# ASYMMETRIC VOLATILITY SPILLOVER BETWEEN OIL MARKET, GOLD MARKET AND MALAYSIAN STOCK MARKET

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DECLARATION

We hereby declare that:

1) This undergraduate research project is the end result of our own work and that due acknowledgement has been given in the references to ALL sources of information be they printed, electronic, or personal.

2) No portion of this research project has been submitted in support of any application for any other degree or qualification of this or any other university, or other institutes of learning.

3) Equal contribution has been made by each group member in completing the research project.

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LIST OF ABBREVIATIONS

| | |
|---|---|
| ADF | Augmented Dickey Fuller |
| AFC | Asian Financial Crisis |
| AIC | Akaike Information Criterion |
| ARCH LM | Autoregressive Conditional Heteroskedasticity Lagrange Multiplier |
| ARDL | Autoregressive Distributed Lag |
| CBOE | Chicago Board Option Exchange |
| CUSUM | Cumulative Sum |
| CUSUMSQ | Cumulative Sum of Square |
| DOLS | Dynamic Ordinary Least Square |
| E&E | Electrical and Electronic |
| ECM | Error Correction Model |
| ESDC | European Sovereign Debt Crisis |
| EU | European Union |
| GCC | Gulf Cooperation Council |
| GDP | Gross Domestic Product |
| GE14 | $14^{th}$ General Election Malaysia |
| GVZ | CBOE Gold Volatility Index |
| GVZ- | Negative Shock of Gold Volatility Index |
| GVZ+ | Positive Shock of Gold Volatility Index |
| HNX index | Hanoi Stock Exchange Index |

| | |
|---|---|
| KLCI | Kuala Lumpur Composite Index |
| KPSS | Kwiatkowski-Phillips-Schmidt-Shin |
| LM | Breusch-Godfrey Lagrange Multiplier |
| MBS | Mortgage-Backed Securities |
| MTAR | Momentum Threshold Autoregressive |
| NARDL | Non-linear Autoregressive Distributed Lag |
| OPEC | Organization of Petroleum Exporting Countries |
| OVX | CBOE Crude Oil Volatility Index |
| OVX- | Negative Shock of Oil Volatility Index |
| OVX+ | Positive Shock of Oil Volatility Index |
| PP | Phillips-Perron |
| RFC | Russian Financial Crisis |
| RV | Realized Volatility |
| SMC | Subprime Mortgage Crisis |
| TAR | Threshold Autoregressive |
| U.S. | United States |
| UAE | United Arab Emirates |
| UK | United Kingdom |
| UOB | United Overseas Bank |
| USA | United States of America |
| USO | United States Oil |
| VAR | Vector Autoregression |
| VIX | CBOE Volatility Index |
| VN index | Vietnam Ho Chi Minh Stock Index |

| | |
|---|---|
| VXFXI | CBOE China ETF Volatility Index |
| VXXLE | CBOE Energy Sector ETF Volatility Index |
| WGC | World Gold Council |

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# ABSTRACT

This paper examines the asymmetric relationship between oil market volatility, gold market volatility and Malaysian stock market volatility. Monthly data of KLCI, OVX and GVZ which span over the period from January 2009 to December 2018 was obtained from Bloomberg Terminal. Most of the previous studies investigated the linear relationship between oil prices, gold prices and stock market prices. Oil market volatility, gold market volatility and stock market volatility are less investigated in the past studies, whereby they do not consider the shock of the oil prices and gold prices. Hence, NARDL approach is employed in this paper to ascertain whether OVX and GVZ have asymmetric effects on the realized volatility of KLCI. The empirical results show that there is existence of asymmetric long run relationship among volatility of oil market, volatility of gold market and volatility of Malaysian stock market. Specifically, RV of KLCI tends to react more to OVX+ instead of OVX- which means that an increase in volatility of oil market will increase the volatility of Malaysian stock market. On the other hand, RV of KLCI tends to react more to GVZ- instead of GVZ. This implies that a decline in volatility of gold market will decrease the volatility of Malaysian stock market. The findings of this study carry important implications for investors, fund managers, government policymakers and researcher

# CHAPTER 1: RESEARCH OVERVIEW

## 1.0 Introduction

This chapter will highlight the overview of the study with the research background of crude oil market, gold market and Malaysian stock market and the shock that drove them volatile, research problem, research questions, research objectives, research hypothesis and significance of study.

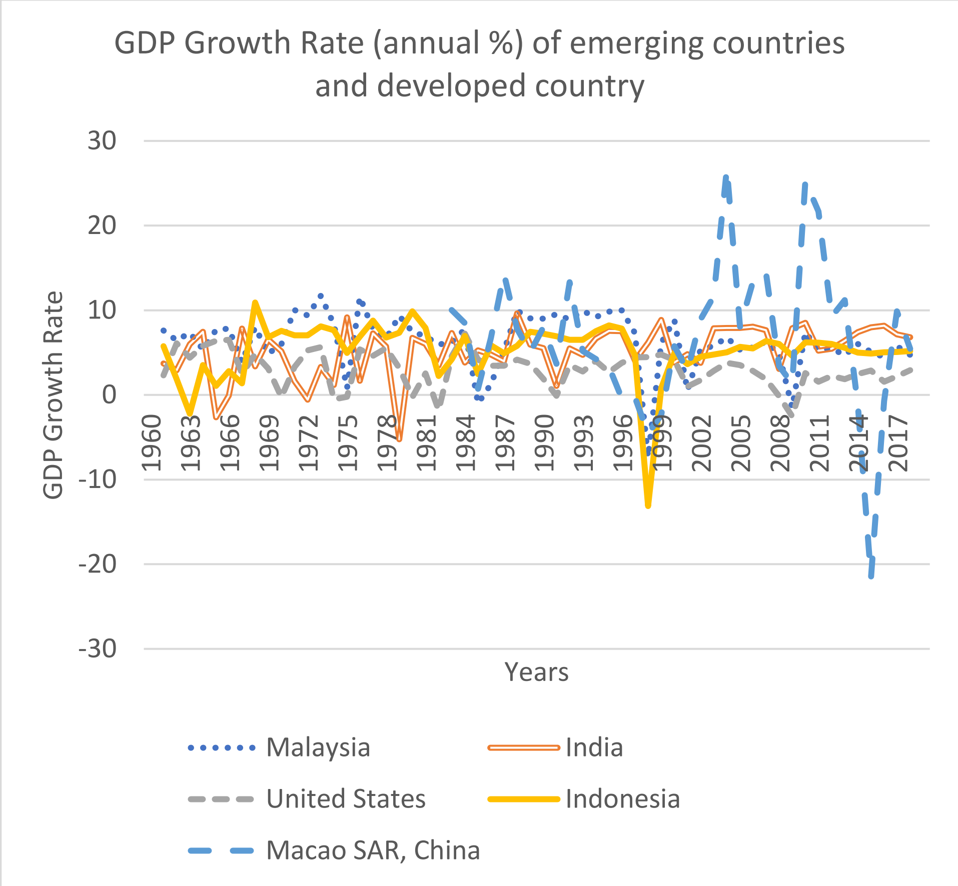
## 1.1 Research Background

### 1.1.1 Background of Malaysian Stock Market

Stock market is the key driver or vital indicator for the performance of the economy (Nordin et al., 2016; Janor et al., 2005; Phang, 2006; Har et al., 2008). Stock market has been documented as an entity for investors or individuals to perform the activity of trading on the company shares and derivatives at a specific price (Omar & Halim, 2015). Besides, the stock market helps in encouraging the mobilization of funds, providing liquidity and promoting large-scale enterprises (Alzaid, 2016).

However, stock market of emerging country should be paid attention due to the economic growth (Strauss, 2018). Emerging market succeeded in dragging the attention of the investors due to the high potential in development and growth compared to the developed country (Carp, 2012). Emerging market will impact the economic growth significantly in terms of the liquidity, market capitalization, risk sharing as well as diversification. Moreover, the liquidity of stock market has been claimed to contribute to the economic growth (Bencivenga et al., 1996). Figure 1.1 demonstrates the annual growth rate of the GDP for the emerging countries that outperformed the U.S. Besides, emerging markets became more attractive in their technology, service sector and customer-driven industries. According to IMF, emerging markets aided to boost 59% of the global economy while U.S. contributed 15% towards the global economy. Hence, with the transformation, most of the people tend to invest in emerging country rather than others in order to reap the rewards. It has been shown that there was an inverse association between the U.S. stock market and emerging markets. When the value of U.S. dollar decreases, its stock market will underperform versus the other countries' stock market, especially those emerging countries (Strauss, 2018). There are studies proved that the emerging economies keep growing from time to time (Basher et al., 2012). They also forecasted that the global GDP will be boosted up by 50% in year 2050 (Basher et al., 2012; Cheng et al., 2007).

Figure 1.1 GDP Growth Rate of emerging countries and developed country




Source: World Bank

Figure 1.1 indicates the annual GDP growth of emerging countries, Malaysia, India, China and Indonesia, versus developed country, U.S. It indicates that the overall GDP growth rate of emerging countries are far higher than the developed country.

Malaysia is one of the top emerging-market countries. It succeeded in transforming from agriculture and commodity-based economy to manufacturing and service sector which allows it to be the lead exporter of electrical appliances, parts and components since year 1957 (The World Bank, 2019). Although Malaysia is ranked as the last in the list of "10 biggest emerging market economies", its surplus of current account, economic stability, growth expectancy and valuation outperformed others.

Besides, Malaysia has undergone an average yearly growth of 5.4% since year 2010 and performed well in year 2018 with the growth rate of 4.4% (IG, 2019). In addition, Malaysia remained as an attractive country for investment due to the attractive investment incentives that will be given to the investors. By introducing the tax reduction in investment, it will definitely heighten the government revenue as it succeeded in attracting local and foreign investors ("Lower corporate tax," 2015). Hence, Malaysia will be viewed as a place that investors can reap more benefit in investment. For instance, United Kingdom (UK) government revenue had been boosted up due to the reduction of corporate tax from 24% to 20%. It has been clarified that cutting the corporate tax will eventually stimulate the government revenue as it is effective in attracting foreign and domestic investors to invest money in Malaysia (Khoo, 2019). Furthermore, the stable and strong economic status and political status tended to attract investors to invest in Malaysia ("Minister: Strong economy," 2017). It aided to enhance the confidence level of the domestic and foreign investors.

Kuala Lumpur Composite Index (KLCI) acted as the accurate measurement for the performance of Malaysian stock market. It comprises of 30 top Malaysian companies which will influence steeply the economic growth due to their broad performance in Malaysia. KLCI is calculated via market capitalization weighted method from the prices of the top 30 companies (Kwong et al., 2017). Stock market index is not only evaluating the worthiness of the investment, but also identifying whether the economic and financial of the nation is stable (Alzaid, 2016).

The companies listed in Bursa Malaysia had been increased from 295 to 977 in year 2008 but dropped slightly to 941 companies due to U.S. Subprime Mortgage Crisis (SMC) which influenced the Malaysian stock market in year 2008 and 2009 (Omar & Halim, 2015). Meanwhile, Malaysian stock market had been significantly affected by Asian Financial Crisis (AFC) (1997). The occurrence of AFC dramatically increased the volatility of KLCI (Bakhtyar, 2017; Malim et al., 2017). During the crisis, the value of

Malaysian Ringgit dropped steeply and depreciated 50% and the stock market lost 50% of the capital and KLCI plunged from 1200 to 600. Moreover, Malaysian construction, manufacturing and agricultural sector shrunk by 23.5%, 9% and 5.9% respectively. Malaysian stock market was not excluded from the crisis, whereas it brought a huge impact to the investors (Omar & Halim, 2015). The assurance of investors will be affected due to the high price swings of stock market in Malaysia. When price swings increased, it will definitely result in high volatility and thus, the higher the chance the investors exposed to the risk or lose their money invested (Patey & Kanaryan, 2003).

Furthermore, SMC in year 2008 that arose from U.S. was one of the worst financial crises that brought a huge impact to the financial and equity markets (Kang et al., 2014; Okubu et al., 2014). SMC arose due to the excessive sales of mortgage loan as to cater the demand of Mortgage-Backed Securities (MBSs) in the secondary market (Amadeo, 2019). MBSs are a pool of home mortgages that sold to individuals (Kenny, 2020). Investors were willing to invest most of their money into the MBSs at that period as they benefited the investors with a higher rate of return and even being named as the safe bet investment by the credit rating agencies. In order to fulfil the market demand, the lenders loosened their requirements and provided the loans to the low credit and low-income group of people. The MBSs investment became unsafe as the default risk increased. Consequently, the housing bubbles took place due to the speedy increase of the housing prices. When the prices of home incredibly increased, the individual failed to neither refinance the loan nor sell their homes. Hence, supply boosted while demand decreased dramatically and thereby collapsed the home prices and the economy (Amadeo, 2019). Besides, SMC was not only impacted U.S., but also spilt over the effect throughout the world including Asian countries such as Malaysia, Singapore and Indonesia. Consequently, stock prices decreased badly and thereby drove the economy into recession during the period (Kang et al., 2014). It indicated that stock market fluctuated in the high uncertain period (Chakrabarti & Roll, 2002; Huyghebaert & Wang, 2010; Morana & Beltratti, 2008; Tuluca & Zwick, 2001; Yang et al., 2010).

Moreover, global economy has been facing slow growth since the SMC in year 2008 to year 2009 (Kenton, 2019; Kenny, 2019). Whereas, in year 2011 to year 2012, European Sovereign Debt Crisis (ESDC) arose with several reasons that some of the European countries failed to refinance the government debt, intensively increased the bond yield spreads in the government securities as well as the slump in financial institutions. Besides, the ESDC had been documented as public sector crisis compared to the SMC which classified as private sector crisis. It was a fiscal crisis due to government's excessive borrowing and unrestricted taking on level of debts (Lee et al., 2013). Malaysia was not exempted in this crisis (Bank Negara Malaysia, 2011). Malaysia was noticeably impacted in two major channels which were trade channel and financial channel as European was claimed to be the vital Asian exports market and growth for years (Lee et al., 2013). Malaysia's main exported goods to European consist of E&E manufactures, semiconductors, computers and their parts, rubber gloves and chemical products (Bank Negara Malaysia, 2011). During the crisis, Malaysia's direct exports declined from 13.7% in year 2000 to 10.4% in year 2011. On the other hand, in financial channel, the crisis brought uncertainty and volatility in the worldwide financial market.

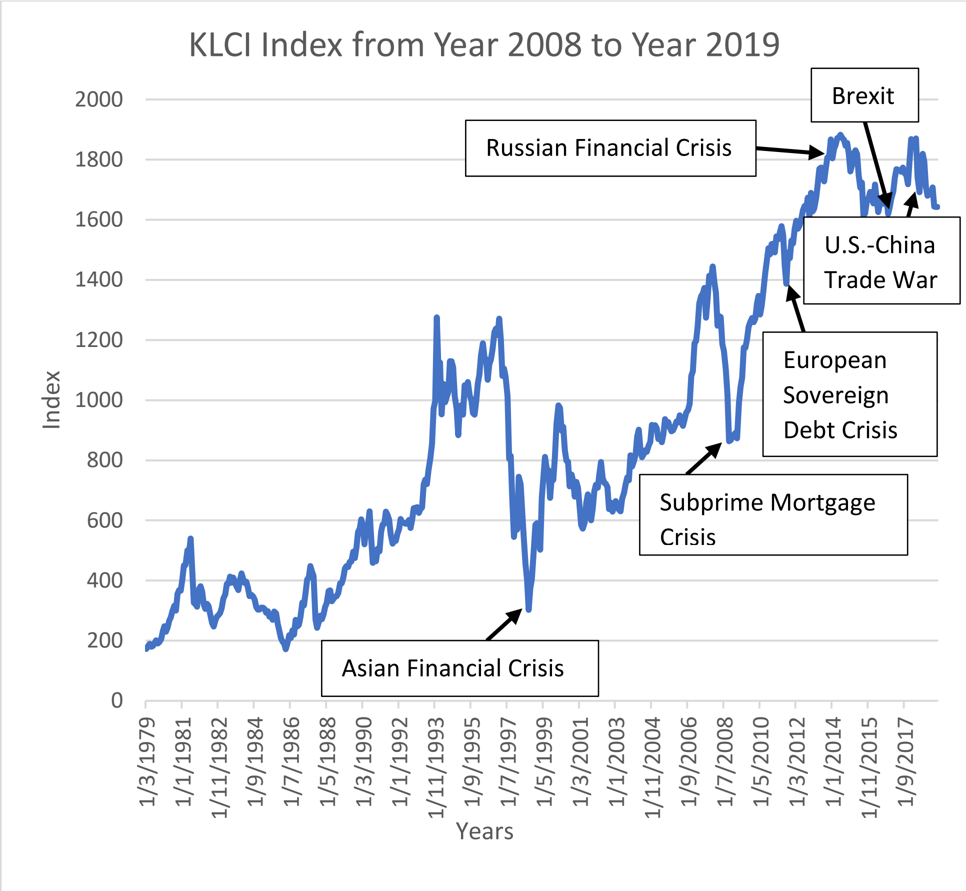
Furthermore, Russian Financial Crisis (RFC) hit Malaysian stock market indirectly. In year 2014, the depletion of crude oil prices reduced Russian currency value as well as the currencies of those countries which closely related to crude oil business (Rogov, 2014). Malaysia also involved in this crisis as Malaysia is a crude oil manufacturing country and major exporter of crude oil (Palm Oil Health, 2018). Narayan and Narayan (2010) showed that crude oil prices have a positive association with the stock prices. It means that a surge in crude oil prices will increase the stock prices. Besides, RFC took place due to two notable causes which were depletion of crude oil prices and economic sanction. Russia ranked as one of the major crude oil exporters as crude oil occupied 70% of its exports. In a simple word, Russia is entirely dependent on crude oil. During the crisis, crude oil prices depleted from roughly $100 per barrel to $30 per barrel and thereby dramatically knocked-off the revenue of the country. Consequently, the two main causes of crisis impacted Russian economy badly. Its GDP slumped sharply from year to year in which the GDP growth was 1.06% in 2013, -1.07% in 2014 and -309% in 2015 (Admiral Markets, 2020).

Apart from that, Brexit or “British exit” is another crisis that impacted the economy and financial market (Amadeo, 2020). Brexit happened in year 2016 when UK left the European Union (EU). Consequently, the growth of UK slumped from 2.4% in year 2015 to 1.5% in year 2018 and it was estimated that the crisis will plunge the growth of UK about 6.7% over the 15 years. Besides, UK no longer benefited from the tariff-free trade due to the crisis (Amadeo, 2020). It directly boosted up the prices of imports as most of the goods were imported from EU. Consequently, it raised up the inflation rate and lowered the standard of living due to the increment of the price level of goods. On the other hand, Brexit brought a huge and significant bang towards the financial market. After the crisis, the dollar grew due to the fall of Euro of 2% and Pounds of 8%. However, there was negative effect as well in which the American stocks became more expensive especially for foreign investors. Meanwhile, Malaysian stock market and Malaysian ringgit will be impacted (Khoo, 2016; Ng, 2016). KLCI slumped about 22.66 points on the day of vote while the Malaysian Ringgit dropped noticeably against U.S. dollar.

In the recent year of 2018, U.S.-China Trade War which is due to the supply chain factor, brought a huge impact and spilt over the effect globally and Malaysia is not exempted. Initially, U.S president introduced 10% to 20% tariffs against China’s high-tech products which worth $500 billion in total (the amount that U.S. imported goods from China) due to the reasons of unfair trading actions as well as the trade deficit with China. However, China took the same action as revenge. China imposed tariffs for American agriculture products such as soybeans and cotton (Berstein, 2020; Adilla, 2019). Consequently, it brought the impact to other counties especially for those traded between China and U.S. were impacted heavily (Shamsudin, 2018). Ariff (2019) claimed that Malaysia's exports were affected significantly in terms of the electronic industry and crude oil. Besides, Malaysia is one of the important trade partners of China and U.S., hence any shocks or policies implemented will definitely affect the trading position of Malaysia. However, Shamsudin (2018) and Lim and Tan (2020) documented that Malaysia will be benefited in this trade war in agriculture exports as China will switch from buying soybeans to palm oil due to the new tariff on soybeans that imposed by the U.S president. A boost in the demand of palm oil will contribute a significant rise on crude oil prices. The swing in crude oil prices will be increased and thereby affected the performance of the stock market. While in the long run, the negative impact will be documented significantly in terms of gross domestic product, economic growth, manufacturing and trading.

It has been found out that the election effect also drove the volatility of the stock market performances (Liew & Rowland, 2016). The expectation of investors will alter the stock market performance. Investors tend to invest more if the election effect was within their expectation or they glad about the policy and future of the economy (Chia, 2018; Tan et al., 2014). For example, in the pre-election of GE14, KLCI increased to 2.8% but dropped roughly 6.9% after the election conducted (Toh, 2018).

Figure 1.2 KLCI from Year 2008 to Year 2019




Source: Bloomberg

Figure 1.2 shows the volatility of KLCI over the time. It obviously shows that KLCI plunged dramatically during the AFC, in the year 1997 until 1998. Fortunately, it had been recovered after the crisis. In year 2007 and 2008, KLCI encountered a huge decline due to SMC. Apart from that, the ESDC in year 2011, RFC in year 2014, Brexit in year 2016 and U.S.-China Trade War in year 2018 brought the impact towards the global financial market. This drove the Malaysia KLCI volatile as well.

Crude oil and gold also brought a vital impact towards the Malaysian economy and thereby impacted the KLCI. Raza et al. (2016) documented that oil market volatility, gold market volatility and Malaysian stock market interlinked negatively. If the country heavily depended on crude oil, a crucial spillover effect towards the stock market will be captured

(Maghyereh et al., 2017). Crude oil acted as the input of production, hence it will change the fluctuation of the stock price (Barunik et al., 2015; Ingalhalli et al., 2016). The causality between the crude oil prices and stock prices in long term and short term has been examined. The results showed that stock market responded positively to the crude oil prices shock (Le & Chang, 2015). Apart from that, gold performed as safety asset in the portfolio in order to diminish the risk associated (Kok, 2019).

