

THE PRICE-VOLUME RELATIONSHIP IN WTI AND
BRENT CRUDE OIL FUTURES MARKETS DURING
CRISES

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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.
- (4) The word count of this research report is 8177 words.

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LIST OF ABBERVATIONS

AR	Autoregressive model
ARCH	AutoRegressive Conditional Heteroscedasticity
AR-GARCH	AutoRegressive - Generalized Autoregressive Conditional Heteroscedasticity
ARMA	Autoregressive-Moving Average model
CCF	Cross-Correlation Function
CME	Chicago Mercantile Exchange
CT	Central Time
EST	Eastern Standard Time
GARCH	Generalized Autoregressive Conditional Heteroscedasticity
ICE	Crude Oil Futures and Intercontinental Exchange
IDT	Information-Driven Trade
JB	Jarque-Bera
KLOFFE	Kuala Lumpur Options and Financial Futures Exchange
LDT	Liquidity-Driven Trade
MDH	Mixture of Distribution Hypothesis
NYMEX	New York Mercantile Exchange
OLS	Ordinary Least Square
SAIH	Sequential Arrival of Information Hypothesis
UK	United of Kingdom
US	United States of America
WTI	West Texas Intermediate

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ABSTRACT

This study examines price-volume relationship in West Texas Intermediate (WTI) and Brent crude oil futures markets during crises from January 2008 to December 2015. Based on cross-correlation function, the results provide two findings. First, there is a causality relationship from past trading volume to forecast return in WTI crude oil futures markets in both crises while only return affect the trading volume in Brent crude oil futures markets during 2014 Oil Crisis. Second, it is found that Information-Driven Trade hypothesis is supported in WTI crude oil futures markets during the 2008 Global Financial Crisis. In addition, the Liquidity-Driven Trade hypothesis is supported in Brent crude oil futures markets during 2014 Oil Crisis. Based on both findings, this study suggests that investors should rely on trading volume as a proxy for information about unexpected return. They can further use return to predict trading volume if the fundamental factors such as supply of inventory and consumption growth that cause the occurrence of oil price bubbles.

CHAPTER 1: INTRODUCTION

1.1 The Importance of Price-Volume Relation

Price-volume relation is important in financial markets because it provides a signal of price movement for market participants in futures markets. It provides information flow and insight into the structure of financial markets such as how the information is disseminated, rate of information flow to the market and others. Market participants cannot receive the information at the same time, so the arrival of new information is a key to affect the trading activities in financial markets.

Besides that, the behaviour of market participants can be recognized like hedgers or speculators. Hedgers and speculators are act differently; hedgers are responding strongly to price changes. They are preferable to short their contracts when the futures price increase. They further reduce their short selling positions when the futures prices decrease in order to offset the price risks. Hence they are frequently changed their positions over the time when markets are inefficient.

Speculators approach the financial markets with the intention to make largest profit by buying low and selling high. They intend for making a high return on their capital by looking the long-term price movement no matter in bull or bear market. When the assets price is increasing, they are preferable long futures contracts to hedge the risk and vice versa. Speculators are short-term motivated traders and they

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are willing to take a higher risk in their investment compared to hedgers (Tang & Tang, 2014).

Table 1.1: Characteristics between Brent and WTI crude oil futures contracts

	Brent	WTI
Market	Intercontinental Exchange (ICE)	New York Mercantile Exchange (NYMEX)
Market participants	About two-thirds around the world	Mostly in United States
Location extracted	North Sea (Brent, Forties, Oseberg, Ekofisk)	Wells in United States
Supply of crude oil	Water-borne	Land-locked
Refined location	Northwest Europe	Midwest and Gulf Coast region in US
Density (API Gravity)	38.3	39.6 (lighter)
Level of sweetness	0.37% sulphur	0.24% sulphur (sweeter)
Usage	Diesel fuel, gasoline and middle distillates	Gasoline refining
Transportation cost	Lower (due to the supply is water-borne)	Higher (due to transport via pipeline)
Major benchmark	Europe and Africa	America
Refined venue	Northwest Europe	Midwest and Gulf regions of US

