-1}$ (-0.07) (-13.92)

Model	
oil-resource	$\Delta r_{1,t} = 1.09 \times 10^{-4} - 0.4354\Delta r_{1,t-1}$ (0.18) (-13.16) $\Delta r_{2,t} = -6.93 \times 10^{-5} - 0.4405\Delta r_{2,t-1}$ (-0.13) (-12.21)
oil-service	$\Delta r_{1,t} = 9.29 \times 10^{-5} - 0.4343\Delta r_{1,t-1}$ (0.18) (-13.12) $\Delta r_{2,t} = 3.25 \times 10^{-5} - 0.4561\Delta r_{2,t-1}$ (0.11) (-13.30)
oil-technology	$\Delta r_{1,t} = 1.07 \times 10^{-4} - 0.4343\Delta r_{1,t-1}$ (0.18) (-13.11) $\Delta r_{2,t} = -9.44 \times 10^{-5} - 0.4969\Delta r_{2,t-1}$ (-0.14) (-13.78)

Note: the t-statistics are in parentheses.

Mean equation: Post-crisis

Model	
oil-SET index	$\Delta r_{1,t} = 5.01 \times 10^{-7} - 0.5885\Delta r_{1,t-1} - 0.3295\Delta r_{1,t-2}$ (0.00) (-25.98) (-14.55) $\Delta r_{2,t} = 1.39 \times 10^{-4} - 0.6453\Delta r_{2,t-1} - 0.3082\Delta r_{2,t-2}$ (0.56) (-27.59) (-13.72)
oil-SET50 index	$\Delta r_{1,t} = 3.02 \times 10^{-5} - 0.4.559\Delta r_{1,t-1}$ (0.08) (-20.86) $\Delta r_{2,t} = 2.83 \times 10^{-4} - 0.4946\Delta r_{2,t-1}$ (1.00) (-22.86)
oil-agriculture	$\Delta r_{1,t} = -2.11 \times 10^{-5} - 0.45137\Delta r_{1,t-1}$ (-0.06) (-20.28) $\Delta r_{2,t} = 1.28 \times 10^{-4} - 0.4864\Delta r_{2,t-1}$ (0.49) (-22.18)

Model	
oil-consumption	$\Delta r_{1,t} = -2.37 \times 10^{-5} - 0.4458\Delta r_{1,t-1}$ (-0.07) (-20.11) $\Delta r_{2,t} = 8.02 \times 10^{-6} - 0.5051\Delta r_{2,t-1}$ (0.04) (-21.07)
oil-finance	$\Delta r_{1,t} = -7.43 \times 10^{-6} - 0.4451\Delta r_{1,t-1}$ (-0.02) (-20.16) $\Delta r_{2,t} = 2.85 \times 10^{-6} - 0.4658\Delta r_{2,t-1}$ (0.87) (-20.24)
oil-industry	$\Delta r_{1,t} = -1.60 \times 10^{-5} - 0.4528\Delta r_{1,t-1}$ (-0.04) (-20.65) $\Delta r_{2,t} = 2.37 \times 10^{-4} - 0.4916\Delta r_{2,t-1}$ (0.73) (-22.76)
oil-prop con	$\Delta r_{1,t} = 4.57 \times 10^{-5} - 0.4378\Delta r_{1,t-1}$ (0.13) (-19.69) $\Delta r_{2,t} = 9.84 \times 10^{-4} - 0.0083\Delta r_{2,t-1}$ (3.69) (-30.56)
oil-resource	$\Delta r_{1,t} = 1.86 \times 10^{-5} - 0.4694\Delta r_{1,t-1}$ (0.05) (-21.67) $\Delta r_{2,t} = 3.43 \times 10^{-4} - 0.4922\Delta r_{2,t-1}$ (0.96) (-23.12)
oil-service	$\Delta r_{1,t} = -1.39 \times 10^{-5} - 0.4458\Delta r_{1,t-1}$ (-0.04) (-20.11) $\Delta r_{2,t} = 2.08 \times 10^{-5} - 0.4966\Delta r_{2,t-1}$ (0.08) (-23.79)
oil-technology	$\Delta r_{1,t} = -1.53 \times 10^{-5} - 0.4385\Delta r_{1,t-1}$ (-0.04) (-19.86) $\Delta r_{2,t} = 6.06 \times 10^{-5} - 0.4997\Delta r_{2,t-1}$ (0.18) (-22.50)

Note: the t-statistics are in parentheses

BIOGRAPHY

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ACADEMIC BACKGROUND	Bachelor of Business Administration(Finance),Rangsit University (2000); Master of Science in Finance, Oxford Brookes University, Oxford, UK(2009)
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