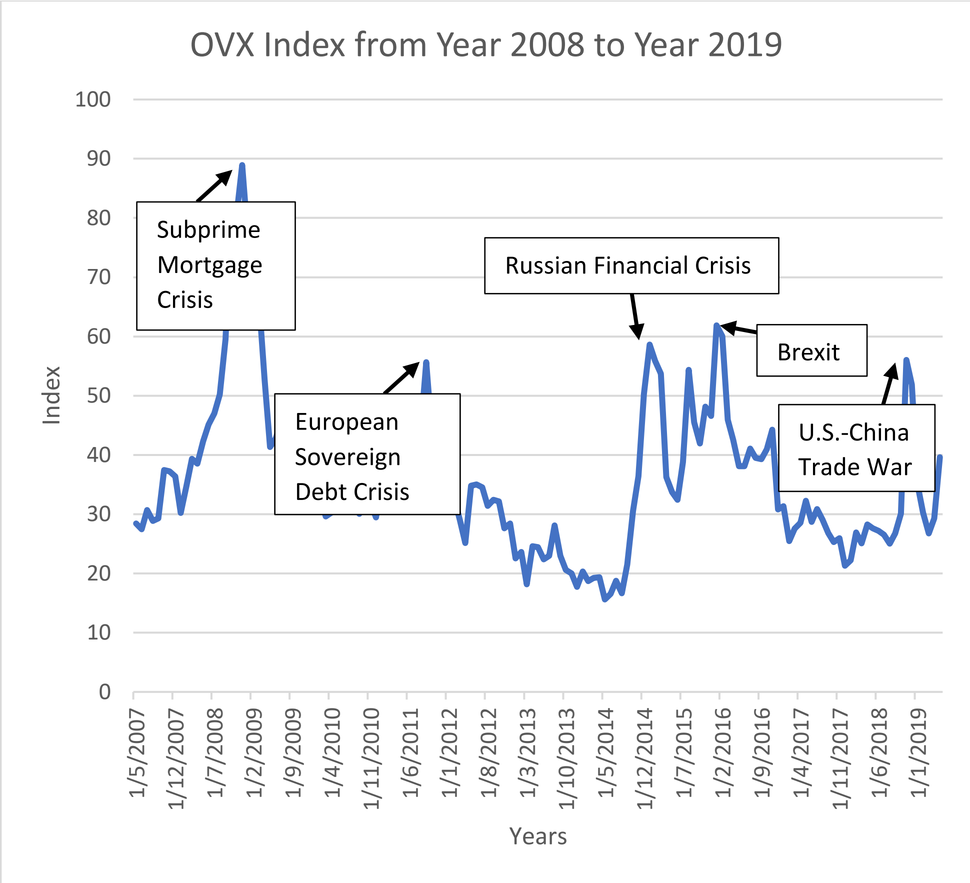
### 1.1.2 Background of Crude Oil Market

Crude oil is classified as one of the crucial commodities in the global (Basta & Molnar, 2018). It has been widely used by traders in their portfolio as an attempt to reduce the market risks and uncertainty associated. Crude oil is vital to Malaysia's business and it is one of the top export commodities (Workman, 2019). It impacted the country's GDP about 20% to 30% (International Trade Administration, 2018). Therefore, a remarkable impact will be brought to economy and Malaysian financial market if there is any variations in crude oil prices (Hamilton, 1983; Chen et al., 1986; Huang et al., 1996; Jones & Kaul,1996; Hammoudeh et al., 2004; Kilian, 2008; Kilian & Park, 2009; Aloui & Jammazi, 2009; Scholtens & Yurtsever, 2012; Wen et al. 2012; Yaya et al., 2016; Ji et al., 2018; Gong & Lin, 2018a; Gong & Lin, 2018b). In addition, crude oil market plays a vital role for Malaysia as Malaysia is a crude oil manufacturing country and major exporter of crude oil (Palm Oil Health, 2018). Palm oil plantation area had been boosted up dramatically from 55,000 ha in year 1960 until 5.849 million ha in 2018. It has also been claimed that oil palm contributed 4.67% to Malaysian GDP and 46.6% to agricultural GDP (Shamsudin, 2019; Shevade & Loboda, 2019).

Crude oil is ranked as the worldwide dominant asset as compared to gold as it has been widely used in daily life (Phoong, 2015). Crude oil market has been recognized as the energy source, hence it tended to impact the economy impressively (Ural, 2016). In addition, crude oil prices are able to affect the economy level across the countries (Bhar & Hammoudeh, 2011). It interconnected positively with the stock market and the swing in crude oil prices will bring a huge effect towards emerging and developing economies rather than developed economies (Hamilton, 1983; Hamilton & Lin, 1996; Chaudhuri & Daniel, 1998; Uwubanmwen & Omorokunwa, 2015; Taskin et al., 2016).

Crude Oil Volatility Index (OVX) introduced by Chicago Board Option Exchange (CBOE) as a global benchmark. It can be used as the risk indicator of the market (Chen & Zou, 2015). It captured and traced the prospective 30-day volatility crude oil prices in future. It was acquired by annualizing the interpolated value, taking the square root and showed in the percentage point form. Besides, OVX has been popularly used on the U.S. Oil Fund via the real-time bid/ask quotes with the expiration of at least 8-days (Chen et al., 2015).

Figure 1.3 OVX from Year 2008 to Year 2019




Source: Bloomberg

Figure 1.3 shows the monthly data of OVX from year 2007 to year 2019. It illustrates the fluctuation of OVX and the issues arose influencing its movement. It shows that SMC caused OVX to fluctuate greater during the crisis period. It boosted up the demand of crude oil and hence, drove the crude oil prices up. There was same outcome with the crises such as ESDC in year 2011, RFC in year 2014, Brexit in year 2016 and U.S.- China Trade War in year 2018.

Volatility of crude oil prices is prominent to every single country as it has been claimed as a key driver in affecting the economy (Plante, 2015). The fluctuation in crude oil prices negatively influenced the investment spending when the unchangeable investment decision taken into account (Bernanke, 1983). Besides, the economic activity tended to be negatively influenced by crude oil prices shock (Ferderer, 1996; Guo & Kliesen, 2005; Elder & Serletis, 2010; Jo, 2012).

Moreover, crude oil acts as a key driver in global economic development and considered as one of the most common energy sources (Alqattan & Alhayky, 2016). Due to the different determinants that will affect the crude oil prices, its volatility is difficult to be estimated. Therefore, the stabilization of crude oil prices was more significant than the prices of itself (Ulusoy & Ozdurak, 2018). As crude oil is a significant economic resource in developing the economy growth of a country, it attracted many foreign direct investments with transfer of technology, evolution of infrastructure and related foreign exchange earnings. Inflationary pressures will be captured due to the increment of crude oil prices. The costs of services as well as the productions will increase as the crude oil prices rise. Moreover, central bank will reinforce the monetary policy and improve the interest rate to deal with the inflation that is caused by the increment in crude oil prices. It will indirectly affect the company to have higher borrowing cost that made the company has the difficultly to raise new funds due to high interest rate (Gomes & Chaibi, 2014). Besides, it has documented that the lower fiscal deficit will be resulted from the depletion of crude oil prices.

However, prices of crude oil can be impacted by the imbalance of supply and demand. Supply and demand of crude oil is the main factor in altering the prices of barrel of crude oil. Crude oil producers were able to benefit from high crude oil prices if the supply was approximately equal to the demand (DiLallo, 2018). For example, in year 2016, crude oil prices fell below $30 per barrel due to the issue of the imbalance of demand and supply of crude oil.

Organization of Petroleum Exporting Countries (OPEC) is one of the factors that influenced the crude oil price movements. OPEC is an intergovernmental organization which comprises of 14 crude oil producing countries. It organizes the oil policies implemented for the purpose of maintaining stability of crude oil prices from moving volatile for its members. OPEC tends to influence the market oil prices instead of control them directly. OPEC acts as a role to intervene the crude oil production of the countries by using production quota (DiLallo, 2018). For instance, in 30 November 2016, OPEC influenced crude oil prices by reducing its countries' crude oil production. In doing so, it succeeded to resolve the oversupply of crude oil in the market and thereby surged the prices of crude oil (Forrester et al., 2017). OPEC is only effective in influencing the prices of crude oil in short term as the power is limited in long term (DiLallo, 2016).

### 1.1.3 Background of Gold Market

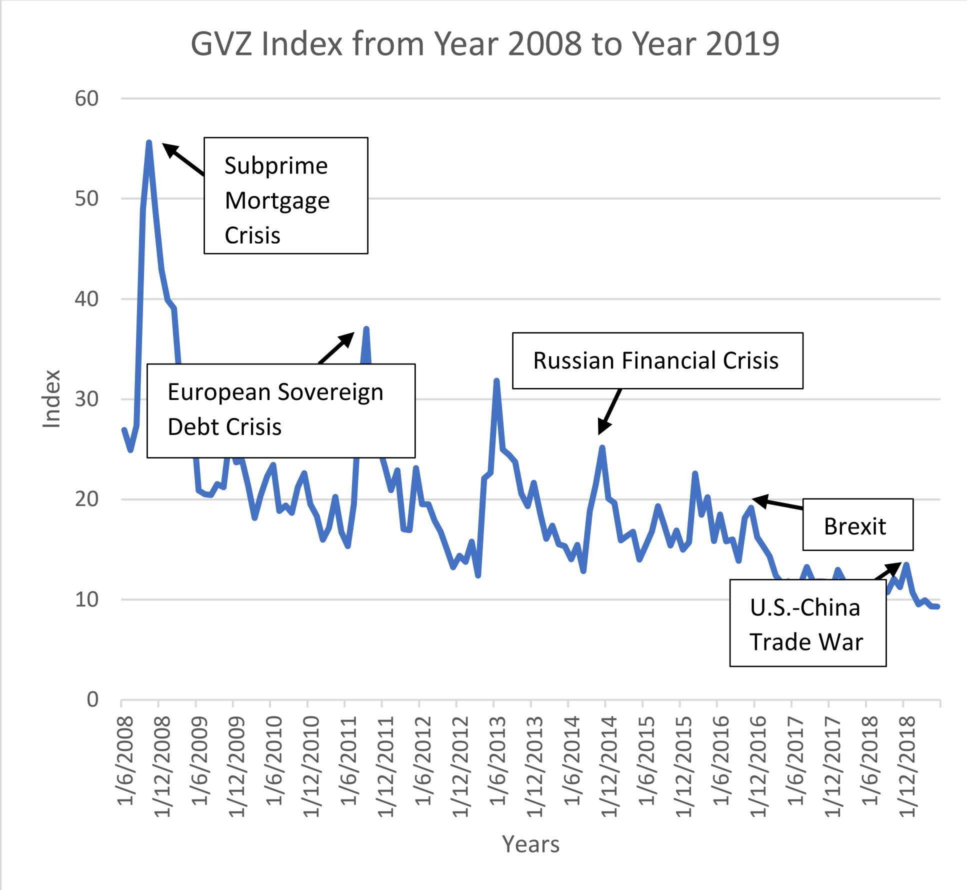
Gold can be classified as a strategic resource that is mostly used in the national security as well as the activities of nation's economy (Bouri et al., 2017). This is because gold is viewed as the most precious metal which plays the role as a safe investment tool for public based on the traditional belief (Balcilar et al., 2017). Gold is known as the portfolio diversifier as it is one of the best alternatives in reducing the risk in the portfolio because of its low interconnection of price returns with other assets (Kok, 2019). Besides, the commodities including the gold are emerging to become part of the asset portfolio allocations (Jain & Biswal, 2016). Dill Choo Chooi Lin, the UOB Malaysia head of private bank indicated that gold was well-known in the investment. It was also named as "safe-haven" asset especially during uncertainty. Holding the gold roughly about 2% to 10% of the portfolio's value will definitely assist in balancing and diversifying the portfolio investment and even boosting the performance as recommended by World Gold Council (WGC) (Kok, 2019). In addition, Singapore-based analyst also suggested Malaysian to acquire some of the funds in gold market since the ringgit of Malaysia keeps depreciating and weakening (Kok, 2019).

Inflation and some volatile assets can be hedged by the gold, which has been widely used by the investors as a hedger (Balcilar et al., 2017). If the inflation rate in a nation was high, the investors in that nation will involve in gold market to diversify the uncertainty associated with the high inflation due to low fluctuation of gold prices (Pandey & Vipul, 2018). However, if the investors kept investing in gold, gold prices will increase significantly. The gold prices will tend to fluctuate greater, thereby affecting stock market performance. In addition, gold is also essential for the oil-exporting countries as they hold the gold reserves to hedge against the fluctuations in U.S. Dollars (Maghyereh et al., 2017). It will actually affect the income of a nation, thus affecting the economy and stock market of the nation.

Significance of the usage of gold especially in the portfolio has highlighted that gold aimed to intensify the overall rate of return of the investments, portfolio diversification and provide flexibility for the portfolio manager to hedge the risk associated (Kumar, 2014; Sherman, 1982). Involving gold into the investment will definitely help to diminish political risk, inflation and currency risk (Ghosh et al., 2000). For example, a study determined that gold helped to diversify the exchange rate risk of sterling-dollar and yen-dollar. Gold assisted in providing hedging ability during the crisis and crashes (Capie et al., 2005).

Gold volatility index (GVZ) introduced by CBOE, captured and traced the prospective 30-day future gold prices volatility which can be used as the risk indicator of the market (CBOE, 2020).

Figure 1.4 GVZ from Year 2008 to Year 2019



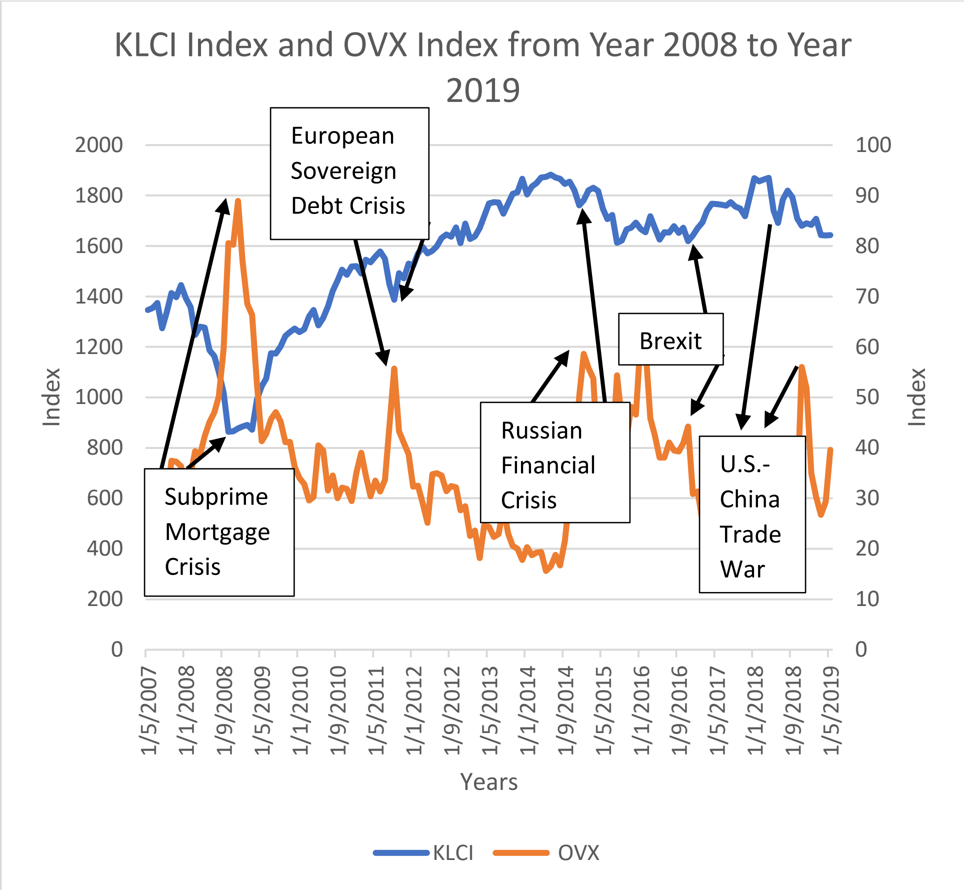

Source: Bloomberg

Figure 1.4 marks the sign of GVZ. In year 2008 which the SMC occurred, it boosted up the demand of gold and increased the gold prices and gold price volatility. However, in the following years, investors switched back to the stock market rather than investing in gold market as the stock market began to perform well. This resulted in lower demand of gold, hence the gold prices and gold price volatility decreased. This indicated that gold was widely used as the safe haven especially during the crisis and economy downturn (Joshi, 2012). Besides, the volatility of gold prices rose due to ESDC in year 2011, RFC in year 2014, Brexit in year 2016 and U.S.- China Trade War in year 2018. The demand and prices of gold during the crisis had been increased as gold acted as one of the best investment tools to hedge against the risk especially during the crisis (Kok, 2019).

### 1.1.4 Relationship between Crude Oil Market, Gold Market and Stock Market

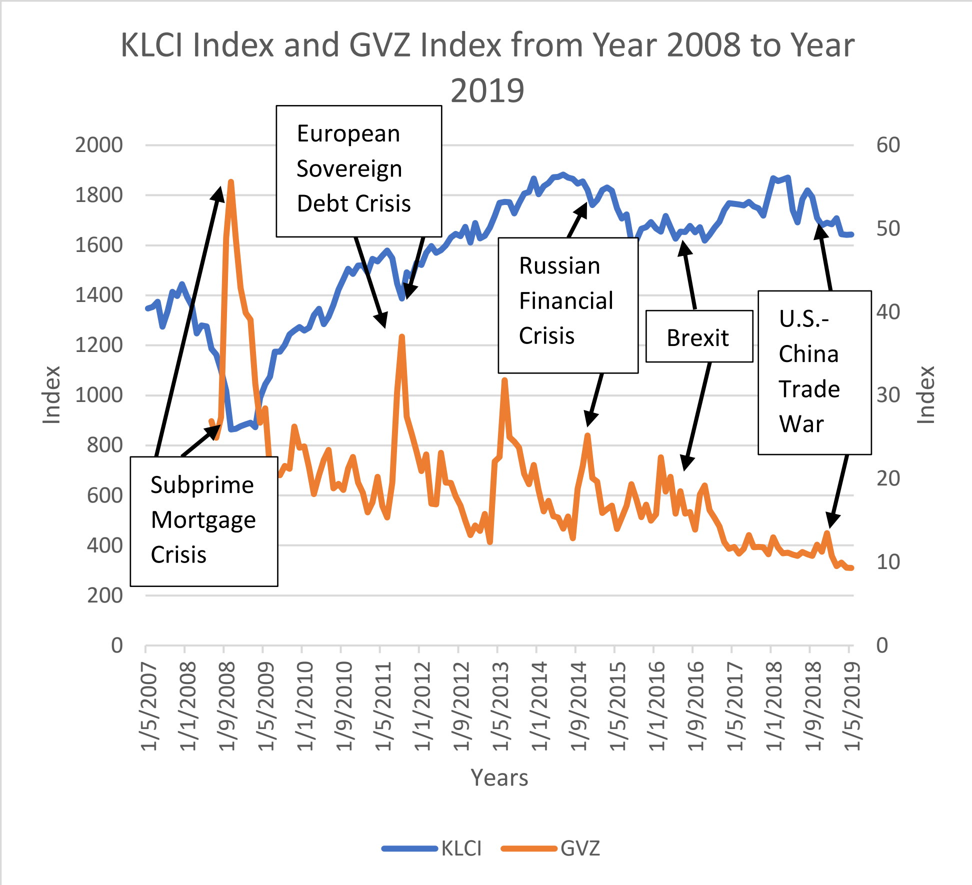
Fluctuations in crude oil market and gold market will bring challenge to the participants who move heaven and earth in forecasting the prices of crude oil and gold (Bouri et al., 2017). Besides, fluctuation in crude oil prices will bring a crucial impact to input production cost as well as the inflation rate and trade balance (Hamilton, 1996; Pandey & Vipul, 2018). Due to the swing in prices of crude oil, gold market will be used as the tool to combat the inflation rate and even being used by the central banks as one of their safe investments (Pandey & Vipul, 2018). Moreover, it has been claimed that crude oil prices and inflation are interconnected while gold can be served as an useful mechanism to minimize the inflation. Hence, the crude oil market and gold market are interrelated.

Figure 1.5 KLCI and OVX from Year 2008 to Year 2019




Source: Bloomberg

Figure 1.6 KLCI and GVZ from Year 2008 to Year 2019




Source: Bloomberg

Figure 1.5 and Figure 1.6 show the consequences of ESDC, SMC, RFC, Brexit and U.S.-China Trade War spilt over to the economy, crude oil market, gold market and Malaysian stock market. Based on the graphs above, two highly liquid commodities succeeded to attract the interest of investors to choose as the alternatives for their portfolio during the economic downturns or financial crises (Tiwari & Sahadudheen, 2015). However, some of the studies proved that gold market was preferable due to its role as a safe haven (Narayan & Sharma, 2011; Arouri et al., 2011).

The stock market in developing country was highly exposed to bad news and issues happened on commodity, gold and crude oil markets (Ebrahim et al., 2014; Arouri et al., 2011; Chang et al., 2010; Hammoudeh & Yuan, 2008; Lin et al., 2014; Sadorsky, 2014). The changes in stock market connected closely with the gold when the economy not performing well (Adjasi & Biekpe, 2006; Hood & Malik, 2013; Joshi, 2012). The inverse correlation between stock market and gold prices had been proven by the authors. Besides, crude oil prices could provide assistance in predicting the stock prices movement. When crude oil prices rose, the input cost will grow and thereby the economy activities will decline (Nandha & Faff, 2008). The increment in crude oil prices will reduce the profits and dividends paid to shareholders. Consequently, stock prices will plunge and stock market index will decrease owing to the surge in crude oil prices (Nandha & Hammoudeh, 2007; Park & Ratti, 2008).

## 1.2 Research Problem

Since last two decades, the mutual association between stock market and crude oil market has been identified. Crude oil is heavily depended by nearly every production sector in the international economy as an energy source (Chang et al., 2010). In recent years, prices of crude oil fluctuated globally. The variations of crude oil prices tended to drive the supply and demand sides of the Malaysian economy. On the demand side, the consumption and expenditure pattern of households will be influenced owing to the low-price elasticity of crude oil demand. Higher crude oil prices may cause the households to reduce their expenditure on other goods and services, which lower the demand for those goods and services as well. On the supply side, higher cost of production which results from the firms' productions will be reduced due to crude oil prices increase (Basnet & Upadhyaya, 2015). Therefore, the changes in economic, financial system and asset returns will be resulted from the unpredictability in the crude oil market (Xiao et al., 2018). In addition, due to the immature of financial policies and investors, Malaysia tended to be influenced heavily by the fluctuations of crude oil prices even though it is an oil-producing country (You et al., 2017). There are many researchers inspected the relation between variations of crude oil and variations of stock market, but asymmetric relationship between these markets has always been neglected.