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Table 1.1: (Continue)

	Brent	WTI
Trading hours	*UK Hours: 01:00 (23.00 on Sundays) - 23:00 London local time. *EST Hours: 20:00 (18:00 on Sundays) - 18:00 (next day) *Chicago Hours: 19:00 (17:00 on Sundays) -17:00 (next day) *Singapore Hours: 08:00 (06:00 on Monday) - 06:00 (next day)	*CME Globex: Sunday - Friday 6:00 p.m. - 5:00 p.m. (5:00 p.m. - 4:00 p.m. Chicago Time/CT) with a 60-minute break each day beginning at 5:00 p.m. (4:00 p.m. CT)

1.2 Problem Statement

In the context of financial markets, problem of asymmetric information would occur where one party has different information to another in one transaction. They do not have the same information in doing their trading activities. Asymmetric information will occur in crude oil futures markets especially during high volatile period. It would affect the information flow and behaviour of investors. Hence, the price-volume relationship would change when asymmetric information occur. During crises, part of investors could not obtain the private information in doing their investments. It was because some information unable to access by individual investors, while the information that can be access could be very costly. Therefore, considerable information was needed in order to assess potential risk in assisting them to make rational decision.

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There were two main problems in WTI and Brent crude oil futures markets during 2008 Global Financial Crisis and 2014 Oil Crisis. The first problem in WTI and Brent crude oil futures markets was the information flow will be differ to non-crisis periods. Besides, the second problem is the investors' behaviour would heterogeneous in crisis periods due to they received the information at different timing. From Figures 1 and 2, the two high-volatile sub-periods for each crude oil market had observed.

The first problem for two high volatile sub-periods in WTI and Brent crude oil futures market in the sample period from 2008 to 2015 was the new arrival of information would affect the changes of price in both futures markets. Hence, the price-volume relationship will affected by the rate of information flow. Information flow caused investors take more cautions in trading activities because the information was not stability during crisis periods.

The new information was considered to be the reflection for rate of price changes for the next period. For example, crude oil demand declined and the price was expected to decrease around 64 per cent in 2009. Therefore, investors' trading activities will turn to gold market to hedge financial risk in futures market (Goyari & Jena, 2010). Besides, oil prices decreased in the second event caused the production and exploration in global investment dropped from \$700 billion to \$550 billion in 2014 and 2015 respectively (Kenneth, 2016).

The second problem was heterogeneity in behaviour of investors arises when asymmetric information occurs. They would react differently because some of the investors trade by using private information. The private information arrivals would caused investors behave differently in their trading activities. This would lead to the crude oil futures markets become inefficient. There were two groups of investors

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namely as informed and uninformed investors (Wang, 1994). These two groups of investor are totally trade in different ways.

Uninformed investors obtained information from public signals for their trading purpose and this can be explained by Liquidity-Driven Trade hypothesis. Informed investors will carry out their trading activities by accessing the private information and obtained a more stable return, which is argued under Information-Driven Trade hypothesis. For example, under the constant equilibrium in oil supply and demand, there was explosive rise in crude oil futures price. These happened because of 60 per cent of pure speculation were speculated by the investors in 2008 (William, 2008). Nevertheless, in June 2014, speculators were collectively long the net 813,566 futures contracts. Since, the price of crude oil fell and speculators only left 234,000 contracts. In other words, speculators have reduced their investment because of the price was dropped dramatically in crude oil futures market (Bloomberg, 2014).