Asymmetric relationship might cause the fluctuations of one market to spillover to another market's price index. It is crucial for individual to understand well the importance of the asymmetric or non-linear relationship between the variables. If there is an increase in oil market volatility, it will impact the stock market while a decrease in oil market volatility will not affect the stock market. For example, an increase in oil market volatility will significantly hit the disposable income, business cost and the consumer spending on energy (Maghyereh et al., 2016). Then, the performance of the company will be affected due to high costs, low sales and low profits. In contrary, a decrease in oil market volatility will not significantly bring the impact towards the disposable income, business cost and the consumer spending on energy. Therefore, the performance of the company will not be significantly influenced. Hence, this issue will be addressed by the research objectives.

Gold is one of the precious commodity investment tools that is traded around the world and it is vital to the financial market and international economy. When there is a severe distress, gold becomes valuable (Huang & Kilic, 2019). This trait is showed in the research of Akbar et al. (2019), the value of gold is similar to its previous trend during the international financial crisis. Whereas, it is expected that the upcoming replay of SMC of the year 2008 is in year 2020. Anxiety on the 2020 recession would trigger the financial market in chaos. Notably, a study in the aspect of gold is important as it may serve as a cushion for the investors to transfer their risk during the uncertainty period. Singhal et al. (2019) clarified that there is a linkage or transmission effect between the gold prices and stock prices. Majority of the studies ignored the non-linear relationship between the gold market and stock market (Choudhry et al., 2015). There may have a distinct effect of positive and negative shock of gold market volatility on the variation of stock prices. For example, since gold is acting as an investment tool to hedge against the stock market, individuals tend to invest in gold market during the period of high uncertainty in stock market and low uncertainty in gold market (Shahzad et al., 2017). Therefore, high or low volatility in gold market will influence the decision making of individuals. Furthermore, investors, researchers, and regulators have to pay more attention on volatility in order to evaluate the value of any asset as the volatility will influence the risk, return and value of an investment or asset (Horpestad et al., 2019). Hence, a research concerns on the asymmetric volatility in term of stock and gold is significant for a developing country like Malaysia.

## 1.3 Research Questions

i. Is there any spillover effect between oil market volatility and Malaysian stock market volatility?

ii. Is there any spillover effect between gold market volatility and Malaysian stock market volatility?

iii. Is there any asymmetric relationship between oil market volatility and Malaysian stock market volatility?

iv. Is there any asymmetric relationship between gold market volatility and Malaysian stock market volatility?

## 1.4 Research Objectives

i. To investigate the spillover effect between oil market volatility and Malaysian stock market volatility.

ii. To investigate the spillover effect between gold market volatility and Malaysian stock market volatility.

iii. To investigate the potential asymmetry relationship between oil market volatility and Malaysian stock market volatility.

iv. To investigate the potential asymmetry relationship between gold market volatility and Malaysian stock market volatility.

## 1.5 Research Hypothesis

$H_1$: There is no significant spillover effect between oil market volatility and Malaysian stock market volatility.

$H_2$: There is significant spillover effect between oil market volatility and Malaysian stock market volatility.

$H_3$: There is no significant spillover effect between gold market volatility and Malaysian stock market volatility.

$H_4$: There is significant spillover effect between gold market volatility and Malaysian stock market volatility.

$H_5$: There is no significant asymmetric relationship between oil market volatility and Malaysian stock market volatility.

$H_6$: There is significant asymmetric relationship between oil market volatility and Malaysian stock market volatility.

$H_7$: There is no significant asymmetric relationship between gold market volatility and Malaysian stock market volatility.

$H_8$: There is significant asymmetric relationship between gold market volatility and Malaysian stock market volatility.

## 1.6 Significance of Study

This research will bring benefit to existing and prospective investors of Malaysian stock market. By referring to this study, the investors can improve their risk management strategies that applied in the stock market for the purpose of maximizing their profits and minimizing the risks at the same time. They could be able to invest in the stock market at the best timing by taking considerations of crude oil prices volatility and gold prices volatility. From this research, they would have a clear idea about when to increase or decrease their investments in the stock market according to the price changes in crude oil market and gold market. Furthermore, the study could help the investors in making a suitable decision to cope with the uncertainty in the stock market which resulted from the uncertainty in crude oil market and gold market. They would have some ideas about when the stock market will become high uncertainty as this would aid them in managing their sentiments well and making appropriate decisions. Hence, the result of the study would give signals to investors about the performance of stock market in the later time by observing the volatility of crude oil prices and gold prices. This could help the investors to decide whether to draw out some capital from the stock market or increase investment capital in stock market.

Besides, fund managers will get benefits from this study as well. From this study, fund managers would be able to evaluate the uncertainty of the stock market in the later time by observing the volatility of the crude oil prices and gold prices. Therefore, fund managers would have enough time to manage or adjust their portfolio before the unfavourable stock market conditions affect the profits of the companies. This study could help the fund managers in managing diversified portfolio properly to minimize risk incurred by companies. In addition, the result of study could help the fund managers to determine whether the increase or decrease in volatility of crude oil prices and gold prices will influence the stock market performance. Hence, the fund managers are able to develop some investment strategies for their companies to deal with the stock market performance, either in favourable or unfavourable conditions.

Furthermore, this study is useful to the government policymakers. This is because they could observe the shocks of crude oil prices and gold prices against the Malaysian stock market. The changes in volatilities of crude oil prices and gold prices significantly affected Malaysian stock market. It also could be utilized as a measure to control the economy growth in the country. Therefore, government policymakers could maintain the stock market and strengthen the economy growth.

This research is also fruitful for researchers as they could further study about the relation between the volatility of crude oil market, gold market and stock market in Malaysia. Non-linear auto regressive distributed lag (NARDL) model is used in the research to examine whether there is asymmetric relationship between volatility of crude oil market, gold market and stock market in Malaysia. Therefore, this paper could serve as a channel for the researchers to strengthen their understanding on the spillover effect which could affect the market volatility.

## 1.7 Chapter Layout

This study consists of five chapters. Chapter 1 focuses on the overview of crude oil market, gold market and Malaysian stock market, research problem, research questions, research objectives, research hypotheses and significance of study. Chapter 2 highlights the theoretical framework of Prospect Theory that studied the investors' decision making under the uncertainty and literature review. In Chapter 3, data, variables, empirical model, diagnostic checking are provided while the results and the main findings will be discussed in Chapter 4. Chapter 5 will emphasize the implications of study, limitations and recommendations for the study.

## 1.8 Conclusion

In short, research background, research problem, research questions, research objectives, research hypothesis and significance of study are studied in this chapter. The elements that drove the volatility of the variables of our study, crude oil market, gold market and Malaysian stock market are provided as well. The main purpose of this study is to investigate the asymmetric volatility spillover effect between crude oil market, gold market and Malaysian stock market. Furthermore, the detailed elaboration and discussion on the relationship between the variables, results and findings will be analysed in following chapters.

# CHAPTER 2: LITERATURE REVIEW

## 2.0 Introduction

This chapter will discuss the theoretical framework that studies the human behaviour towards the risk that they face in the crude oil market, gold market and stock market. Particularly, this framework might affect their investment decision that might cause fluctuation in these markets in different magnitude. In addition, the review of the past research is vital in this chapter as it provides a clearer understanding of the relationship between these aforementioned markets. The relationship will be presented in linear and non-linear accordingly.

## 2.1 Proposed Theoretical Framework

### 2.1.1 Prospect Theory

Prospect theory, also known as loss-aversion theory, was implemented by psychologists Amos Tversky and Daniel Kahneman in the year 1979 in Econometrica (Tversky & Kahneman, 1981; Prosad et al., 2015; McDermott, 2020). It described the investors' decision making under the uncertainty (Mutuku, 2012). Contrary to the expected utility theory, prospect theory was more accurate and was considered as the backbone of the theory of behavioural finance. The moment that the investors thought about the potential losses from investment will transcend the feeling of thinking about the gains (Schindler & Pfattheicher, 2016; McGraw et al., 2010). The enjoyment of reaping the rewards will be far being replaced by the pain of losing, thereby brought a huge emotional impact to the individual. Hence, individual will tend to be more concerned and pay more attention while encountering losses and avoiding them compared to the gains (Tversky & Kahneman, 1981). For instance, penalty frame implemented will be effective in dragging the attention of individual instead of rewards given (Gachter et al., 2009). People will be more enlightened about the penalty given and ways to avoid it instead of the rewards reaped.

Besides, prospect theory consisted two phases which are editing phase or framing effect and evaluation phase (Tversky & Kahneman, 1981). The first phase of the prospect theory which is editing phase or framing effect helped in identifying and analysing every single possible outcome, value and possibilities of the options. It has also been stated by Mutuku (2012) that framing effect aimed to describe the measures that the options introduced to the decision maker. It was preferable if the information was presented in a positive way instead of being described negatively. Individual will avoid risk if positive frame being presented and seek for the risks if the negative frame being described. Individual will make different options depending on how the order of the options being introduced. The purpose of the editing was to clarify the choices evaluation. Besides, it has been specified by Kahneman and Tversky (1979) that editing phase or framing effect comprised some mechanisms that reshape the outcomes and probabilities of the prospect, which including coding, combination, segregation and cancellation. These editing implications were vital as they will influence the decision significantly.

The latter aimed to evaluate the edited prospects and select the outperformed prospect among the options via value function and weighting function. Value function mentioned that individuals tended to be risk seeking in the situation of losses and risk averse in the condition of gains in which they were willing to take risks in an attempt to regain from the previous losses (McDermott, 2020; Mutuku, 2012). It can be concluded that losses hurt more than the gains. Hence, individuals were afraid of losses and tended to pay more attention while they were encountering losses as to retrogress to the previous stage. In weighting function, it has been emphasised by McDermott et al. (2008) that individuals will normally overweigh and pay more attention on small probability incidents and under weigh the high probability incidents that they actually deserved. However, the events that were perceived to be unlikely to happen tended to bring a huge impact to the outcome. For example, individuals were still willing to take the risk to buy lottery although they understood that they were not guaranteed to benefit from it. They were considered as risk seeking in gain, even though the probability of gain is low.

In short, based on the prospect theory discussed above, individuals will concern more on losses rather than gains as the losses will bring a huge impact to them. They tended to under weigh high probability events and overweigh low probability events. It has been mentioned by Kahneman and Tversky (1979) that individuals tended to evaluate the losses as twice as powerful to the same size of the gains when money was taken into consideration. Taking investment into account, Barberis et al. (2006), Gomes (2005), Mutuku (2012), Berkelaar et al. (2004), Ang et al. (2005) and Polkovnichenko (2005) mentioned that if the individuals are loss-averse, they will either escape from involving in equity market or invest less of their wealth into it. The pain will outweigh the joy of benefiting from it if their investments in the stock market were volatile or had decreased in value. Although individuals understood the risk associated with their investments in which they may lose all of their money invested, they are still willing to get themselves involved in it as they believe that there is a possibility for them to reap the rewards even the probability is small. The low probability event has been outweighed. Moreover, individuals will tend to be risk seeking when they are encountering the risk as to recover or regain to the previous stage. The greater the volatility, the higher the risk of the investment which the investment will provide huge gain or huge loss to individual. Hence, they will keep an eye out on the stock market to avoid suffering from the inevitable risk.

## 2.2 Oil Market and Stock Market

### 2.2.1 Linear Relationship between Oil Market and Stock Market

The linear relationship between oil market and stock market is one of the popular research topics that has been carried out by lots of researchers since few decades ago. In the paper of Narayan and Narayan (2010), they scrutinized the linear association between crude oil prices and Vietnam's stock prices by utilizing daily data ranging from 28 July 2000 to 16 June 2008. Cointegration tests were employed to examine whether there is association between the variables. The main finding of the paper showed that prices of crude oil cointegrated with stock prices. In other words, prices of crude oil are positively and statistically significant towards the stock prices. As mentioned by the authors, the relationship existed due to the contribution of some factors towards the stock market in Vietnam when the Vietnamese stock market was booming while crude oil prices were rising rapidly. The factors included the rise in foreign portfolio investments inflows and the change of preferences of local investors from domestic bank deposits and foreign currencies to stocks (Narayan & Narayan, 2010).

Besides, Sahu et al. (2014) studied the association between crude oil prices and Indian stock market by applying Johansen's cointegration test. Daily data ranging from January 2001 until March 2013 is utilized in the study. The outcome revealed that there is existence of positive relationship between prices of crude oil and Indian stock market index. The positive movement of Indian stock market indicated that the companies were having optimistic performance because of the increase in consumption and manufacturing of goods and services. The crude oil prices increased because of the demand of crude oil increased which resulted from the increase in production of goods and service. In addition, although the international crude oil prices increased in the study period, the production cost and earnings performance of the companies would not be significantly influenced due to oil price subsidies would be given by Indian government which preventing a dramatical rise in production costs of companies. It could lead the companies in Indian stock market to perform better. Moreover, the remarkable improvement in the income generation rate was completed by Indian government during the study period, and it led to economic development of the country. Therefore, overall consumption trend would not be significantly affected by the higher inflation and rise of interest rate, and it also led to an upsurge in Indian stock market index (Sahu et al., 2014).

In addition, Alqattan and Alhayky (2016) conducted a study to examine the influence of crude oil prices on stock market indices of Gulf Cooperation Council (GCC) by utilizing the monthly data from November 2006 to February 2015. ARDL model is applied in the study. The result showed that prices of crude oil positively and significantly affected the stock market indices in short run model while there is no correlation between prices of crude oil and the stock market in the long run model. It means that the short run stock market indices were sensitive to fluctuation in crude oil prices in GCC countries. The authors stated that oil is still acting as a prominent role in developing the global economic and considered as one of the most common energy sources, thus the prices of crude oil could impact the prices of stock market in GCC countries in the short run (Alqattan & Alhayky, 2016).

Moreover, Maghyereh et al. (2016) examined the after global financial crisis correlation between the oil prices fluctuation and stock prices fluctuation in eleven stock market exchanges by utilizing the daily data from the period of 3 March 2008 to 3 February 2015. A directional connectedness econometric technique that introduced by Diebold and Yilmaz was employed to study the transmission between oil prices fluctuation and stock prices fluctuation. The result of the study indicated that positive shock of oil prices fluctuation had a positive impact on volatility of stock market. It signified that stock prices fluctuation would increase as oil prices fluctuation increased. This is because a greater uncertainty in prices of crude oil would exert greater uncertainties in spending of consumer on energy, disposable income and production cost, which leading the stock market to swing greater. Hence, high fluctuation in oil market would lead to a higher volatility of stock market (Maghyereh et al., 2016).

Moreover, Khai et al. (2017) carried out a study to inspect the impact of crude oil market on Vietnamese stock market. The time period that being used by previous researchers was from March 2006 until June 2015. ARDL model was used in the research. The outcome showed that there was long-term relationship between crude oil prices and Vietnamese stock market index. The prices of crude oil negatively impacted the Vietnamese stock market index. However, when it comes to short term, the result exhibited that crude oil prices positively affected the Vietnamese stock market index. According to the research, there was large fluctuations during the economic crisis in 2008. During the crisis period, it affected the short term relationship between the world crude oil prices, VN-index and HNX-index. Changes in the crude oil prices positively impacted the VN-index and HNX-index. It could also be said that the economic crisis sped up the impact of crude oil prices on the stock market. The prices of crude oil could determine whether the economy of a country in good or bad condition in the short run. The world economy was signified as well-developed if the crude oil prices rose in short term, which would lead to the stock market to perform better, and vice versa. Hence, there was significant positive short term impact of crude oil prices on Vietnamese stock market (Khai et al., 2017).

Furthermore, Dutta (2018) conducted a research to examine the relationship between OVX, the implied volatility index of U.S. stock market (VIX) and implied volatility index of U.S. energy sector stocks (VXXLE). The researcher employed ARDL bounds tests with weekly data from 16 March 2011 to 30 June 2017 to inspect whether association between OVX, VIX and VXXLE existed. The result showed OVX and VIX were not interrelated with each other. In addition, OVX had positive impact on VXXLE in the long run, which indicated volatility of U.S. energy sector stocks tended to fluctuate greater as volatility in crude oil market was higher. This is because the performance of U.S. energy sectors company was depending on the crude oil prices. If there was high uncertainty in crude oil market, the performance of the companies would be adversely influenced. Besides, volatility in crude oil market could give some signals about the future economic condition, thus the volatility of stock market in U.S. could be influenced by high volatility in crude oil market (Dutta, 2018).

Furthermore, Elian and Kisswani (2018) had also examined the relationship between crude oil prices and Kuwait stock market returns by utilizing daily data from the period of 3 January 2000 to 9 December 2015. ARDL bounds test and dynamic ordinary least square (DOLS) were applied in the research to examine whether there was presence of long run relationship among the variables. The result of the study indicated that the prices of crude oil negatively influenced the Kuwait stock market returns. It means that the stock market returns would decrease when crude oil prices increased. This condition happened due to the escalation in oil prices that increased the cost of production. This would also burden the corporations in producing the goods and services, which then increasing in the price of goods and services. Consequently, this would trigger a higher level of inflation rate and consumers would demand less goods and services, corporations would eventually earn less profit which resulting in a lower stock market return. Besides, the authors asserted that an upsurge in the inflation rate would cause the market interest rate to increase, and this signalled a higher level of cost of capital which would then lower down the stock market returns (Elian & Kisswani, 2018).

Another research by Anyalechi et al. (2019) sought to explore the effect of fluctuation in crude oil prices, interest rate, inflation and exchange rate on stock market returns in Nigeria by utilizing monthly data from January 1994 until December 2016. ARDL bounds test is adopted to examine the short run and long run cointegration relationship between the variables. The result indicated that there is insignificant association between the crude oil prices and stock market returns in Nigeria in both long term and short term (Anyalechi et al., 2019).

### 2.2.2 Non-Linear Relationship between Oil Market and Stock Market

Mohanty et al. (2011) investigated the asymmetric relationship between crude oil prices and stock market returns of six Gulf Cooperation Council (GCC) countries by utilizing weekly data from June 2005 to December 2009. The GCC countries in the study included Bahrain, Kuwait, Qatar, Oman, UAE and Saudi Arabia. The finding showed that the stock market returns of Bahrain, Kuwait and Qatar tended to react more to negative shock in crude oil prices instead of positive shock in crude oil prices, thus crude oil prices had significant asymmetric effect on stock market returns in these countries. The authors found that a decline in the prices of crude oil would give a negative influence to corporate profits and cash flows as well as consumer demand in oil exporting countries, thus it eventually would cause the stock market returns to decrease. However, the stock market returns of Oman, UAE and Saudi Arabia tended to react to both positive shock and negative shock in crude oil prices, thus the crude oil prices did not have any asymmetric effect on stock market returns in these three countries (Mohanty et al., 2011).

Apart from that, the research of Muhtaseb and Al-Assaf (2017) studied the asymmetric relationship between crude oil prices and stock market returns in Jordan. This research utilized quarterly data from the period of year 2000 to year 2015. Two threshold asymmetric cointegration tests of Enders Siklos (TAR and MTAR test) and asymmetric error correction model (ECM) were adopted in the paper to examine the presence of asymmetric relationship among the variables. The result concluded that there was an asymmetric pattern between the crude oil prices and Jordan stock market returns in long run. In particular, the positive shock of oil prices exerted a greater consequence than the negative shock of oil prices on stock market returns. This is because different country has different influence of oil prices shock on stock market returns and it is depended on whether the country is an oil-exporter or oil-importer. The authors claimed the fact that Jordan is a net importing country and an increase in the prices of crude oil plays a significant role on the behaviour of stock market returns (Muhtaseb & Al-Assaf, 2017). They also suggested the researchers to have a further contribution in explaining this asymmetric reaction between the variables.

In addition, Al-haji et al. (2018) conducted a research to study the asymmetric association between crude oil prices and Malaysian stock market returns by utilizing NARDL test with monthly data from January 1990 to November 2016. The authors investigated the asymmetric effect of crude oil prices on the aggregate stock market, consumer product sector, property sector, mining sector, technology sector, construction sector, industrial production sector, trading or services sector, plantation sector as well as finance sector. The outcome of the study indicated that the returns of construction sector, trading or services sector and plantation sector tended to react more to negative shock of crude oil prices instead of positive shock of crude oil prices while the returns of industrial production sector and finance sector tended to react more to positive shock of crude oil prices instead of negative shock of crude oil prices. Therefore, the crude oil prices had asymmetric effect on returns of these sectors in Malaysia. The authors stated that the negative shock in the prices of crude oil negatively affected the Malaysian stock market. This is because inflation will increase and economic growth will reduce due to the escalation in crude oil prices. Furthermore, the prices of goods that produced from petroleum will be affected due to the increase in prices of crude oil. Thus, the production costs of goods and services will increase as the crude oil prices increase. Eventually, the supply of the goods and services will decrease due to the higher costs of production. However, the asymmetric effect of crude oil prices on aggregate stock market returns, consumer product sector, property sector, mining sector and technology sector was absent in the study because these sectors tended to react to both positive shock and negative shock of crude oil prices (Al-haji et al., 2018).

Besides, the research of Mohanty et al. (2017) studied and examined the asymmetric relationship between the crude oil prices and stock market returns of sector level and country level in Saudi Arabia by utilizing data in weekly basis which ranging from 23 April 2007 until 27 January 2016. Step-wise regression approach was applied in the study. The result showed that the stock market returns of different sectors tended to react to both positive shock of crude oil prices and negative shock of crude oil prices, thus the asymmetric effect of crude oil prices on stock market returns of different sectors in Saudi Arabia did not exist. It indicated that an upsurge in crude oil prices would stimulate an upsurge in the stock market returns in Saudi Arabia, and vice versa. This is because the expenditure of the government in Saudi Arabia would increase if prices of crude oil rose, it eventually would stimulate the employment and the economic output in Saudi Arabia. Therefore, crude oil prices had positive symmetric relationship with the stock market returns of all sectors in Saudi Arabia instead of asymmetric relationship (Mohanty et al., 2017)

Obi et al. (2018) also explored the asymmetric effect of crude oil prices on volatility of stock market in Nigeria. The study was carried out by using NARDL approach with quarterly data from year 1986 to year 2016. The outcome of the study signified that the Nigerian stock market volatility tended to react to both positive shock and negative of crude oil prices, thus the asymmetric relationship between crude oil prices and stock market volatility did not exist in Nigeria. The authors stated that positive shock of crude oil prices would have significant positive impact on the fluctuation of stock prices in both long run and short run. In addition, negative shock of crude oil prices would also have significant negative impact on the fluctuation of stock prices in both long run and short run. This is because crude oil prices shock could negatively influence the corporations in terms of value of the firms, cash flows and production costs, thereby affecting the overall stock market as well as economy in Nigeria. Hence, the positive shock and negative shock of crude oil prices would bring significant impact to Nigerian stock market (Obi et al., 2018).

Furthermore, the research done by Khan et al. (2019) with the objective to inspect the asymmetric impact of crude oil prices on Shanghai stock market returns by utilizing data in monthly basis ranging from January 2000 to December 2008. NARDL approach was adopted to examine the asymmetric relationship between exogenous variables and endogenous variable. The result signified that the stock market returns in Shanghai tended to react to both positive shock and negative shock of crude oil prices, thus asymmetric impact of crude oil prices on stock market returns did not exist in Shanghai stock exchange. The authors illustrated that positive shock of oil prices had negative impact on the stock returns of Shanghai stock exchange while negative shock of crude oil prices has positive impact on the stock returns. This is because a rise in crude oil prices would lead to a rise in production costs of businesses, thus it could increase the prices of goods and services. Besides, the investment ability of individuals would be reduced due to lower saving rate and higher costs of living which resulting from higher prices of goods and services (Khan et al., 2019).

Apart from that, Xiao et al. (2019) inspected the asymmetric effect of changes in OVX on the changes in the implied volatility index of the Chinese stock market (VXFXI). Quantile regression approach and daily data from 16 March 2011 to 9 May 2018 were utilized in the study. The result of the research showed that VXFXI tended to react more to positive shock of OVX instead of negative shock of OVX, thus the asymmetric effect of OVX on VXFXI did exist in China. The authors found that a rise in positive shock of OVX would cause the VXFXI to increase in bearish market condition. This is because high volatility in crude oil market might indicate that the economy would be worse off in the future, which could affect the earnings performance of the corporations. Besides, the individuals would be more sensitive to the bad news instead of good news during bear market condition, and the high uncertainty in crude oil market would be considered as bad news. Hence, higher fluctuation in crude oil market would cause stock market to volatile greater due to expectation of future falling economy by individuals.

## 2.3 Gold Market and Stock Market

### 2.3.1 Linear Relationship between Gold Market and Stock Market

There were a lot of studies had investigated the symmetric or linear relationship between gold market and stock market. There were some studies had claimed that the gold is acting as safe investment tool for the stock market. Gokmenoglu and Fazlollahi (2015) had carried out a research to examine the symmetric long run association between the crude oil prices, gold prices, OVX, GVZ and the stock market in U.S. by using the daily data ranging from January 2013 until November 2014. ARDL bounds test was employed in the study to determine whether there is existence of symmetric long run relationship among the variables. The result of the study showed that an upsurge in gold prices would give a significant negative impact on the U.S. stock market index. It indicated that gold was considered as safe investment tool for the U.S. stock market, thus the investors in U.S. might move out their money from stock market and invest in the gold market when the gold prices increased (Gokmenoglu & Fazlollahi, 2015). If there were a lot of investors tended to switch from stock market to gold market, it eventually would cause the stock index in U.S. to drop (Gokmenoglu & Fazlollahi, 2015). In addition, the authors discovered that the there was a positive association between the GVZ and the U.S. stock market index, which meant an increase in GVZ would cause the stock market index in U.S. to increase. This is because the investors in U.S. would tend to involve themselves in the stock market instead of gold market when gold prices fluctuated greater (Gokmenoglu & Fazlollahi, 2015).

Besides, Shahzad et al. (2017) had inspected the correlation between the bond index returns, gold returns and the stock market returns in United Kingdom (UK), United States of America (USA), Canada, Italy, Germany, Japan, Portugal, Spain, Greece and Ireland by utilizing data in monthly basis, which was from January 1991 until December 2015. The study employed the Quantile-on-Quantile approach to examine the symmetric association between independent variables and dependent variables. The result stated that symmetric negative association between the gold returns and stock market returns exists in Japan, USA, UK, Canada and Germany during the normal and bullish economic condition, which implying that the gold could be classified as the diversifier for the stock market in these countries. Therefore, the investors in these countries could diversify their risk incurred in the stock market by counting the gold in their investment portfolio (Shahzad et al., 2017). This is because the gold return would increase as the stock market in these countries decreased during the stable market condition as well as bullish period (Shahzad et al., 2017). Besides, the authors also found that the gold could not be considered as the hedging tool against the stock markets during the strongly bearish market condition.

Furthermore, Tursoy and Faisal (2018) had carried out a study to explore the symmetric relationship between crude oil prices, gold prices and the stock market in Turkey by utilizing the monthly data starting from the period of January 1986 to November 2016. The study applied ARDL bounds test to inspect symmetric association between variables. The outcome illustrated that gold prices interlinked with Turkish stock market in long term and short term. The study suggested that the negative association between the gold prices and stock prices in long term and short term because the gold was served as safe haven asset for the stock market in Turkey. The gold gave a chance to the investors to move out from stock market and involve themselves in gold market in order to prevent a significant loss during a crisis period (Tursoy & Faisal, 2018). During the crisis period, there was a high uncertainty in the stock market, which causing the investors tended to hold more gold instead the shares of the corporations. The gold prices would increase as the demand for gold increased, and it eventually would cause the stock prices to decrease due to less people involved in the stock market.

Moreover, Haider (2018) inspected the symmetric relationship between gold prices, inflation rate, interest rate, currency value of Pakistani Rupee and the stock market index in Pakistan by utilizing data in monthly basis ranging from July 2011 until June 2016. The study employed the Multiple Regression Model to examine the impact of exogenous variables on endogenous variables. The result of the study signified that the gold prices had a significant negative relationship with the stock market index in Pakistan, thus the gold was classified as the safe investment tool for investors who investing in Pakistan stock market. It indicated that the gold prices increased, the Pakistan stock market index would decrease. When the Pakistan stock market was underperformed, the investors would prefer to involve themselves in the gold market instead of Pakistan stock market for the purpose of compensating their losses in stock market (Haider, 2018). As more people involved in the gold market instead of stock market, it eventually would cause the gold prices to increase due to high demand in gold and the Pakistan stock market index to decrease due to low demand in corporations' shares.

Besides, Akbar et al. (2019) scrutinized the relationship between interest rate, gold prices, currency value for Pakistani Rupee and Pakistan stock market index by employing the monthly data, which was from January 2001 until August 2016. The study adopted Bayesian VAR model to test the association between the independent variables and dependent variables. The finding of the study revealed that there was an inverse relationship between the gold prices and the stock prices in Pakistan, which implying that the gold was acting as safe haven alternative for stock market in Pakistan. It indicated that the gold prices increased, the stock prices in Pakistan would decrease, and vice versa. This is because the investors in Pakistan considered the gold market as the substitute of the stock market for their investment's portfolio. When the stock market became high uncertainty, the investments in stocks would become high risk and the gold was considered safe haven asset, thus the investors would decide to invest in gold with lower risk rather than investing in the corporate stocks with higher risk.

However, some of the studies had claimed that the gold did not act as safe investment tool for the stock market. Ingalhalli et al. (2016) explored the relationship between crude oil prices, gold prices, currency value of Indian Rupee and the stock market in India by utilizing the monthly data, which was from January 2005 to July 2015. The Correlation Matrix and Ganger causality tests were applied in the study to test the relationship between the variables. The result of the study revealed that there was a positive relationship between the gold prices and stock market index in India, thus the gold was not considered as a safe investment tool for the Indian stock market. It indicated that when Indian stock market was outperforming, the gold prices would increase as well. This is because a good performance in the stock market in India would lead to economic growth in India, and the residents or investors in India would possess more money in their hands to invest in the gold market (Ingalhalli et al., 2016). The gold prices would increase during the period of economic growth as the demand for gold increased (Ingalhalli et al., 2016). The study also stated that the residents in India did not buy or hold the gold for investment purpose, and they bought it as jewelry purpose (Ingalhalli et al., 2016). Hence, the gold was not served as the safe haven asset for the investors in India.

Besides, Shaique et al. (2016) determined the long run relationship between gold prices and the Pakistan stock market index by utilizing the monthly data for twenty years, which was from October 1993 until May 2014. The study utilized the Johnson Co-integration test and Vector Error Correction Model to identify whether there was presence of long run relationship between gold prices and Pakistan stock market index. The outcome of the study signified that long run relationship between the gold prices and the stock market index did not exist in Pakistan. It specified that the gold could not be served as safe investment tool for equity investments in Pakistan, thus investors in Pakistan should not consider the gold as safe haven asset when making the investment or hedging decisions. The result of the study was conflicting with the studies of Haider (2018) and Akbar et al. (2019), who classified that the gold was safe haven assets for stock market in Pakistan.

In addition, Singhal et al. (2019) examined the relationship between exchange rate for Mexican Peso, crude oil prices, gold prices and the Mexican stock market index by utilizing monthly data ranging from January 2006 until April 2018. ARDL bounds test was adopted in the study. The result signified that the gold prices had a significant positive impact on the stock market in Mexico, which implying the gold could not be considered as safe investment tool for Mexican equity market. The study indicated that if the gold prices increased, the Mexican stock market index would increase as well. Since Mexico is considered as the gold exporter, the movements of gold prices and Mexican stock market would be tended to move in the same direction (Singhal et al., 2019). This is because an upsurge in the gold price would improve the economic growth of Mexico, and it eventually would drive the stock prices in Mexico as well (Singhal et al., 2019). Hence, the investors in Mexico were not suitable to use the gold as hedger for stock investments due to positive correlation between gold prices and Mexican stock market index.

### 2.3.2 Non-Linear Relationship between Gold Market and Stock Market

Apart from the linear relationship between gold market and the stock market, there were also some studies had examined the asymmetric relationship between gold market and stock market. Jain and Biswal (2016) had examined the asymmetric relationship between exchange rate, gold prices, crude oil prices and Indian stock market by using daily data for ten years, which was from 2006 to 2015. The study applied the Kyrtsou–Labys asymmetric causality test to run the data to examine the asymmetric effect of the variables. The result showed that negative shock in gold prices reacted significantly on the Indian stock market index instead of positive changes in gold prices, thus the gold prices had a significant asymmetric effect on stock market index in India. The authors stated that a decrease in the gold prices would depreciate the value of Indian Rupee, and it would cause the stock market index in India to decrease. This is because the demand for gold would rise once the gold prices decreased, and it eventually would lead to an increase in imports of gold (Jain & Biswal, 2016). The value of Indian Rupee would decrease once the imports of gold increased due to the high supply of Indian Rupee, and it could cause the foreign institutional investors to sell their portfolio of securities and move out from the Indian stock market (Jain & Biswal, 2016). This is because the depreciation of Indian currency value would cause the benchmark of Indian stock market index became weaker, hence it eventually would cause the stock market index in India to decline (Jain & Biswal, 2016).

Furthermore, Raza et al. (2016) had studied about the asymmetric relationship between the crude oil prices, gold prices, OVX, GVZ and the stock prices of developing markets by adopting the monthly data ranging from January 2008 until June 2015. The developing stock markets included Russia, Chile, Brazil, Malaysia, China, India, Thailand, Indonesia, Mexico and South Africa. NARDL bounds test had been adopted to examine asymmetric long run relationship between variables in the study. The result of the study showed that positive shock of gold volatility would affect the stock market indices in most of the nations including Brazil, Chile, China, India, Indonesia and South Africa in the long run, thus the gold volatility had asymmetric impact on the stock market indices in these nations in the long run. The outcome also indicated that an increase in the gold volatility would cause the stock market indices in those nations to decrease in the long run. The authors found that GVZ was vital to the investors to predict the future economic conditions, thus the investors were recommended to consider the movement of GVZ when making the decision for investment and hedging. However, the result of the study signified that the asymmetric impacts of gold volatility on stock market indices did not exist in other nations like Malaysia, Mexico, Russia and Thailand in the long run.

Moreover, Bouri et al. (2017) examined the asymmetric relationship between OVX, GVZ and Indian stock market volatility by using the daily data ranging from June 2009 until May 2016. The study applied NARDL bounds test and Kyrtsou-Labys non-linear causality test to investigate whether there was asymmetric long run relationship among the variables. The result indicated that the positive shock of the gold volatility would influence the Indian stock market volatility significantly instead of negative shock of the gold volatility, thus the gold volatility had a significant asymmetric effect on Indian stock market. The study indicated that Indian stock market volatility tended to rise during period of high uncertainty as the gold volatility went up. The authors stated that the gold was acting as safe investment tool instead of stock investments in India, thus the people in India tended to invest in gold when the stock market fluctuated. It eventually would cause the gold market to volatile greater, and the volatility of Indian stock market would also increase because of the liquidity in the stock market decreased once the people in India tended to switch from stock investments to gold investments (Bouri et al., 2017).

Besides, Saeed (2018) observed asymmetric relationship between crude oil prices, gold prices and the Pakistan stock market by adopting the annual data in the year 1990 until 2016. The study adopted a NARDL bounds test to run the data in an attempt to examine the asymmetric effect of the variables in the long run. The result of the study suggested that the positive changes in gold prices had a significant effect on stock market performance rather than the negative changes in gold prices, thus the gold prices had a significant asymmetric effect on Pakistan stock market performance. The study stated that an increment in the gold prices would decrease aggregate market capitalization in Pakistan. This is because the previous study of Haider (2018), who also studied the Pakistan stock market, had mentioned that gold could be considered as the safe investment tool for the stock investments in Pakistan. During the high fluctuation in stock market, gold would be preferred by Pakistan investors instead of corporations' shares, thus it would drive up the gold prices due to its demand increased. It eventually would cause the stock prices to plunge, and its aggregate market capitalization would decrease as well.

## 2.4 Research Hypothesis

$H_1$: There is no significant spillover effect between oil market volatility and Malaysian stock market volatility.

$H_2$: There is significant spillover effect between oil market volatility and Malaysian stock market volatility.

$H_3$: There is no significant spillover effect between gold market volatility and Malaysian stock market volatility.

$H_4$: There is significant spillover effect between gold market volatility and Malaysian stock market volatility.

$H_5$: There is no significant asymmetric relationship between oil market volatility and Malaysian stock market volatility.

$H_6$: There is significant asymmetric relationship between oil market volatility and Malaysian stock market volatility.

$H_7$: There is no significant asymmetric relationship between gold market volatility and Malaysian stock market volatility.

$H_8$: There is significant asymmetric relationship between gold market volatility and Malaysian stock market volatility.

## 2.5 Conclusion

Most of the past research investigated the linear relationship between oil prices, gold prices and stock market prices. Oil market volatility, gold market volatility and stock market volatility are less investigated in the past studies, whereby they do not consider the shock of the oil prices and gold prices. Besides, the asymmetric relationship between the gold market and stock market is rarely observed in past studies. There are only a few researches studied in asymmetric relationship between gold market and equity market such as the studies of Raza et al. (2016), Jain and Biswal (2016), Bouri et al. (2017), Saeed (2018). Hence, the asymmetric volatility spillover effect of oil market and gold market on stock market is served as the literature gap the in this research. Nevertheless, there is only one similar study of Bouri et al. (2017) which serves as the main reference in this study as the authors use OVX, GVZ and Indian stock market volatility to investigate asymmetric relationship between the OVX, GVZ and stock market volatility. Hence, this study exploits the NARDL test to ascertain whether OVX and GVZ have asymmetric effects on the realized volatility of KLCI to overcome the literature gap. The prospect theory and the review of the past study between the variables have been discussed in chapter. The findings of the past researches are inconsistent. Some of the researches have proven that there are linear and non-linear relationships between crude oil market, gold market and stock market, but some are not. Hence, the following chapter will focus on adopted research methodology to inspect the relationship between the variables.

# CHAPTER 3: METHODOLOGY

## 3.0 Introduction

The methodologies to study the effect of asymmetric volatility spillover between oil market, gold market and Malaysian stock market will be discussed in this chapter. There are several tests will be applied in this study which are NARDL test, Breusch-Godfrey LM test, ARCH LM test, CUSUM test and CUSUM of squares test. Diagnostic checking is the most important part in this chapter as it ensures that whether the models encounter autocorrelation problem and heteroskedasticity. Besides, it is also required to check whether the coefficients in both models are stable.

## 3.1 Research Design

This study uses monthly data of crude oil market, gold market and Malaysian stock market to examine whether there is existence of asymmetric volatility spillover effect between these three markets. The monthly data spans over the period from 2009 to 2018. For Malaysian stock market, KLCI is utilized in this study. It is made up of top 30 companies listed in Bursa Malaysia Exchange. Realized volatility for KLCI is used to determine the actual market volatility which introduced by Andersen and Bollerslev (Andersen & Bollerslev, 1998). For independent variable, OVX for oil market and GVZ for gold market are being utilized to examine its volatility spillover effect towards the Malaysian stock market.

### 3.1.1 Data

This study utilizes three variables including realized volatility (RV), crude oil volatility index (OVX) and gold volatility index (GVZ) in attempt to investigate the asymmetric effect of OVX and GVZ on the Malaysian stock market volatility.

The proxy for the oil price volatility is OVX while the proxy for the gold price volatility is GVZ. The proxy for the Malaysian stock market volatility is RV, which is measured by using historical prices of KLCI. The selections of the all variables are motivated from Bouri et al. (2017) because they used the same variables as this study. However, the study used implied volatility as their variable. In this study, realized volatility of Malaysian stock market is adopted as dependent variable.

All the data are acquired from Bloomberg Terminal on monthly basis. This study includes the 10 years' time period, which is from January 2009 until December 2018 which consists of 120 observations. The OVX and GVZ are transformed into natural logarithms form while RV is calculated by using historical prices of KLCI, which is also in natural logarithms form. The detailed descriptions will be discussed in the following table.

Table 3.1: Data Sources and Descriptions

| Variables | Definition | Source |
|---|---|---|
| RV | Realized volatility is the historical volatility because it is calculated by using the historical prices of securities (Barndorff-Nielsen & Shephard, 2002). The prices of KLCI index is used to calculate the realized volatility for the stock market in Malaysia. | Bloomberg Terminal (Monthly data from January 2009 to December 2018) |
| OVX | Crude oil volatility index (OVX) introduced by Chicago Board Option Exchange (CBOE), estimates the market's expectation of 30-day volatility of crude oil prices by adopting the VIX methodology to options in the United States Oil Fund (USO) (CBOE, 2020). | Bloomberg Terminal (Monthly data from January 2009 to December 2018) |
| GVZ | Gold volatility index (GVZ) introduced by Chicago Board Option Exchange (CBOE), captures and traces the prospective 30-day future gold prices volatility which can be used as the risk indicator of the market (CBOE, 2020). | Bloomberg Terminal (Monthly data from January 2009 to December 2018) |

## 3.1.2 Variables

### 3.1.2.1 Realized Volatility (RV)

Realized volatility (RV), introduced by Andersen and Bollerslev (1998), can be calculated in two steps. The first step is to calculate the natural logarithm of returns for the securities by using the natural log of closing price at period *t* minus the natural log of closing price at period *t-1*. The second step is to square the natural logarithms of returns. The realized volatility can be defined as the historical volatility because it is measured by using actual historical prices of security, and it gauges the price movement of the security that are actually fluctuated before (Barndorff-Nielsen & Shephard, 2002). In this study, the realized volatility for Malaysian stock market represents the volatility of stock market in Malaysia, and it is calculated by using the historical prices of KLCI on monthly basis. Nikmanesh and Nor (2016) claimed that the stock market volatility is very crucial to a nation because it can give a huge impact on the growth of its economic and financial system. Government needs to analyse the volatility of stock market in an attempt to monitor stock market stability (Nikmanesh & Nor, 2016). In consideration of the stock market as the economic indicator for a nation economy performance, the fluctuation in stock market will affect the decision making of the policymakers as well as the financial risk management (Nasir et al., 2013). Hence, the stock market volatility is significant to emerging and developed countries. In order to investigate the asymmetric effect of OVX and GVZ on the RV, the realized volatility for Malaysian stock market is used as a dependent variable. The realized volatility of Malaysian stock market formula is shown as below:

$$RV = [Ln(P_t) - Ln(P_{t-1})]^2$$

Where,

$RV = Realized\ volatility\ of\ KLCI\ index$

$P_t = KLCI\ price\ index\ for\ this\ month$

$P_{t-1} = KLCI\ price\ index\ for\ previous\ month$

### 3.1.2.2 CBOE Crude Oil Volatility Index (OVX)

There is high tendency among investors to diminish market risk by utilizing global portfolio scheme and hold commodity assets, for instance, crude oil and gold. This is primarily due to the expedition of global market integration and rapid expansion of information carriers. The active transactions of crude oil since 2000s has driven up the crude oil prices for a long period, thus enhancing the financialization of crude oil market (Hung et al., 2011). In addition, another factor contributes to crude oil prices fluctuation is the climate mitigations and renewable energy policies. The effect is remarkable when the crude oil prices plummeted during the 2008 Global Financial Crisis (Liu et al., 2013). To deliver a new information source on crude oil market during those extremely uncertain periods, CBOE published the first OVX.

OVX is a significant instrument for measuring oil price volatility. OVX has been published by CBOE since the middle of 2007. CBOE is the U.S. largest options marketplace and also the creator of listed options. OVX predicts the expectation of market of 30-day volatility of crude oil prices by adopting the VIX methodology to options on the United States Oil (USO) Fund. The USO is an exchange-traded security established to trace shock of oil prices (Chen & Zou, 2015). The real-time bid or ask quotes of nearby and second nearby options with at least 8 days to expiration are considered, and a constant which is the 30-day estimate of the expected volatility is derived by weighting these options (Dutta et al., 2017).

OVX is an implied volatility and is considered as a better measurement of market uncertainty. This is because it includes the historical information of market and the expectation of investors on the future changes in the market (Liu et al., 2013). Due to its useful features, many past studies have widely adopted OVX as their proxy of oil market volatility. A case in point of Wen et al. (2012) and Raza et al. (2016) utilized OVX in the NARDL model to investigate the asymmetric effect of crude oil prices uncertainty on the emerging economies. The findings showed that the volatility in crude oil prices has brought effect towards the stock market. Besides, empirical results of Dutta (2018) and Bouri et al. (2017) which employed OVX in the ARDL bounds tests exhibited that there is strong association between the implied volatilities of oil and stock markets.

After the 2008 Global Financial Crisis, the interrelation between volatility index and expectation of investors on future market changes could largely reflect the uncertainty spillover between crude oil and other underlying markets (Ji & Fan, 2012). Furthermore, there are some specific characteristics in OVX compared to the volatility indices of financial markets. To illustrates, a decrease in stock prices tend to shoot up the stock volatility index (VIX) as it mainly considers the downside risk. However, the fall in commodity price may bring advantage to investors in commodity markets as they can both long or short the futures. This illustrated that there are uncertain impacts of crude oil price changes on OVX. Hence, the expected volatility mechanism in commodity markets can be understood by examining the asymmetric effects between commodity and financial volatility indices (Fleming et al., 1995).

#### 3.1.2.3 CBOE Gold Volatility Index (GVZ)

Gold is a tangible and valuable item that can be handled with ease. Gold is classified as a monetary asset and a commodity which is also being known as one of the valuable metals in the world. Gold is also known to have the similar features with money as it acts as a medium of exchange, a unit of value as well as a store of wealth throughout the centuries. The changes in gold prices can affect the holding of Central Bank of these precious metals (Sopipan, et al., 2012). Nowadays, gold is not only known as a commodity but also a financial asset. There are a lot of investors keep gold as their future assets investment in order to get more profit as gold is a safe storage (Sukri et al., 2015).

Sukri et al. (2015) documented that gold is known as a hedging tool which helps investors to offset the major losses. For example, it is used to lessen the risk of devaluation of an asset and losses on an investment. Investors take gold as an investment asset in order to avoid high risk from unexpected economic instability. Furthermore, gold futures is one of the alternative investment tools that its value depends on the gold prices movement. Due to the negative correlation towards the stock market, the stock market fluctuation can be hedged via gold futures. Therefore, this will offer a greater chance to make profit when the stock market drops during an economic recession (Sopipan et al., 2012). Moreover, gold is also acting as the inflation hedging tool because the increase in inflation rate will cause the gold prices to increase. It could be said that even though there is an inflation occurs in that moment, gold can retain its value and shows a direct relationship (Hashim et al., 2017).

Gold price volatility is very important as it is used to analyse the uncertainty of expected gold prices in current and future as well as the risk in the entire markets. If the gold prices fluctuate, they will lead to negative impact in the financial markets. It has been claimed that the increment in gold price volatility during the financial crisis will cause an unsafe investment condition (Baur, 2012). Hence, an upsurge in volatility of gold prices will raise the awareness of investors and producers of the gold industry in order for them to avoid the risk associated. Zakaria et al. (2015) have carried out a study to examine the drivers that influence the fluctuation of gold price in Malaysia. The results revealed some of the factors such as prices of crude oil, exchange rate, inflation rate and real interest rate are significantly influence the gold price volatility. Sukri et al. (2015) also carried out a research that aimed to investigate the association between macroeconomic factors and gold prices in Malaysia. It has been found out that there are three drivers such as Gross Domestic Product (GDP), crude oil price and currency exchange rate have significant association with the gold prices.

GVZ has been widely used as the independent variable in some studies. Gokmenoglua and Fazlollahia (2015) utilized prices of gold and crude oil, GVZ and OVX as exogenous variables to test whether there is significant relationship between the exogenous variables and stock market price index. In addition, the study of Bouri et al. (2017) investigate the non-linear relationship between OVX, GVZ and implied volatility of Indian stock market. There is non-linear and positive impact as well as the presence of cointegration relationships showed in the outcome.

## 3.2 Empirical Model

Equation 1 (EQ 1) is the linear model for this study.

$$RV_t = c_0 + c_1 OVX_t + c_2 GVZ_t + \varepsilon_t \qquad \text{(EQ 1)}$$

Where $c = c_0, c_1, c_2$ is the estimate for the Malaysian stock market, and $c_0$ is the constant term. All of the variables are expressed in natural logarithm form although the realized volatility of KLCI index (RV) is not specific.

Equation 2 (EQ 2) is non-linear model for this study.

$$RV_t = \beta_0 + \beta_1 OVX_t^+ + \beta_2 OVX_t^- + \beta_3 GVZ_t^+ + \beta_4 GVZ_t^- + \varepsilon_t \quad \text{(EQ 2)}$$

Where $\beta_0$ is the constant term that may be the intercept term, $\beta_1, \dots, \beta_4$ are the estimates for the long run elasticity of Malaysian stock market against the changes of respective regressors. The $OVX_t^+$, $OVX_t^-$, $GVZ_t^+$ and $GVZ_t^-$ are the non-linear or asymmetry components in the model and they are drawn out from

$$OVX_t^+ = \sum_{j=1}^{t} \Delta OVX_j^+ = \sum_{j=1}^{t} \max(OVX_t, 0) \quad \text{(EQ 3)}$$

And

$$OVX_t^- = \sum_{j=1}^{t} \Delta OVX_j^- = \sum_{j=1}^{t} \min(OVX_t, 0) \quad \text{(EQ 4)}$$

Where $OVX_t^+$ is the positive changes (rise) in oil price volatility and $OVX_t^-$ is the negative changes (drop) in oil price volatility that influence the stock market in Malaysia. Simply put, $OVX_t^+$ indicates that oil market volatility keep increasing while $OVX_t^-$ indicates that oil market volatility keep decreasing.

$$GVZ_t^+ = \sum_{j=1}^{t} \Delta GVZ_j^+ = \sum_{j=1}^{t} \max(GVZ_t, 0) \quad \text{(EQ 5)}$$

And

$$GVZ_t^- = \sum_{j=1}^{t} \Delta GVZ_j^- = \sum_{j=1}^{t} \min(GVZ_t, 0) \quad \text{(EQ 6)}$$

Where $GVZ_t^+$ is the positive changes (rise) in gold price volatility and $GVZ_t^-$ is the negative changes (drop) in gold price volatility that influence the stock market in Malaysia. $GVZ_t^+$ indicates that gold market volatility keeps increasing while $GVZ_t^-$ indicates that gold market volatility keeps decreasing.

### 3.2.1 NARDL Framework

The study is intended to scrutinize the asymmetric long run relationship between the independent variables and dependent variables. The cointegration ARDL testing approach has gained popularity in light of the study of Pesaran et al. (2001). However, the hidden cointegration may exist in the variables, which means the long run cointegration relationship can be explained between the positive and negative components of explanatory variables. With the hidden or asymmetric cointegration, Shin et al. (2014) established the NARDL testing approach through the work of Pesaran et al. (2001) in attempt to yield reliable estimation. In general, NARDL studies the positive and negative variation of explanatory variables that may have different impact on the response variable. There is an asymmetric relationship when either the positive or negative component of explanatory variables is significant in the model. The cointegration NARDL testing approach by Shin et al. (2014) is adopted in this study which render a testing on non-linear long run correlation between oil market volatility, gold market volatility and realized volatility of KLCI index. From Equation 2, the NARDL model can be constructed as:

$$\Delta RV_t = \beta_0 + \beta_1 RV_{t-1} + \beta_2 OVX^{+}_{t-1} + \beta_3 OVX^{-}_{t-1} + \beta_4 GVZ^{+}_{t-1} + \beta_5 GVZ^{-}_{t-1} + \sum_{i=1}^{t} \theta_1 \Delta RV_{t-i} + \sum_{i=0}^{t} \theta_2 \Delta OVX^{+}_{t-i} + \sum_{i=0}^{t} \theta_3 \Delta OVX^{-}_{t-i} + \sum_{i=0}^{t} \theta_4 \Delta GVZ^{+}_{t-i} + \sum_{i=0}^{t} \theta_5 \Delta GVZ^{-}_{t-i} + \varepsilon_t$$

where $\beta_0$ is constant intercept term and $\beta_1, \ldots, \beta_5$ are long run parameter to be estimated, and $t$ is the different optimum lag length that are used in light of Akaike Information Criterion (AIC). The long run cointegration relationship is denoted as $\theta_1, \ldots, \theta_5$, difference operator is denoted as $\Delta$, $OVX^{+}$, $OVX^{-}$, $GVZ^{+}$, $GVZ^{-}$ are the positive changes (rise) and negative changes (drop) of oil price volatility and gold price volatility respectively and $\varepsilon_t$ is white noise error term. Shin et al. (2014) used Wald F-statistic bounds testing approach from the study of Pesaran et al. (2001) to detect the cointegration relationship between the variables. The null hypothesis can be constructed as:

$$H_0: \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0 \text{ (no long run relationship)}$$

The hypothesis testing can draw three conclusions. If the F statistic is greater than upper bound critical value I (1), this indicated that there is long run cointegration relationship between realized volatility and independent variables. Nonetheless, there is no long run correlation between variables when the F statistic is less than lower bound critical value I (0). If F statistic falls within the upper and lower bound critical value, it is said to have an inconclusive relationship.

## 3.3 Diagnostic Checking

### 3.3.1 ARCH LM Test

The ARCH test, a Lagrange multiplier (LM) is used to test the ARCH in the error terms (Engle, 1982). The existence of heteroskedasticity is always seen in financial time series, which the magnitude of residuals shows association with the magnitude of latest residuals. The standard LS inference is not nullified by the ARCH itself. However, there will be loss in efficiency if ARCH effects are neglected.

To determine the presence of ARCH effect in the error terms, the following auxiliary model is estimated:

$$\hat{\mu}_t^2 = \alpha_0 + \theta_1 \hat{\mu}_{t-1}^2 + \theta_2 \hat{\mu}_{t-2}^2 + \cdots + \theta_q \hat{\mu}_{t-q}^2 + v_t$$

which is an ARCH($q$) model consisting a constant term $\alpha_0$, a white-noise error term $v_t$, and lagged squared error term up to order $q$. The null hypothesis of the ARCH test assumes all coefficients of the lagged squared error terms are jointly insignificant, algebraically

$$H_0: \theta_1 = \theta_2 = \cdots = \theta_q = 0$$

The estimated error variance $\hat{\mu}_t^2$ is homoscedastic or constant if the null hypothesis holds. This means that there is no issue of the ARCH effect in the NARDL model. The null hypothesis of absence of ARCH effect is rejected when the LM test statistics $nR^2$ is greater than the chi-square critical value of $q$ degrees of freedom at certain significance level, which testify that the error terms are conditionally heteroscedastic.

### 3.3.2 Breusch-Godfrey LM Test

One of the methods to detect the autocorrelation problem is the Breusch-Godfrey LM test. Breusch and Godfrey (1978) introduced LM test to detect whether there is correlation between error term at period *t* and the error term before period *t*. LM test is allowed for higher autoregressive order. Below is the auxiliary model:

$$\hat{\varepsilon}_t = \beta_0 + \beta_1 X_{1t} + \cdots + \beta_k X_{kt} + \rho_1 \hat{\varepsilon}_{t-1} + \cdots + \rho_p \hat{\varepsilon}_{t-p} + v_t$$

Where $\hat{\varepsilon}_t$ is the residuals of NARDL model, $X_{1t}$ is the independent variable of NARDL model and $v_t$ is white noise error term. The following null hypothesis $H_0$ can be used to detect whether the residuals, $\hat{\varepsilon}_t$, is interdependent with the lagged residuals follow the $\rho$-th autoregressive order.

$$H_0: \rho_1 = \rho_2 = \cdots = \rho_p = 0$$

The null hypothesis assumes that the $\widehat{\varepsilon_t}$ has no relationship with the lagged residuals, thus there is no serial correlation problem in the model. If the LM test statistics $nR^2$ surpass the critical chi-square value at a specific level of significance, it will support the rejection of null hypothesis $H_0$, thus the model is subject to serial correlation problem.

### 3.3.3 CUSUM and CUSUMSQ Tests

Khan et al. (2019) and Pesaran et al. (2001) developed CUSUM test and CUSUMSQ test to examine the stability of the coefficients in the NARDL model. The test statistic of CUSUM test is

$$W_t = \sum_{r=k+1}^{t} \frac{w_r}{s}, \qquad \text{for } t = k+1, \ldots, T$$

where *w* is the recursive residual terms, *s* is the standard deviation of the recursive residual terms. If the estimated coefficient keeps unchanged over time, the expected value of $W_t$ will be zero, E ($W_t$) = 0 as well. But it will be digressed from the zero mean value line when the coefficient changes respectively. The parameter will be stable if the CUSUM and CUSUMSQ are both within the two significant lines, blue line moves inside red line, at significance level of 5% (Brown et al., 1975).

Specifically, CUSUMSQ test is used to observe the stability of the residual variance during the period. The test statistics of the CUSUMSQ test is

$$S_t = \sum_{r=k+1}^{t} w_t^2 \Big/ \sum_{r=k+1}^{T} w_t^2, \qquad \text{for } t = k+1, \dots, T$$

The expected value of $S_t$ can be noted as

$$E(S_t) = \frac{t-k}{T-k}$$

which the scale from 0 at $t = k$ to 1 at $t = T$. CUSUMSQ test is identical to CUSUM test where the residual variance is stable if it moves within the 2 critical lines at the significance level of 5%.

## 3.4 Conclusion

The chapter includes the research design, empirical model and diagnostic checking. There are five approaches which are NARDL bounds test, Breusch-Godfrey LM test, ARCH LM test, CUSUM test and CUSUM of squares tests used to investigate the asymmetric volatility spillover between oil market, gold market and Malaysian stock market. It could provide a clear and better understanding for the researchers on the overall study. The next chapter will further discuss the empirical result.

# CHAPTER 4: DATA ANALYSIS AND FINDINGS

## 4.0 Introduction

In this chapter, linear model will be examined to investigate whether there is presence of symmetric long run relationship between exogenous variables and endogenous variable in the linear model. Non-linear model will also be tested to inspect whether asymmetric long run relationship between exogenous variables and endogenous variable exists. Variables used consist of realized volatility (RV) of KLCI, GVZ, OVX, positive shock of oil price volatility (OVX+), negative shock of oil price volatility (OVX-), positive shock of gold price volatility (GVZ+) and negative shock of gold price volatility (GVZ-). The tests that are included to analyze the models are unit root tests, ARDL long run form and bounds test, ARCH LM test, Breusch-Godfrey LM test, CUSUM test and CUSUM of squares test. All of the data are obtained from Bloomberg Terminal, and the empirical tests are conducted by using E-views 10. Besides, this chapter will also focus on the main findings of Malaysian stock market, oil market as well as gold market. Lastly, linear model will be compared with non-linear model to see whether which model is the most appropriate to analyze relationship among volatilities of Malaysian stock market, oil market and gold market.

## 4.1 Descriptive statistics

Table 4.1 Results of Descriptive Statistics

| | RV | OVX | GVZ |
|---|---|---|---|
| Mean | 0.000860 | 3.492173 | 2.870624 |
| Median | 0.000297 | 3.475067 | 2.872364 |
| Maximum | 0.016137 | 4.345103 | 3.686376 |
| Minimum | 2.46E-07 | 2.747912 | 2.373975 |
| Std. Dev. | 0.001849 | 0.331570 | 0.294017 |
| Skewness | 5.566140 | 0.083869 | 0.300060 |
| Kurtosis | 42.06002 | 2.717183 | 2.891377 |
| Jarque-Bera | 8248.065 | 0.540607 | 1.859709 |
| Observations | 120 | 120 | 120 |

The results of all the descriptive statistics are computed by using 120 observations. According to Table 4.1, it clearly displays that OVX has highest mean value of 3.492173, while RV of KLCI has the lowest mean value of 0.000860. Besides, OVX is deemed to have the highest median value of 3.475067 as compared to other two variables, while RV of KLCI is deemed to have the lowest median value of 0.000297. Moreover, OVX also has the highest maximum and minimum value which are 4.345103 and 2.747912 respectively, and the RV of KLCI has the lowest maximum and minimum value which are 0.016137 and 2.46E-07 respectively. Furthermore, OVX possesses the highest standard deviation of 0.331570 as compared to other variables, but it has the lowest skewness of 0.083869 among three variables. The lowest standard deviation of 0.001849 falls on the RV of KLCI, but it has the highest skewness of 5.566140 as compared to other two variables.

## 4.2 Unit Root Tests

Table 4.2 Results of Unit Root Test at Level Basis

| | RV | OVX | GVZ |
|---|---|---|---|
| ADF | -6.792749*** | -3.167860** | -3.665739*** |
| PP | -10.19061*** | -3.288242** | -3.665739*** |
| KPSS | 0.400567*** | 0.187690*** | 1.112347 |

Note: "*" indicates that the series is significant at the significance level of 10%, "**" indicates that the series is significant at the significance level of 5 % and "***" indicates that the series is significant at the significance level of 1%.

In this study, three unit root tests are applied, which are Augmented Dickey Fuller (ADF) test, Phillips-Perron (PP) test and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test (Dickey & Fuller, 1979; Phillips & Perron, 1988; Kwiatkowski et al., 1992). Unit root tests are conducted to investigate whether RV of KLCI series, OVX series and GVZ series are stationary by using ADF, PP and KPSS tests. The null hypothesis for the ADF and PP tests indicates that the series is not stationary, thus there is existence of unit root in the series. However, the null hypothesis for KPSS test indicates that the series is stationary, thus unit root does not exist in the series. According to Table 4.2, it clearly shows that null hypothesis for both ADF and PP tests will be rejected at significance level of 5% for RV series, OVX series and GVZ series, thus these two tests support the stationarity of three series. However, it does not reject null hypothesis for KPSS at significance level of 5% for RV series and OVX series only, and null hypothesis for KPSS will be rejected for GVZ series. In other words, KPSS test only supports the stationarity of RV series and OVX, and it does not support the stationarity of GVZ series. Hence, the three tests support the stationarity of RV series and OVX, but the results of three tests for GVZ series are conflicted.

Table 4.3 Results of Unit Root Test at 1st Difference

| | RV | OVX | GVZ |
|---|---|---|---|
| ADF | -8.795352*** | -10.47424*** | -12.78461*** |
| PP | -46.50573*** | -10.57224*** | -14.12486*** |
| KPSS | 0.216468*** | 0.240378*** | 0.108177*** |

Note: "*" indicates that the series is significant at the significance level of 10%, "**" indicates that the series is significant at the significance level of 5 % and "***" indicates that the series is significant at the significance level of 1%.

The three series will be first differenced and examined again to detect whether unit root exists in this study. According to the results showed in Table 4.3, it obviously shows that all the three tests support the stationarity of RV series, OVX series and GVZ series. Hence, all of the three series are integrated either 0 or 1 in order to support its stationarity.

# 4.3 Linear Model (ARDL model)

## 4.3.1 ARDL Bounds Test

Table 4.4 Results of ARDL Bounds Test

| | OVX | GVZ |
|---|---|---|
| Coefficients | 0.000512 | 0.000402 |
| P-value | 0.2949 | 0.4748 |
| F statistics | 13.12191*** | |
| Lower bound critical value I(0) | 2.63 (10%), 3.10 (5%), 4.13 (1%) | |
| Upper bound critical value I(1) | 3.35 (10%), 3.87 (5%), 5.00 (1%) | |

Note: "*" indicates significant at significance level of 10%, "**" indicates significant at significance level of 5 % and "***" indicates that significant at significance level of 1%.

ARDL bounds test are carried out to examine whether exogenous variables and endogenous variable are interlinked among them in the long run. In this model, exogenous variables are OVX and GVZ while the endogenous variable is the RV of KLCI. The OVX and GVZ have relationship with RV of KLCI in long run if the F-statistics is greater than the upper bound critical value I(1) at a certain significance level. Besides, ARDL test is also required to examine whether the OVX and GVZ have the significant impact on the RV of KLCI. The null hypothesis indicates that the OVX and GVZ will not significantly affect the RV of KLCI, while alternative hypothesis denotes that OVX and GVZ will influence RV of KLCI significantly. It should reject null hypothesis once p-value displays a figure which is lower than a certain significance level.

Referring to Table 4.4, F-statistics is computed as 13.12191, and it shows a digit greater than upper bound critical value I(1) at significance level of 10%, 5% and 1%. It indicates that relationship between OVX, GVX and RV of KLCI exists in long run. Besides, the p-value for OVX and GVZ are counted as 0.2949 and 0.4748 respectively, which are greater than the significance level of 10%, 5% and 1%. Hence, it will reject null hypothesis, and this condition indicates that the RV of KLCI will not be significantly affected by the OVX and GVZ in the ARDL model. Even though the relationship between OVX, GVZ and RV of KLCI exists in long run, the results of ARDL test show that OVX and GVZ would not significantly influence the RV of KLCI in this ARDL model. In other words, the changes in the movement of OVX and GVZ will not cause any changes in the movement of RV of KLCI.

In this ARDL model, a conclusion can be drawn which is symmetric effect between oil market volatility, gold market volatility and Malaysian stock market volatility does not exist because GVZ and OVX in the model are insignificant.

### 4.3.2 ARCH LM Test

Table 4.5 Results of ARCH LM Test

| **Test statistic** | **P-value** |
|---|---|
| 8.710143 | 0.7275 |

In this study, ARCH LM test is conducted to verify whether ARDL model has ARCH effect in error terms (Engle, 1982). The null hypothesis shows that ARCH effect is absent in this model, while alternative hypothesis indicates that the existence of ARCH effect in this model. It should reject null hypothesis once the p-value shows a figure which is lesser than a certain level of significance, and the model will be deemed to have ARCH effect.

Referring to Table 4.5, p-value is computed as 0.7275, and it is greater than the significance level of 10%, 5% and 1%. Hence, it should not reject null hypothesis after running ARCH LM test, and this condition indicates that ARCH effect does not exist in this ARDL model. In other words, the error terms and the exogenous variables in the ARDL model will not influence each other.

### 4.3.3 Breusch-Godfrey LM Test

Table 4.6 Results of Breusch-Godfrey LM Test

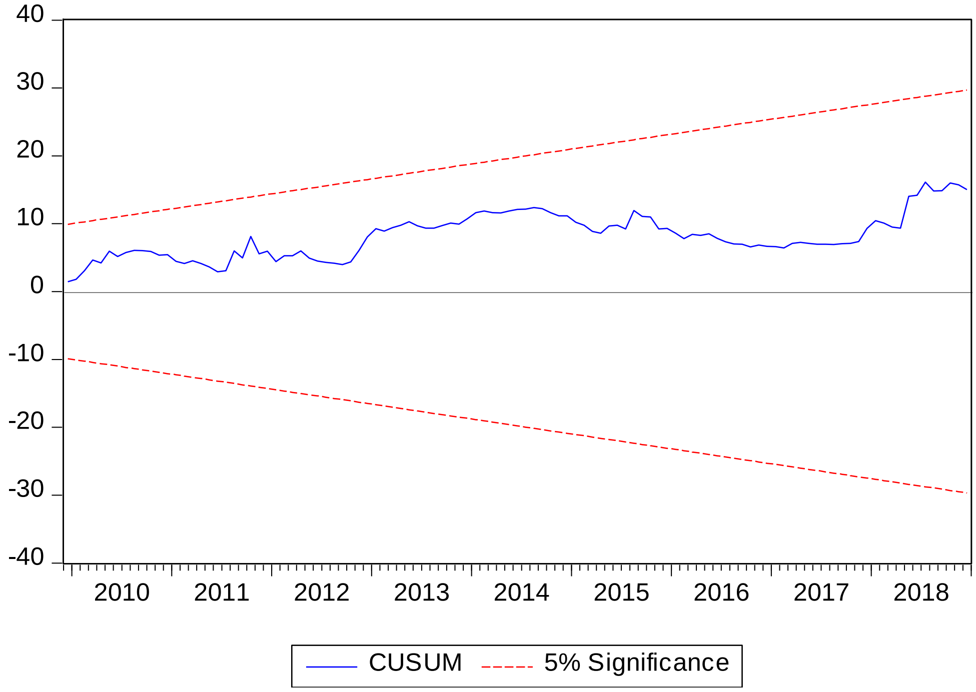
| **Test statistic** | **P-value** |
|---|---|
| 2.238536 | 0. 1346 |

Breusch-Godfrey LM test is applied in order to determine whether ARDL model has serial correlation problem (Breusch, 1978; Godfrey, 1978). The null hypothesis exhibits that ARDL model does not have any serial correlation problem, while alternative hypothesis indicates that serial correlation problem does present in the model. It will reject null hypothesis once the p-value shows a digit which is lower than a certain level of significance, and the model will be deemed to have serial correlation problem.

According to the results showed in Table 4.6, p-value is counted as 0.1346, and it is greater than the significance level of 10%, 5% and 1%. Hence, it should not null hypothesis after applying Breusch-Godfrey LM test, and it indicates that ARDL model will not have any serial correlation problem. In other word, the error terms at current period are not interrelated with error terms at previous period.

### 4.3.4 CUSUM Test

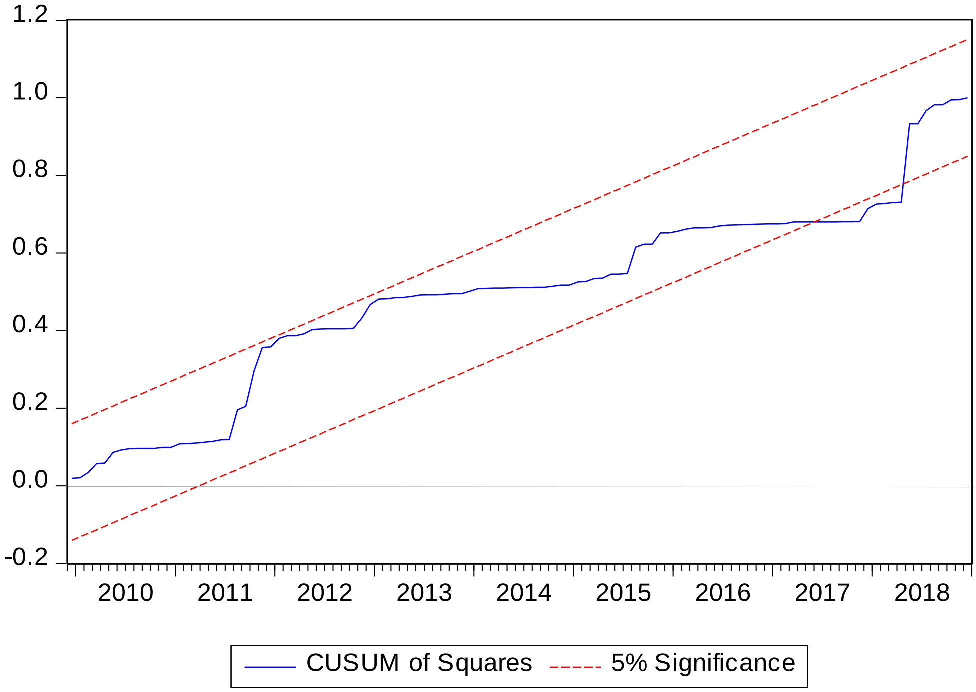
Figure 4.1 Results of CUSUM Test




CUSUM test is implemented to inspect whether coefficients in ARDL model are stable (Khan et al., 2019; Pesaran et al, 2001). The coefficients are considered as stable if the cumulative sum (CUSUM) line moves within the 2 critical lines at significance level of 5 % (Brown et al., 1975). Referring to the Figure 4.1, the CUSUM line is moving within the 2 critical lines at significance level of 5%, hence it supports stability of coefficients in ARDL model.

### 4.3.5 CUSUM of Squares Test

Figure 4.2 Results of CUSUM of Squares Test




CUSUM of squares test is also applied to inspect whether coefficients in ARDL model are stable (Khan et al., 2019; Pesaran et al, 2001). The coefficients are considered as stable if cumulative sum (CUSUM) of squares line moves within 2 critical lines at significant level of 5% (Brown et al., 1975). Referring to the Figure 4.2, the overall CUSUM of squares line is moving within the 2 critical lines at significance level of 5%. Although the line is moving out of the critical lines from May 2017 to April 2018, it eventually moves back within the 2 critical lines. Hence, it supports stability of coefficients in ARDL model.

# 4.4 Non-linear Model (NARDL model)

## 4.4.1 Non-linear ARDL Bounds Test

Table 4.7 Results of NARDL Bounds Test

| | OVX+ | OVX- | GVZ+ | GVZ- |
|---|---|---|---|---|
| Coefficients | 0.000575* | -0.000987 | 0.000175 | 0.001612** |
| P-value | 0.0529 | 0.1621 | 0.6978 | 0.0390 |
| F statistics | 6.284291*** | | | |
| Lower bound critical value I(0) | 2.20 (10%), 2.56 (5%), 3.29 (1%) | | | |
| Upper bound critical value I(1) | 3.09 (10%), 3.49 (5%), 4.37 (1%) | | | |

Note: "*" indicates significant at the significance level of 10%, "**" indicates significant at the significance level of 5 % and "***" indicates that significant at the significance level of 1%.

NARDL bounds test is conducted to ascertain whether there is existence of asymmetric relationship between OVX+, OVX-, GVZ+, GVZ- and RV of KLCI in long run. The dependent variable is RV of KLCI, while the independent variables are OVX+, OVX-, GVZ+ and GVZ-. The long run relationship exists if the F-statistics is higher than the upper bound critical value I(1) at a certain significance level. The asymmetric relationship between volatility of Malaysian stock market and volatility of oil market exists, if either OVX+ or OVX- has significant spillover effect on RV of KLCI. Moreover, the asymmetric relationship between volatility of Malaysian stock market and volatility of gold market exists, if either GVZ+ or GVZ- has significant spillover effect on RV of KLCI. This test is also required to investigate whether OVX+, OVX-, GVZ+ and GVZ- have the significant spillover effect on RV of KLCI. The null hypothesis indicates that the OVX+, OVX-, GVZ+ and GVZ- do not have significant spillover effect on the RV of KLCI, while alternative hypothesis signifies that OVX+,

OVX-, GVZ+ and GVZ- have the significant spillover effect on the RV of KLCI. It will reject null hypothesis once the p-value shows a digit which is lower than a certain significance level.

Referring to Table 4.7, F-statistics is computed as 6.284291, and it is greater than the upper bound critical value at the significance level of 10%, 5% and 1%. It demonstrates that relationship among OVX+, OVX-, GVZ+, GVZ- and RV of KLCI exists in long run.

Besides, the p-value for OVX+ and OVX- are computed as 0.0529 and 0.1621 respectively. The p-value of OVX- is greater than significance level of 10%, 5% and 1%, thus it will not reject null hypothesis. This condition signifies that OVX- does not have any spillover effect on RV of KLCI. The p-value of OVX+ is lower than significance level of 10%, thus it should reject null hypothesis at the significance level of 10%. It signifies that OVX+ has the significant spillover effect on RV of KLCI at the significance level of 10%. Since OVX+ has significant spillover effect on the RV of KLCI while OVX- does not, it can be concluded that asymmetric relationship between Malaysian stock market volatility and oil market volatility does exist. The coefficient for OVX+ is 0.000575. It implies that the 1% increase in OVX+ will cause the RV of KLCI to increase by 0.000575%. That is to say, when the oil market volatility increases by 1%, Malaysian stock market volatility will also rise by 0.000575%.

Furthermore, the p-value of GVZ+ and GVZ- are counted as 0.6978 and 0.0390 respectively. The p-value of GVZ+ is greater than significance level of 10%, 5% and 1%, thus null hypothesis should not be rejected. It indicates that the GVZ+ does not have significant spillover effect on RV of KLCI. The p-value of GVZ- is smaller than significance level of 10% and 5%, it should reject thus null hypothesis at significance level of 10% and 5%. This condition indicates that the GVZ- has significant spillover effect on RV of KLCI at the significance level of 10% and 5%. Since GVZ- has significant spillover effect on RV of KLCI while GVZ+ does not, it can be concluded that asymmetric correlation between volatility of Malaysian stock market and volatility of gold market does exist. The coefficient of GVZ- is 0.001612. It means that the 1% decrease in GVZ- will cause the RV of KLCI to decrease by 0.001612%. In other words, when the gold market volatility decreases by 1%, which will lead to a 0.001612% drop in volatility of Malaysian stock market.

In this NARDL model, it can be concluded that asymmetric volatility spillover effect between oil market, gold market and Malaysian stock market does exist.

### 4.4.2 ARCH LM Test

Table 4.8 Results of ARCH LM Test

| **Test statistic** | **P-value** |
|---|---|
| 4.814809 | 0.9639 |

ARCH LM test is also implemented to detect whether NARDL model has ARCH effect in this study (Engle, 1982). It will reject null hypothesis once the p-value shows a figure which is lower than a certain significance level, and NARDL model will be deemed to have ARCH effect.

According to Table 4.8, the p-value is calculated as 0.9639, and it is greater than the significance level of 10%, 5% and 1%. Thus, it will not reject null hypothesis after running ARCH LM test, and it can be believed that NARDL model does not include any ARCH effect. In other words, exogenous variables will not affect or be affected by the error terms in the NARDL model.

### 4.4.3 Breusch-Godfrey LM Test

Table 4.9 Results of Breusch-Godfrey LM Test

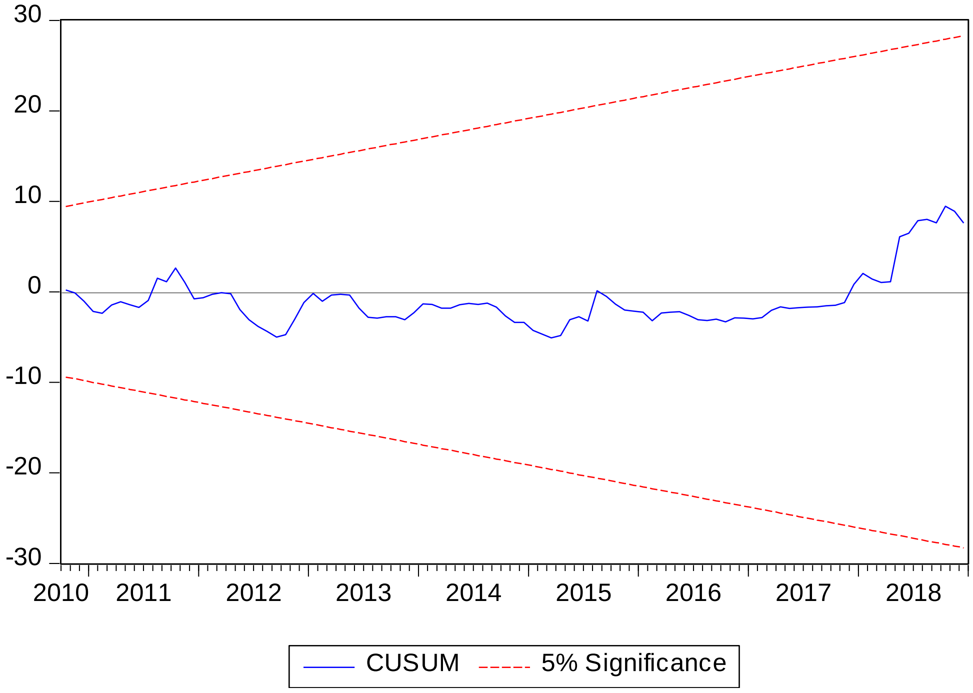
| Test statistic | P-value |
|---|---|
| 15.72875 | 0.2040 |

Breusch-Godfrey LM test is also implemented to detect whether this NARDL model includes serial correlation problem (Breusch, 1978; Godfrey, 1978). It will reject null hypothesis once the p-value shows a digit which is lower than a certain significance level, and NARDL model will be deemed to have serial correlation problem.

According to Table 4.9, the p-value is computed as 0.2040, and it is greater than significance level of 10%, 5% and 1%. Thus, it will not reject null hypothesis after running Breusch-Godfrey LM test, and it can be revealed that NARDL model does not include any serial correlation problem. That is to say, the error terms at current period are not interrelated with error terms at previous period.

### 4.4.4 CUSUM Test

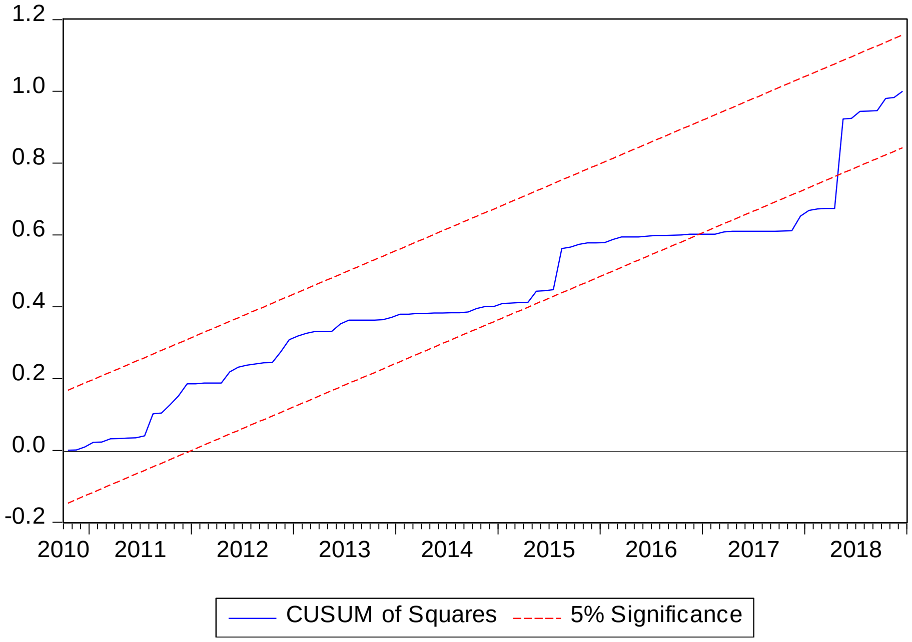
Figure 4.3 Results of CUSUM Test




The coefficients can be concluded as stable if the cumulative sum (CUSUM) line moves within the 2 critical lines at significant level of 5% (Brown et al., 1975). According to the Figure 4.3, the CUSUM line is moving within 2 critical lines at significance level of 5%, thus it supports the stability of coefficients in NARDL model.

### 4.4.5 CUSUM of Squares Test

Figure 4.4 Results of CUSUM of Squares Test




The coefficients can be concluded as stable if the cumulative sum (CUSUM) of squares line moves within the 2 critical lines at significant level of 5% (Brown et al., 1975). Referring to the Figure 4.4, the overall CUSUM of squares line is moving within the 2 critical lines at significant level of 5%. Although the line is moving out of the critical lines from November 2016 to April 2018, it eventually moves back within the 2 critical lines. Hence, the coefficients in the ARDL model are considered as stable.

# 4.5 Summary of Empirical Results and Major Findings

## 4.5.1 Summary of Empirical Results

Table 4.10 Results of T-Statistics for Non-linear Model

| Independent Variables | Parameter | Significance | Coefficients |
|---|---|---|---|
| Positive shock of oil price volatility (OVX+) | $\beta_2$ | Significant | Positive |
| Negative shock of oil price volatility (OVX-) | $\beta_3$ | Insignificant | Negative |
| Positive shock of gold price volatility (GVZ+) | $\beta_4$ | Insignificant | Positive |
| Negative shock of gold price volatility (GVZ-) | $\beta_5$ | Significant | Positive |

Table 4.10 demonstrates summarized results of NARDL model of this study. It can be summarized as the OVX+ and GVZ- have the significant spillover effect on RV of KLCI. Moreover, there is presence of asymmetric long run correlation among volatility of oil market, volatility of gold market and volatility of Malaysian stock market.

### 4.5.2 Main Findings about Oil Market Volatility and Malaysian Stock Market Volatility

According to the summary in Table 4.10, the realized volatility (RV) of KLCI tends to react more to positive shock of oil price volatility (OVX+) instead of negative shock of oil price volatility (OVX-). It indicates that an rise in volatility of oil market, volatility of Malaysian stock market will rise as well. The result of this study is similar to some of previous research such as research of Xiao et al. (2019), Maghyereh et al. (2016) and Dutta (2018), which claimed that higher volatility in crude oil market will lead to stock market to volatile greater. High volatility in crude oil market may affect macroeconomic environment and the capital market significantly (Maghyereh et al., 2016). This is because the disposable income, business costs and consumer spending on energy will be affected if crude oil prices tend to volatile greater, and it eventually will lead to stock market to fluctuate greater (Maghyereh et al., 2016). Since Malaysian stock market performance is depending on performance of Malaysian listed companies, the business costs or production costs are vital to the corporations in Malaysia. For example, if crude oil prices rise sharply, it might cause the corporations' production costs to increase and its production rates to decrease (Demirbas et al., 2017). Then, it will affect the performance of the corporations in Malaysia, thus it eventually will influence the Malaysian stock market. Besides, consumer spending on energy and disposable income of consumer that used to spend will also influence the performance of Malaysian listed companies. For instance, if the crude oil prices increase dramatically, consumers spending and disposable income will decrease as well as leading the products become more expensive (Liu et al., 2015). Then, it will affect the profits of the corporations as well as their performance, it eventually will affect Malaysian stock market significantly. Hence, volatility of Malaysian stock market tends to increase as oil market fluctuates greater.

### 4.5.3 Main Findings about Gold Market Volatility and Malaysian Stock Market Volatility

Referring to the summary in Table 4.10, the realized volatility (RV) of KLCI tends to react more to negative shock of gold price volatility (GVZ-) instead of positive shock of gold price volatility (GVZ+). It implies that a decline in volatility of gold market, the volatility of Malaysian stock market will decrease as well. The result of this research is conflicting with some previous studies such as study of Bouri et al. (2017) and Raza et al. (2016) who argued that the positive changes of GVZ would significantly affect the stock market volatility instead of negative changes of GVZ. Shahzad et al. (2017) claimed that gold can be considered as an useful tool to hedge against stock market during period of bullish and stable market condition, thus gold should be included in a diversified investment portfolio. It implies that when the economy of a country performs stably, individuals tend to involve in both gold market and stock market to construct a diversified portfolio. The liquidity of both markets will increase as people involving in the gold investment and stock investment increase, it eventually will cause gold market and stock market to volatile smaller. This is because liquidity of assets will have negative relationship with volatility of assets, which is proved by the study of Cheriyan and Lazar (2019). Hence, volatility of Malaysian stock market tends to decrease as gold market fluctuates smaller.

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## 4.6 Conclusion

In this study, ARDL model has been examined by using the ARDL long run form and bounds test in order to investigate whether OVX and GVZ have the symmetric long run relationship with RV of KLCI. Besides, ARDL bounds test is also adopted on NARDL model to test whether asymmetric relationship between OVX+, OVX-, GVZ+, GVZ- and RV of KLCI exists in long run. After applying the test on both models, it can be found that empirical results of the models are different from each other.

Before applying the ARDL bounds test on both models, unit root tests have been implemented to inspect whether RV of KLCI series, OVX series and GVZ series are stationary by using ADF, PP and KPSS tests. The results show that all of 3 series are integrated either 0 or 1 in order to support its stationarity.

After that, ARDL bounds test has been applied on ARDL model. The result of ARDL model shows that long run relationship between OVX, GVZ and RV of KLCI does exist, but the OVX and GVZ would not significantly influence the RV of KLCI. The model can be concluded that it does not have any ARCH effect and serial correlation problem after applying the ARCH LM and Breusch-Godfrey LM tests. The coefficients in the model can be considered as stable after running CUSUM test and CUSUM of squares test.

Furthermore, ARDL bounds test is also being used to examine NARDL model. The result of NARDL model shows that asymmetric relationship between OVX+, OVX-, GVZ+, GVZ- and RV of KLCI does exist in long run because OVX+ and GVZ- have significant impact on RV of KLCI. After conducting ARCH LM and Breusch-Godfrey LM tests, the model can be concluded that it does not have any ARCH effect and serial correlation problem. After running CUSUM test and CUSUM of squares test, the coefficients in the model are also considered as stable.

Lastly, it can be concluded that NARDL model is more suitable to investigate spillover effect between volatility of oil market, volatility of gold market and volatility of Malaysian stock market. This is because all exogenous variables in ARDL model are insignificant even though the model passes all the diagnostic checking. However, the OVX+ and GVZ- in the NARDL model are significant, which can be explained as there is existence of asymmetric spillover effect between Malaysian stock market volatility, crude oil market volatility and gold market volatility.

# CHAPTER 5: CONCLUSION

## 5.0 Introduction

This study will contribute to several parties which are investors, fund managers, researchers and government. There is asymmetric long run correlation between oil market, gold market, and Malaysian stock market volatility which is illustrated in the empirical results. Meanwhile, the Malaysian stock market volatility tends to react positively towards positive shock of oil price volatility, which means that the Malaysian stock market volatility will increase if the oil market volatility increases. Apart from that, Malaysian stock market volatility tends to react positively towards the negative shock of gold price volatility, which indicates that if the Malaysian stock market volatility is decreased, gold market volatility will also be decreased. This chapter will present the implication and limitation of the study along with recommendation of the limitation.

## 5.1 Implication of Study

Investors and fund managers could be the parties who reap the greatest rewards among the four parties via the study. As the Prospect Theory discussed above, individuals tend to under weigh the high probability events and overweigh the low probability events. When they suffer from the losses, they will concern and focus more on losses rather than gains as the pain will outweigh the joy (Kahneman & Tversky, 1979). Therefore, fund managers and investors could concentrate on the rise of oil market volatility as Malaysian stock market volatility tends to react more to positive shock of oil price volatility. On the other hand, they could pay more attention on the decline of gold market volatility as Malaysian stock market volatility tends to react more to negative shock of gold price volatility. By concerning on relationship between these variables and understand the stock market condition could help to prevent themselves from suffering huge losses in the stock market.

In addition, government policymakers will also gain benefit from the study. They could pay attention on oil market volatility and gold market volatility that will give impacts to the Malaysian stock market volatility. Crude oil is vital for Malaysia's business and tends to impact the country's GDP for about 20% to 30% (Workman, 2019; International Trade Administration, 2018). Moreover, gold is classified as a safe haven investment tool that hedge against the risk arising from the financial crisis and economy downturn (Joshi, 2012). The results showed that the changes in volatility of oil market and volatility of gold market will significantly affect the Malaysian stock market volatility. Therefore, government policymakers are recommended to pay more attention on the rise of oil market volatility and decline of gold market volatility as well in order to maintain stock market performance, thereby boosting the economy in Malaysia.

Furthermore, researchers could take advantages by reviewing this study. Since there is no research employs NARDL model to study about the asymmetric spillover effect on oil market volatility and gold market volatility towards the Malaysian stock market volatility, hence researchers could utilize this study for their further understanding on emerging countries stock market like Malaysia.

Apart from that, investors and fund managers are recommended to diversify the investment risk by investing in consumer staple stock. Consumer staples are classified in consumer products sector, which are claimed as the important and essential products for the individuals if they want to continue surviving in the world (Chen, 2018). Individuals tend to demand the consumer staples in order to survive regardless of the economy conditions. Besides, consumer staples stocks are determined as one of the best choices for the investors to invest, especially during the financial crisis or economic recession due to their steady growth, reliable dividends and low volatility. The consumer staples stocks are also being comprised in the portfolio to minimize the risk as the stocks tend to perform in opposite side with the consumer discretionary stocks in the market.

Moreover, parties such as fund managers, investors and government policymakers could engage in gold prices or crude oil prices risk management to mitigate the effects of prices fluctuations. By developing risk management strategies, the parties could be able to make proper decision in order to cope with the uncertainty in stock market. Financial market instruments such as futures, forward, options and swaps can be used to hedge the risk exposure. Through these instruments, a known price can be locked for a given period, thus the prices uncertainty can be eliminated. Besides, they are able to transfer the price risk to the market rather than self-insuring (Dionne, 2013). Therefore, these parties are encouraged to develop a proper risk management in order to minimize the risks associated and maximize their profits at the same time.

## 5.2 Limitations

This study is subject to several limitations. The first limitation is lack of related prior research regarding this topic, which is the asymmetric long run correlation between oil market, gold market, and stock market volatility in the case of Malaysia. There is only one research which is done by Raza et al. (2016) that studies partly on this asymmetric effect between the aforementioned markets in Malaysia. This would lead to only a few insights that could be employed in our research particularly in the context of Malaysia. Since different countries have different relationship between these markets, thus reviewing on other studies in different scope of research might provide inconsistent results to our study.

Besides, this research limits to paucity of existing literatures which studied on the non-linear correlation between oil market, gold market and stock market volatilities. Most of the prior research merely study on the linear relationship on these variables especially for gold volatility. It implies that there is insufficient reference material to lay a solid foundation for literature review, which leading to a weak understanding on the gap of this research. Therefore, accessible to a larger range of existing literature is important in this study.

Another limitation is failed of diagnostic checking due to the range of the data. Initially, the monthly data for six years from the period of year 2011 to year 2017 is being used to obtain the idlest results. However, diagnostic checking are unable to pass by using the monthly data of this period. Eventually, the data that used in this research has been changed from the starting of year 2009 until the end of year 2018, and it is able to pass all the diagnostic checking.

## 5.3 Recommendations

This study investigates the correlation between oil market, gold market and Malaysian stock market volatility. There are some recommendations can be given to the future researchers for them to come out with an ideal result.

Researchers are recommended to largely adopt Malaysia as their scope of study as well. This is because similar reference materials are needed in order to provide more literature review regarding this topic, and also to improve the consistency of results for future studies.

Besides, longer time period is suggested to be used by future researchers to run the data instead of using a short period. This is because the results will be more accurate by using the longer period data. Shorter study period might exclude some significant effects between the variable and provide a misleading result. Normally, it is expected to include a sample study period that is greater than thirty observations. However, this study included a study period of ten years as it is able to provide the idlest results.

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# APPENDICES

## Appendix 4.1 ADF Test for RV of KLCI Series at Level Basis

Null Hypothesis: RV_KLCI_ has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=12)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -6.792749 | 0.0000 |
| Test critical values: | 1% level | -3.486551 | |
| | 5% level | -2.886074 | |
| | 10% level | -2.579931 | |

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(RV_KLCI_)
Method: Least Squares
Date: 11/23/19 Time: 20:33
Sample (adjusted): 2009M03 2018M12
Included observations: 118 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| RV_KLCI_(-1) | -0.860361 | 0.126659 | -6.792749 | 0.0000 |
| D(RV_KLCI_(-1)) | -0.072984 | 0.092971 | -0.785015 | 0.4341 |
| C | 0.000751 | 0.000204 | 3.675557 | 0.0004 |

| | | | |
|---|---|---|---|
| R-squared | 0.466879 | Mean dependent var | -7.33E-08 |
| Adjusted R-squared | 0.457607 | S.D. dependent var | 0.002537 |
| S.E. of regression | 0.001868 | Akaike info criterion | -9.702656 |
| Sum squared resid | 0.000401 | Schwarz criterion | -9.632215 |
| Log likelihood | 575.4567 | Hannan-Quinn criter. | -9.674055 |
| F-statistic | 50.35539 | Durbin-Watson stat | 2.030663 |
| Prob(F-statistic) | 0.000000 | | |

## Appendix 4.2 PP Test for RV of KLCI Series at Level Basis

Null Hypothesis: RV_KLCI_ has a unit root
Exogenous: Constant
Bandwidth: 4 (Newey-West automatic) using Bartlett kernel

| | | Adj. t-Stat | Prob.* |
|---|---|---|---|
| Phillips-Perron test statistic | | -10.19061 | 0.0000 |
| Test critical values: | 1% level | -3.486064 | |
| | 5% level | -2.885863 | |
| | 10% level | -2.579818 | |

*MacKinnon (1996) one-sided p-values.

| | |
|---|---|
| Residual variance (no correction) | 3.40E-06 |
| HAC corrected variance (Bartlett kernel) | 4.18E-06 |

Phillips-Perron Test Equation
Dependent Variable: D(RV_KLCI_)
Method: Least Squares
Date: 11/23/19 Time: 20:34
Sample (adjusted): 2009M02 2018M12
Included observations: 119 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| RV_KLCI_(-1) | -0.926571 | 0.092207 | -10.04880 | 0.0000 |
| C | 0.000803 | 0.000188 | 4.265070 | 0.0000 |

| | | | |
|---|---|---|---|
| R-squared | 0.463249 | Mean dependent var | -3.02E-07 |
| Adjusted R-squared | 0.458662 | S.D. dependent var | 0.002526 |
| S.E. of regression | 0.001858 | Akaike info criterion | -9.721544 |
| Sum squared resid | 0.000404 | Schwarz criterion | -9.674836 |
| Log likelihood | 580.4318 | Hannan-Quinn criter. | -9.702577 |
| F-statistic | 100.9784 | Durbin-Watson stat | 2.010714 |
| Prob(F-statistic) | 0.000000 | | |

# Appendix 4.3 KPSS Test for RV of KLCI Series at Level Basis

Null Hypothesis: RV_KLCI_ is stationary
Exogenous: Constant
Bandwidth: 4 (Newey-West automatic) using Bartlett kernel

| | | LM-Stat. |
|---|---|---|
| Kwiatkowski-Phillips-Schmidt-Shin test statistic | | 0.400567 |
| Asymptotic critical values*: | 1% level | 0.739000 |
| | 5% level | 0.463000 |
| | 10% level | 0.347000 |

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

| | |
|---|---|
| Residual variance (no correction) | 3.39E-06 |
| HAC corrected variance (Bartlett kernel) | 4.64E-06 |

KPSS Test Equation
Dependent Variable: RV_KLCI_
Method: Least Squares
Date: 11/23/19 Time: 20:34
Sample: 2009M01 2018M12
Included observations: 120

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 0.000860 | 0.000169 | 5.092237 | 0.0000 |

| | | | |
|---|---|---|---|
| R-squared | 0.000000 | Mean dependent var | 0.000860 |
| Adjusted R-squared | 0.000000 | S.D. dependent var | 0.001849 |
| S.E. of regression | 0.001849 | Akaike info criterion | -9.739932 |
| Sum squared resid | 0.000407 | Schwarz criterion | -9.716703 |
| Log likelihood | 585.3959 | Hannan-Quinn criter. | -9.730498 |
| Durbin-Watson stat | 1.850203 | | |

## Appendix 4.4 ADF Test for OVX Series at Level Basis

Null Hypothesis: OVX has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=12)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -3.167860 | 0.0244 |
| Test critical values: | 1% level | -3.486064 | |
| | 5% level | -2.885863 | |
| | 10% level | -2.579818 | |

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(OVX)
Method: Least Squares
Date: 11/23/19 Time: 20:38
Sample (adjusted): 2009M02 2018M12
Included observations: 119 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| OVX(-1) | -0.134028 | 0.042309 | -3.167860 | 0.0020 |
| C | 0.464203 | 0.148241 | 3.131404 | 0.0022 |

| | | | |
|---|---|---|---|
| R-squared | 0.078996 | Mean dependent var | -0.003331 |
| Adjusted R-squared | 0.071125 | S.D. dependent var | 0.157500 |
| S.E. of regression | 0.151796 | Akaike info criterion | -0.915898 |
| Sum squared resid | 2.695907 | Schwarz criterion | -0.869190 |
| Log likelihood | 56.49596 | Hannan-Quinn criter. | -0.896932 |
| F-statistic | 10.03534 | Durbin-Watson stat | 1.838799 |
| Prob(F-statistic) | 0.001959 | | |

## Appendix 4.5 PP Test for OVX Series at Level Basis

Null Hypothesis: OVX has a unit root
Exogenous: Constant
Bandwidth: 4 (Newey-West automatic) using Bartlett kernel

| | | Adj. t-Stat | Prob.* |
|---|---|---|---|
| Phillips-Perron test statistic | | -3.288242 | 0.0176 |
| Test critical values: | 1% level | -3.486064 | |
| | 5% level | -2.885863 | |
| | 10% level | -2.579818 | |

*MacKinnon (1996) one-sided p-values.

| | |
|---|---|
| Residual variance (no correction) | 0.022655 |
| HAC corrected variance (Bartlett kernel) | 0.025674 |

Phillips-Perron Test Equation
Dependent Variable: D(OVX)
Method: Least Squares
Date: 11/23/19 Time: 20:38
Sample (adjusted): 2009M02 2018M12
Included observations: 119 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| OVX(-1) | -0.134028 | 0.042309 | -3.167860 | 0.0020 |
| C | 0.464203 | 0.148241 | 3.131404 | 0.0022 |

| | | | |
|---|---|---|---|
| R-squared | 0.078996 | Mean dependent var | -0.003331 |
| Adjusted R-squared | 0.071125 | S.D. dependent var | 0.157500 |
| S.E. of regression | 0.151796 | Akaike info criterion | -0.915898 |
| Sum squared resid | 2.695907 | Schwarz criterion | -0.869190 |
| Log likelihood | 56.49596 | Hannan-Quinn criter. | -0.896932 |
| F-statistic | 10.03534 | Durbin-Watson stat | 1.838799 |
| Prob(F-statistic) | 0.001959 | | |

## Appendix 4.6 KPSS Test for OVX Series at Level Basis

Null Hypothesis: OVX is stationary
Exogenous: Constant
Bandwidth: 8 (Newey-West automatic) using Bartlett kernel

| | | LM-Stat. |
|---|---|---|
| Kwiatkowski-Phillips-Schmidt-Shin test statistic | | 0.187690 |
| Asymptotic critical values*: | 1% level | 0.739000 |
| | 5% level | 0.463000 |
| | 10% level | 0.347000 |

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

| | |
|---|---|
| Residual variance (no correction) | 0.109022 |
| HAC corrected variance (Bartlett kernel) | 0.626589 |

KPSS Test Equation
Dependent Variable: OVX
Method: Least Squares
Date: 11/23/19 Time: 20:39
Sample: 2009M01 2018M12
Included observations: 120

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 3.492173 | 0.030268 | 115.3749 | 0.0000 |

| | | | |
|---|---|---|---|
| R-squared | 0.000000 | Mean dependent var | 3.492173 |
| Adjusted R-squared | 0.000000 | S.D. dependent var | 0.331570 |
| S.E. of regression | 0.331570 | Akaike info criterion | 0.638342 |
| Sum squared resid | 13.08270 | Schwarz criterion | 0.661572 |
| Log likelihood | -37.30055 | Hannan-Quinn criter. | 0.647776 |
| Durbin-Watson stat | 0.223842 | | |

## Appendix 4.7 ADF Test for GVZ Series at Level Basis

Null Hypothesis: GVZ has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=12)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -3.665739 | 0.0058 |
| Test critical values: | 1% level | -3.486064 | |
| | 5% level | -2.885863 | |
| | 10% level | -2.579818 | |

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(GVZ)
Method: Least Squares
Date: 11/23/19 Time: 20:39
Sample (adjusted): 2009M02 2018M12
Included observations: 119 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| GVZ(-1) | -0.170718 | 0.046571 | -3.665739 | 0.0004 |
| C | 0.481334 | 0.134488 | 3.579019 | 0.0005 |

| | | | |
|---|---|---|---|
| R-squared | 0.103020 | Mean dependent var | -0.009119 |
| Adjusted R-squared | 0.095353 | S.D. dependent var | 0.156485 |
| S.E. of regression | 0.148838 | Akaike info criterion | -0.955256 |
| Sum squared resid | 2.591862 | Schwarz criterion | -0.908549 |
| Log likelihood | 58.83776 | Hannan-Quinn criter. | -0.936290 |
| F-statistic | 13.43764 | Durbin-Watson stat | 2.193377 |
| Prob(F-statistic) | 0.000372 | | |

## Appendix 4.8 PP Test for GVZ Series at Level Basis

Null Hypothesis: GVZ has a unit root
Exogenous: Constant
Bandwidth: 0 (Newey-West automatic) using Bartlett kernel

| | | Adj. t-Stat | Prob.* |
|---|---|---|---|
| Phillips-Perron test statistic | | -3.665739 | 0.0058 |
| Test critical values: | 1% level | -3.486064 | |
| | 5% level | -2.885863 | |
| | 10% level | -2.579818 | |

*MacKinnon (1996) one-sided p-values.

| | |
|---|---|
| Residual variance (no correction) | 0.021780 |
| HAC corrected variance (Bartlett kernel) | 0.021780 |

Phillips-Perron Test Equation
Dependent Variable: D(GVZ)
Method: Least Squares
Date: 11/23/19 Time: 20:39
Sample (adjusted): 2009M02 2018M12
Included observations: 119 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| GVZ(-1) | -0.170718 | 0.046571 | -3.665739 | 0.0004 |
| C | 0.481334 | 0.134488 | 3.579019 | 0.0005 |

| | | | |
|---|---|---|---|
| R-squared | 0.103020 | Mean dependent var | -0.009119 |
| Adjusted R-squared | 0.095353 | S.D. dependent var | 0.156485 |
| S.E. of regression | 0.148838 | Akaike info criterion | -0.955256 |
| Sum squared resid | 2.591862 | Schwarz criterion | -0.908549 |
| Log likelihood | 58.83776 | Hannan-Quinn criter. | -0.936290 |
| F-statistic | 13.43764 | Durbin-Watson stat | 2.193377 |
| Prob(F-statistic) | 0.000372 | | |

# Appendix 4.9 KPSS Test for GVZ Series at Level Basis

Null Hypothesis: GVZ is stationary
Exogenous: Constant
Bandwidth: 8 (Newey-West automatic) using Bartlett kernel

| | | LM-Stat. |
|---|---|---|
| Kwiatkowski-Phillips-Schmidt-Shin test statistic | | 1.112347 |
| Asymptotic critical values*: | 1% level | 0.739000 |
| | 5% level | 0.463000 |
| | 10% level | 0.347000 |

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

| | |
|---|---|
| Residual variance (no correction) | 0.085726 |
| HAC corrected variance (Bartlett kernel) | 0.483111 |

KPSS Test Equation
Dependent Variable: GVZ
Method: Least Squares
Date: 11/23/19 Time: 20:39
Sample: 2009M01 2018M12
Included observations: 120

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 2.870624 | 0.026840 | 106.9532 | 0.0000 |

| | | | |
|---|---|---|---|
| R-squared | 0.000000 | Mean dependent var | 2.870624 |
| Adjusted R-squared | 0.000000 | S.D. dependent var | 0.294017 |
| S.E. of regression | 0.294017 | Akaike info criterion | 0.397943 |
| Sum squared resid | 10.28711 | Schwarz criterion | 0.421172 |
| Log likelihood | -22.87659 | Hannan-Quinn criter. | 0.407377 |
| Durbin-Watson stat | 0.281852 | | |

## Appendix 4.10 ADF Test for RV of KLCI Series at 1st Difference

Null Hypothesis: D(RV_KLCI_) has a unit root
Exogenous: Constant
Lag Length: 3 (Automatic - based on SIC, maxlag=12)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -8.795352 | 0.0000 |
| Test critical values: | 1% level | -3.488063 | |
| | 5% level | -2.886732 | |
| | 10% level | -2.580281 | |

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(RV_KLCI_,2)
Method: Least Squares
Date: 01/12/20 Time: 17:10
Sample (adjusted): 2009M06 2018M12
Included observations: 115 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| D(RV_KLCI_(-1)) | -2.368018 | 0.269235 | -8.795352 | 0.0000 |
| D(RV_KLCI_(-1),2) | 0.689147 | 0.203095 | 3.393220 | 0.0010 |
| D(RV_KLCI_(-2),2) | 0.213990 | 0.129226 | 1.655933 | 0.1006 |
| D(RV_KLCI_(-3),2) | 0.114141 | 0.061512 | 1.855595 | 0.0662 |
| C | -0.000109 | 0.000122 | -0.894621 | 0.3729 |

| | | | |
|---|---|---|---|
| R-squared | 0.842539 | Mean dependent var | 0.000114 |
| Adjusted R-squared | 0.836813 | S.D. dependent var | 0.003216 |
| S.E. of regression | 0.001299 | Akaike info criterion | -10.41173 |
| Sum squared resid | 0.000186 | Schwarz criterion | -10.29238 |
| Log likelihood | 603.6743 | Hannan-Quinn criter. | -10.36329 |
| F-statistic | 147.1467 | Durbin-Watson stat | 2.056323 |
| Prob(F-statistic) | 0.000000 | | |

## Appendix 4.11 PP Test for RV of KLCI Series at 1st Difference

Null Hypothesis: D(RV_KLCI_) has a unit root
Exogenous: Constant
Bandwidth: 22 (Newey-West automatic) using Bartlett kernel

| | | Adj. t-Stat | Prob.* |
|---|---|---|---|
| Phillips-Perron test statistic | | -46.50573 | 0.0001 |
| Test critical values: | 1% level | -3.486551 | |
| | 5% level | -2.886074 | |
| | 10% level | -2.579931 | |

*MacKinnon (1996) one-sided p-values.

| | |
|---|---|
| Residual variance (no correction) | 4.77E-06 |
| HAC corrected variance (Bartlett kernel) | 4.63E-07 |

Phillips-Perron Test Equation
Dependent Variable: D(RV_KLCI_,2)
Method: Least Squares
Date: 01/12/20 Time: 17:12
Sample (adjusted): 2009M03 2018M12
Included observations: 118 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| D(RV_KLCI_(-1)) | -1.502988 | 0.080252 | -18.72826 | 0.0000 |
| C | 8.85E-07 | 0.000203 | 0.004365 | 0.9965 |

| | | | |
|---|---|---|---|
| R-squared | 0.751472 | Mean dependent var | -1.98E-06 |
| Adjusted R-squared | 0.749329 | S.D. dependent var | 0.004398 |
| S.E. of regression | 0.002202 | Akaike info criterion | -9.382255 |
| Sum squared resid | 0.000562 | Schwarz criterion | -9.335294 |
| Log likelihood | 555.5530 | Hannan-Quinn criter. | -9.363187 |
| F-statistic | 350.7477 | Durbin-Watson stat | 2.438480 |
| Prob(F-statistic) | 0.000000 | | |

## Appendix 4.12 KPSS Test for RV of KLCI Series at 1st Difference

Null Hypothesis: D(RV_KLCI_) is stationary
Exogenous: Constant
Bandwidth: 49 (Newey-West automatic) using Bartlett kernel

| | | LM-Stat. |
|---|---|---|
| Kwiatkowski-Phillips-Schmidt-Shin test statistic | | 0.216468 |
| Asymptotic critical values*: | 1% level | 0.739000 |
| | 5% level | 0.463000 |
| | 10% level | 0.347000 |

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

| | |
|---|---|
| Residual variance (no correction) | 6.33E-06 |
| HAC corrected variance (Bartlett kernel) | 1.58E-07 |

KPSS Test Equation
Dependent Variable: D(RV_KLCI_)
Method: Least Squares
Date: 01/12/20 Time: 17:14
Sample (adjusted): 2009M02 2018M12
Included observations: 119 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | -3.02E-07 | 0.000232 | -0.001306 | 0.9990 |

| | | | |
|---|---|---|---|
| R-squared | 0.000000 | Mean dependent var | -3.02E-07 |
| Adjusted R-squared | 0.000000 | S.D. dependent var | 0.002526 |
| S.E. of regression | 0.002526 | Akaike info criterion | -9.116128 |
| Sum squared resid | 0.000753 | Schwarz criterion | -9.092774 |
| Log likelihood | 543.4096 | Hannan-Quinn criter. | -9.106645 |
| Durbin-Watson stat | 3.005794 | | |

## Appendix 4.13 ADF Test for OVX Series at 1st Difference

Null Hypothesis: D(OVX) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=12)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -10.47424 | 0.0000 |
| Test critical values: | 1% level | -3.486551 | |
| | 5% level | -2.886074 | |
| | 10% level | -2.579931 | |

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(OVX,2)
Method: Least Squares
Date: 01/12/20 Time: 17:15
Sample (adjusted): 2009M03 2018M12
Included observations: 118 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| D(OVX(-1)) | -0.970817 | 0.092686 | -10.47424 | 0.0000 |
| C | -0.002283 | 0.014586 | -0.156499 | 0.8759 |

| | | | |
|---|---|---|---|
| R-squared | 0.486065 | Mean dependent var | 0.000342 |
| Adjusted R-squared | 0.481635 | S.D. dependent var | 0.220044 |
| S.E. of regression | 0.158426 | Akaike info criterion | -0.830253 |
| Sum squared resid | 2.911464 | Schwarz criterion | -0.783292 |
| Log likelihood | 50.98494 | Hannan-Quinn criter. | -0.811186 |
| F-statistic | 109.7096 | Durbin-Watson stat | 1.999244 |
| Prob(F-statistic) | 0.000000 | | |

## Appendix 4.14 PP Test for OVX Series at 1st Difference

Null Hypothesis: D(OVX) has a unit root
Exogenous: Constant
Bandwidth: 9 (Newey-West automatic) using Bartlett kernel

| | | Adj. t-Stat | Prob.* |
|---|---|---|---|
| Phillips-Perron test statistic | | -10.57224 | 0.0000 |
| Test critical values: | 1% level | -3.486551 | |
| | 5% level | -2.886074 | |
| | 10% level | -2.579931 | |

*MacKinnon (1996) one-sided p-values.

| | |
|---|---|
| Residual variance (no correction) | 0.024673 |
| HAC corrected variance (Bartlett kernel) | 0.017335 |

Phillips-Perron Test Equation
Dependent Variable: D(OVX,2)
Method: Least Squares
Date: 01/12/20 Time: 17:15
Sample (adjusted): 2009M03 2018M12
Included observations: 118 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| D(OVX(-1)) | -0.970817 | 0.092686 | -10.47424 | 0.0000 |
| C | -0.002283 | 0.014586 | -0.156499 | 0.8759 |

| | | | |
|---|---|---|---|
| R-squared | 0.486065 | Mean dependent var | 0.000342 |
| Adjusted R-squared | 0.481635 | S.D. dependent var | 0.220044 |
| S.E. of regression | 0.158426 | Akaike info criterion | -0.830253 |
| Sum squared resid | 2.911464 | Schwarz criterion | -0.783292 |
| Log likelihood | 50.98494 | Hannan-Quinn criter. | -0.811186 |
| F-statistic | 109.7096 | Durbin-Watson stat | 1.999244 |
| Prob(F-statistic) | 0.000000 | | |

## Appendix 4.15 KPSS Test for OVX Series at 1st Difference

Null Hypothesis: D(OVX) is stationary
Exogenous: Constant
Bandwidth: 8 (Newey-West automatic) using Bartlett kernel

| | | LM-Stat. |
|---|---|---|
| Kwiatkowski-Phillips-Schmidt-Shin test statistic | | 0.240378 |
| Asymptotic critical values*: | 1% level | 0.739000 |
| | 5% level | 0.463000 |
| | 10% level | 0.347000 |

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

| | |
|---|---|
| Residual variance (no correction) | 0.024598 |
| HAC corrected variance (Bartlett kernel) | 0.018861 |

KPSS Test Equation
Dependent Variable: D(OVX)
Method: Least Squares
Date: 01/12/20 Time: 17:16
Sample (adjusted): 2009M02 2018M12
Included observations: 119 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | -0.003331 | 0.014438 | -0.230695 | 0.8180 |

| | | | |
|---|---|---|---|
| R-squared | 0.000000 | Mean dependent var | -0.003331 |
| Adjusted R-squared | 0.000000 | S.D. dependent var | 0.157500 |
| S.E. of regression | 0.157500 | Akaike info criterion | -0.850414 |
| Sum squared resid | 2.927140 | Schwarz criterion | -0.827060 |
| Log likelihood | 51.59962 | Hannan-Quinn criter. | -0.840930 |
| Durbin-Watson stat | 1.935357 | | |

# Appendix 4.16 ADF Test for GVZ Series at 1st Difference

Null Hypothesis: D(GVZ) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=12)

| | | t-Statistic | Prob.* |
|---|---|---|---|
| Augmented Dickey-Fuller test statistic | | -12.78461 | 0.0000 |
| Test critical values: | 1% level | -3.486551 | |
| | 5% level | -2.886074 | |
| | 10% level | -2.579931 | |

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(GVZ,2)
Method: Least Squares
Date: 01/12/20 Time: 17:17
Sample (adjusted): 2009M03 2018M12
Included observations: 118 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| D(GVZ(-1)) | -1.176044 | 0.091989 | -12.78461 | 0.0000 |
| C | -0.010903 | 0.014339 | -0.760416 | 0.4485 |

| | | | |
|---|---|---|---|
| R-squared | 0.584893 | Mean dependent var | 0.001705 |
| Adjusted R-squared | 0.581315 | S.D. dependent var | 0.240149 |
| S.E. of regression | 0.155390 | Akaike info criterion | -0.868948 |
| Sum squared resid | 2.800958 | Schwarz criterion | -0.821987 |
| Log likelihood | 53.26791 | Hannan-Quinn criter. | -0.849880 |
| F-statistic | 163.4463 | Durbin-Watson stat | 1.958618 |
| Prob(F-statistic) | 0.000000 | | |

## Appendix 4.17 PP Test for GVZ Series at 1st Difference

Null Hypothesis: D(GVZ) has a unit root
Exogenous: Constant
Bandwidth: 9 (Newey-West automatic) using Bartlett kernel

| | | Adj. t-Stat | Prob.* |
|---|---|---|---|
| Phillips-Perron test statistic | | -14.12486 | 0.0000 |
| Test critical values: | 1% level | -3.486551 | |
| | 5% level | -2.886074 | |
| | 10% level | -2.579931 | |

*MacKinnon (1996) one-sided p-values.

| | |
|---|---|
| Residual variance (no correction) | 0.023737 |
| HAC corrected variance (Bartlett kernel) | 0.012430 |

Phillips-Perron Test Equation
Dependent Variable: D(GVZ,2)
Method: Least Squares
Date: 01/12/20 Time: 17:17
Sample (adjusted): 2009M03 2018M12
Included observations: 118 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| D(GVZ(-1)) | -1.176044 | 0.091989 | -12.78461 | 0.0000 |
| C | -0.010903 | 0.014339 | -0.760416 | 0.4485 |

| | | | |
|---|---|---|---|
| R-squared | 0.584893 | Mean dependent var | 0.001705 |
| Adjusted R-squared | 0.581315 | S.D. dependent var | 0.240149 |
| S.E. of regression | 0.155390 | Akaike info criterion | -0.868948 |
| Sum squared resid | 2.800958 | Schwarz criterion | -0.821987 |
| Log likelihood | 53.26791 | Hannan-Quinn criter. | -0.849880 |
| F-statistic | 163.4463 | Durbin-Watson stat | 1.958618 |
| Prob(F-statistic) | 0.000000 | | |

## Appendix 4.18 KPSS Test for GVZ Series at 1st Difference

Null Hypothesis: D(GVZ) is stationary
Exogenous: Constant
Bandwidth: 9 (Newey-West automatic) using Bartlett kernel

| | | LM-Stat. |
|---|---|---|
| Kwiatkowski-Phillips-Schmidt-Shin test statistic | | 0.108177 |
| Asymptotic critical values*: | 1% level | 0.739000 |
| | 5% level | 0.463000 |
| | 10% level | 0.347000 |

*Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1)

| | |
|---|---|
| Residual variance (no correction) | 0.024282 |
| HAC corrected variance (Bartlett kernel) | 0.009684 |

KPSS Test Equation
Dependent Variable: D(GVZ)
Method: Least Squares
Date: 01/12/20 Time: 17:18
Sample (adjusted): 2009M02 2018M12
Included observations: 119 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | -0.009119 | 0.014345 | -0.635698 | 0.5262 |

| | | | |
|---|---|---|---|
| R-squared | 0.000000 | Mean dependent var | -0.009119 |
| Adjusted R-squared | 0.000000 | S.D. dependent var | 0.156485 |
| S.E. of regression | 0.156485 | Akaike info criterion | -0.863342 |
| Sum squared resid | 2.889541 | Schwarz criterion | -0.839988 |
| Log likelihood | 52.36884 | Hannan-Quinn criter. | -0.853859 |
| Durbin-Watson stat | 2.335286 | | |

## Appendix 4.19 ARDL Bounds Test for Linear Model

ARDL Long Run Form and Bounds Test
Dependent Variable: D(RV_KLCI_)
Selected Model: ARDL(4, 0, 0)
Case 2: Restricted Constant and No Trend
Date: 12/22/19 Time: 20:00
Sample: 2009M01 2018M12
Included observations: 116

Conditional Error Correction Regression

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | -0.001596 | 0.001439 | -1.109068 | 0.2698 |
| RV_KLCI_(-1)* | -0.716455 | 0.100934 | -7.098270 | 0.0000 |
| OVX** | 0.000367 | 0.000356 | 1.030577 | 0.3050 |
| GVZ** | 0.000288 | 0.000405 | 0.710396 | 0.4790 |
| D(RV_KLCI_(-1)) | -0.215428 | 0.092384 | -2.331872 | 0.0215 |
| D(RV_KLCI_(-2)) | -0.133259 | 0.077740 | -1.714173 | 0.0893 |
| D(RV_KLCI_(-3)) | 0.108647 | 0.056821 | 1.912101 | 0.0585 |

* p-value incompatible with t-Bounds distribution.
** Variable interpreted as Z = Z(-1) + D(Z).

Levels Equation
Case 2: Restricted Constant and No Trend

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| OVX | 0.000512 | 0.000487 | 1.052435 | 0.2949 |
| GVZ | 0.000402 | 0.000560 | 0.717191 | 0.4748 |
| C | -0.002228 | 0.001958 | -1.137881 | 0.2577 |

EC = RV_KLCI_ - (0.0005*OVX + 0.0004*GVZ -0.0022 )

F-Bounds Test — Null Hypothesis: No levels relationship

| Test Statistic | Value | Signif. | I(0) | I(1) |
|---|---|---|---|---|
| | | | Asymptotic: n=1000 | |
| F-statistic | 13.12191 | 10% | 2.63 | 3.35 |
| k | 2 | 5% | 3.1 | 3.87 |
| | | 2.5% | 3.55 | 4.38 |
| | | 1% | 4.13 | 5 |
| | | | Finite Sample: | |
| Actual Sample Size | 116 | | n=80 | |
| | | 10% | 2.713 | 3.453 |
| | | 5% | 3.235 | 4.053 |
| | | 1% | 4.358 | 5.393 |

## Appendix 4.20 ARCH LM Test for Linear Model

Heteroskedasticity Test: ARCH

| | | | |
|---|---|---|---|
| F-statistic | 0.693168 | Prob. F(12,91) | 0.7541 |
| Obs*R-squared | 8.710143 | Prob. Chi-Square(12) | 0.7275 |

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 12/22/19 Time: 20:02
Sample (adjusted): 2010M05 2018M12
Included observations: 104 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 1.10E-06 | 4.77E-07 | 2.310320 | 0.0231 |
| RESID^2(-1) | -0.021767 | 0.104640 | -0.208021 | 0.8357 |
| RESID^2(-2) | 0.236671 | 0.104628 | 2.262020 | 0.0261 |
| RESID^2(-3) | 0.091241 | 0.107663 | 0.847465 | 0.3990 |
| RESID^2(-4) | -0.094728 | 0.108091 | -0.876373 | 0.3831 |
| RESID^2(-5) | 0.034693 | 0.108223 | 0.320570 | 0.7493 |
| RESID^2(-6) | -0.024310 | 0.108960 | -0.223109 | 0.8240 |
| RESID^2(-7) | -0.033334 | 0.108979 | -0.305876 | 0.7604 |
| RESID^2(-8) | -0.111781 | 0.163231 | -0.684800 | 0.4952 |
| RESID^2(-9) | -0.018524 | 0.161158 | -0.114942 | 0.9087 |
| RESID^2(-10) | 0.007020 | 0.153941 | 0.045599 | 0.9637 |
| RESID^2(-11) | -0.023370 | 0.147083 | -0.158891 | 0.8741 |
| RESID^2(-12) | -0.081851 | 0.147451 | -0.555104 | 0.5802 |

| | | | |
|---|---|---|---|
| R-squared | 0.083751 | Mean dependent var | 1.11E-06 |
| Adjusted R-squared | -0.037073 | S.D. dependent var | 3.35E-06 |
| S.E. of regression | 3.41E-06 | Akaike info criterion | -22.22357 |
| Sum squared resid | 1.06E-09 | Schwarz criterion | -21.89302 |
| Log likelihood | 1168.626 | Hannan-Quinn criter. | -22.08966 |
| F-statistic | 0.693168 | Durbin-Watson stat | 2.002094 |
| Prob(F-statistic) | 0.754092 | | |

## Appendix 4.21 Breusch-Godfrey LM Test for Linear Model

Breusch-Godfrey Serial Correlation LM Test:

| | | | |
|---|---|---|---|
| F-statistic | 2.125165 | Prob. F(1,108) | 0.1478 |
| Obs*R-squared | 2.238536 | Prob. Chi-Square(1) | 0.1346 |

Test Equation:
Dependent Variable: RESID
Method: ARDL
Date: 12/31/19 Time: 21:13
Sample: 2009M05 2018M12
Included observations: 116
Presample missing value lagged residuals set to zero.

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| RV_KLCI_(-1) | 0.062285 | 0.071650 | 0.869294 | 0.3866 |
| RV_KLCI_(-2) | -0.002038 | 0.055432 | -0.036762 | 0.9707 |
| RV_KLCI_(-3) | -0.002195 | 0.055431 | -0.039603 | 0.9685 |
| RV_KLCI_(-4) | -0.012599 | 0.057187 | -0.220322 | 0.8260 |
| OVX | -2.17E-05 | 0.000355 | -0.061238 | 0.9513 |
| GVZ | -6.09E-05 | 0.000405 | -0.150343 | 0.8808 |
| C | 0.000210 | 0.001439 | 0.145616 | 0.8845 |
| RESID(-1) | -0.173531 | 0.119037 | -1.457795 | 0.1478 |

| | | | |
|---|---|---|---|
| R-squared | 0.019298 | Mean dependent var | -9.16E-20 |
| Adjusted R-squared | -0.044266 | S.D. dependent var | 0.001074 |
| S.E. of regression | 0.001097 | Akaike info criterion | -10.72530 |
| Sum squared resid | 0.000130 | Schwarz criterion | -10.53540 |
| Log likelihood | 630.0673 | Hannan-Quinn criter. | -10.64821 |
| F-statistic | 0.303595 | Durbin-Watson stat | 1.940789 |
| Prob(F-statistic) | 0.950899 | | |

## Appendix 4.22 ARDL Bounds Test for Non-linear Model

ARDL Long Run Form and Bounds Test
Dependent Variable: D(RV_KLCI_)
Selected Model: ARDL(8, 0, 0, 0, 0)
Case 2: Restricted Constant and No Trend
Date: 12/22/19 Time: 20:04
Sample: 2009M01 2018M12
Included observations: 112

Conditional Error Correction Regression

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 0.001680 | 0.000490 | 3.428245 | 0.0009 |
| RV_KLCI_(-1)* | -1.186723 | 0.199297 | -5.954557 | 0.0000 |
| OVX_POS** | 0.000682 | 0.000370 | 1.843080 | 0.0683 |
| OVX_NEG** | -0.001171 | 0.000874 | -1.340172 | 0.1833 |
| GVZ_POS** | 0.000208 | 0.000531 | 0.391302 | 0.6964 |
| GVZ_NEG** | 0.001913 | 0.000983 | 1.945792 | 0.0545 |
| D(RV_KLCI_(-1)) | 0.169484 | 0.165178 | 1.026065 | 0.3074 |
| D(RV_KLCI_(-2)) | 0.332291 | 0.145735 | 2.280104 | 0.0247 |
| D(RV_KLCI_(-3)) | 0.271974 | 0.126352 | 2.152514 | 0.0338 |
| D(RV_KLCI_(-4)) | 0.170880 | 0.107903 | 1.583643 | 0.1165 |
| D(RV_KLCI_(-5)) | 0.137512 | 0.099002 | 1.388977 | 0.1680 |
| D(RV_KLCI_(-6)) | 0.117281 | 0.079473 | 1.475731 | 0.1432 |
| D(RV_KLCI_(-7)) | 0.055742 | 0.056574 | 0.985292 | 0.3269 |

* p-value incompatible with t-Bounds distribution.
** Variable interpreted as Z = Z(-1) + D(Z).

Levels Equation
Case 2: Restricted Constant and No Trend

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| OVX_POS | 0.000575 | 0.000293 | 1.959066 | 0.0529 |
| OVX_NEG | -0.000987 | 0.000701 | -1.408436 | 0.1621 |
| GVZ_POS | 0.000175 | 0.000450 | 0.389450 | 0.6978 |
| GVZ_NEG | 0.001612 | 0.000770 | 2.092489 | 0.0390 |
| C | 0.001416 | 0.000325 | 4.353310 | 0.0000 |

EC = RV_KLCI_ - (0.0006*OVX_POS -0.0010*OVX_NEG + 0.0002*GVZ_POS
+ 0.0016*GVZ_NEG + 0.0014 )

F-Bounds Test — Null Hypothesis: No levels relationship

| Test Statistic | Value | Signif. | I(0) | I(1) |
|---|---|---|---|---|
| | | | Asymptotic: n=1000 | |
| F-statistic | 6.284291 | 10% | 2.2 | 3.09 |
| k | 4 | 5% | 2.56 | 3.49 |
| | | 2.5% | 2.88 | 3.87 |
| | | 1% | 3.29 | 4.37 |
| | | | Finite Sample: | |
| Actual Sample Size | 112 | | n=80 | |

| | | | |
|---|---|---|---|
| | 10% | 2.303 | 3.22 |
| | 5% | 2.688 | 3.698 |
| | 1% | 3.602 | 4.787 |

## Appendix 4.23 ARCH LM Test for Non-linear Model

Heteroskedasticity Test: ARCH

| | | | |
|---|---|---|---|
| F-statistic | 0.366731 | Prob. F(12,87) | 0.9717 |
| Obs*R-squared | 4.814809 | Prob. Chi-Square(12) | 0.9639 |

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 12/22/19 Time: 20:06
Sample (adjusted): 2010M09 2018M12
Included observations: 100 after adjustments

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 1.07E-06 | 4.48E-07 | 2.394657 | 0.0188 |
| RESID^2(-1) | -0.040777 | 0.107171 | -0.380482 | 0.7045 |
| RESID^2(-2) | 0.164778 | 0.107063 | 1.539072 | 0.1274 |
| RESID^2(-3) | -0.021738 | 0.108531 | -0.200291 | 0.8417 |
| RESID^2(-4) | -0.066823 | 0.108564 | -0.615515 | 0.5398 |
| RESID^2(-5) | 0.071013 | 0.108543 | 0.654238 | 0.5147 |
| RESID^2(-6) | -0.012115 | 0.109726 | -0.110408 | 0.9123 |
| RESID^2(-7) | -0.041369 | 0.109725 | -0.377023 | 0.7071 |
| RESID^2(-8) | -0.102448 | 0.165901 | -0.617526 | 0.5385 |
| RESID^2(-9) | -0.019276 | 0.164873 | -0.116917 | 0.9072 |
| RESID^2(-10) | -0.012243 | 0.170098 | -0.071978 | 0.9428 |
| RESID^2(-11) | -0.071921 | 0.161645 | -0.444932 | 0.6575 |
| RESID^2(-12) | -0.067718 | 0.162450 | -0.416854 | 0.6778 |

| | | | |
|---|---|---|---|
| R-squared | 0.048148 | Mean dependent var | 9.36E-07 |
| Adjusted R-squared | -0.083142 | S.D. dependent var | 2.92E-06 |
| S.E. of regression | 3.04E-06 | Akaike info criterion | -22.44899 |
| Sum squared resid | 8.04E-10 | Schwarz criterion | -22.11032 |
| Log likelihood | 1135.450 | Hannan-Quinn criter. | -22.31192 |
| F-statistic | 0.366731 | Durbin-Watson stat | 2.002044 |
| Prob(F-statistic) | 0.971721 | | |

## Appendix 4.24 Breusch-Godfrey LM Test for Non-linear Model

Breusch-Godfrey Serial Correlation LM Test:

| | | | |
|---|---|---|---|
| F-statistic | 1.184501 | Prob. F(12,87) | 0.3069 |
| Obs*R-squared | 15.72875 | Prob. Chi-Square(12) | 0.2040 |

Test Equation:
Dependent Variable: RESID
Method: ARDL
Date: 12/22/19 Time: 20:06
Sample: 2009M09 2018M12
Included observations: 112
Presample missing value lagged residuals set to zero.

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| RV_KLCI_(-1) | 0.483448 | 0.677453 | 0.713625 | 0.4774 |
| RV_KLCI_(-2) | -0.177232 | 0.443119 | -0.399965 | 0.6902 |
| RV_KLCI_(-3) | -0.015047 | 0.324111 | -0.046427 | 0.9631 |
| RV_KLCI_(-4) | 0.210237 | 0.301181 | 0.698043 | 0.4870 |
| RV_KLCI_(-5) | 0.009384 | 0.193977 | 0.048378 | 0.9615 |
| RV_KLCI_(-6) | 0.002926 | 0.125564 | 0.023303 | 0.9815 |
| RV_KLCI_(-7) | -0.021879 | 0.121633 | -0.179882 | 0.8577 |
| RV_KLCI_(-8) | 0.045052 | 0.091232 | 0.493822 | 0.6227 |
| OVX_POS | -0.000289 | 0.000499 | -0.579210 | 0.5639 |
| OVX_NEG | 0.000225 | 0.000952 | 0.235968 | 0.8140 |
| GVZ_POS | -1.05E-05 | 0.000534 | -0.019699 | 0.9843 |
| GVZ_NEG | -0.000474 | 0.001169 | -0.405654 | 0.6860 |
| C | -0.000635 | 0.000971 | -0.653745 | 0.5150 |
| RESID(-1) | -0.496116 | 0.675611 | -0.734321 | 0.4647 |
| RESID(-2) | 0.258772 | 0.449583 | 0.575583 | 0.5664 |
| RESID(-3) | -0.206516 | 0.279031 | -0.740121 | 0.4612 |
| RESID(-4) | -0.217758 | 0.272826 | -0.798155 | 0.4270 |
| RESID(-5) | 0.189787 | 0.207527 | 0.914517 | 0.3630 |
| RESID(-6) | -0.126814 | 0.170586 | -0.743401 | 0.4592 |
| RESID(-7) | -0.099907 | 0.162619 | -0.614360 | 0.5406 |
| RESID(-8) | -0.043287 | 0.157411 | -0.274990 | 0.7840 |
| RESID(-9) | -0.064661 | 0.130290 | -0.496282 | 0.6209 |
| RESID(-10) | -0.110365 | 0.125406 | -0.880062 | 0.3813 |
| RESID(-11) | -0.200421 | 0.125280 | -1.599791 | 0.1133 |
| RESID(-12) | -0.054619 | 0.127943 | -0.426897 | 0.6705 |

| | | | |
|---|---|---|---|
| R-squared | 0.140435 | Mean dependent var | 1.24E-18 |
| Adjusted R-squared | -0.096686 | S.D. dependent var | 0.000949 |
| S.E. of regression | 0.000994 | Akaike info criterion | -10.79660 |
| Sum squared resid | 8.59E-05 | Schwarz criterion | -10.18980 |
| Log likelihood | 629.6098 | Hannan-Quinn criter. | -10.55040 |
| F-statistic | 0.592251 | Durbin-Watson stat | 1.961217 |
| Prob(F-statistic) | 0.927244 | | |