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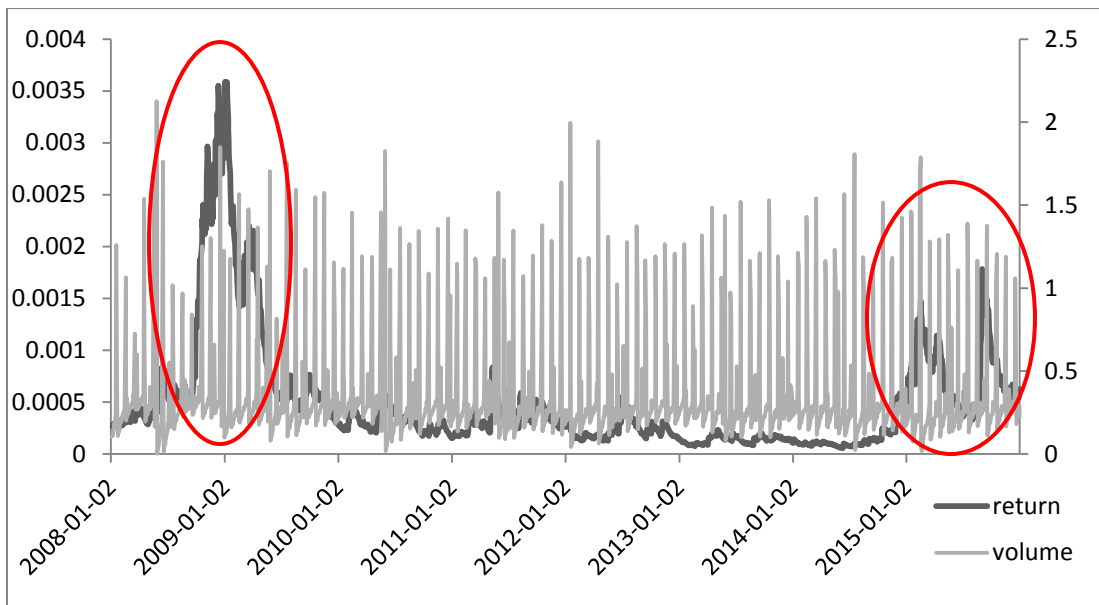


Figure 1.1 : Conditional variance for Brent crude oil futures return and trading volume, January 2, 2008 - December 31, 2015.

Source : Candidates' own estimation based on GARCH (2,1) model.

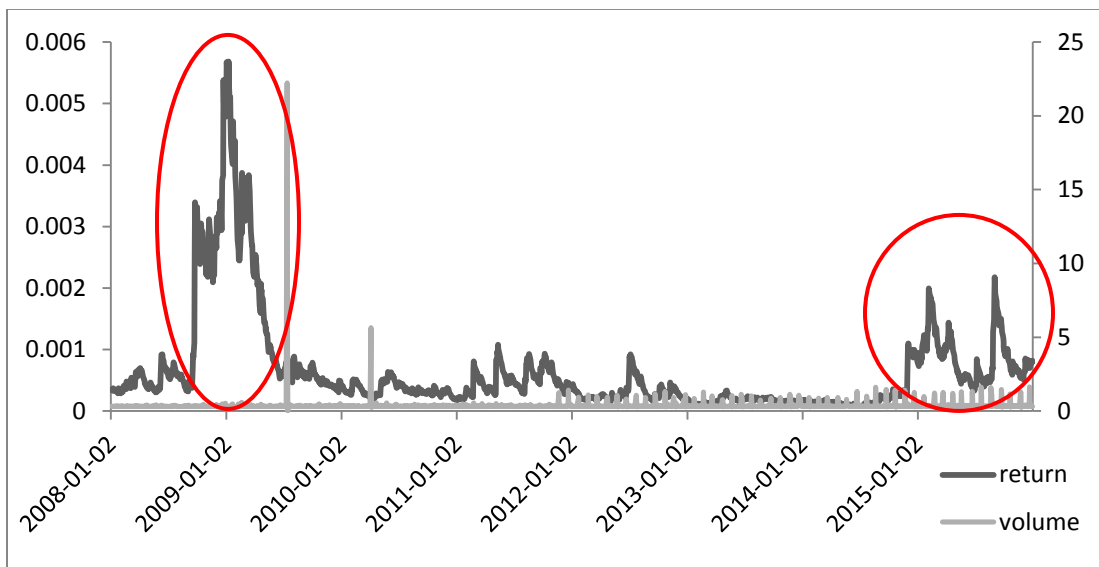


Figure 1.2 : Conditional variance for WTI crude oil futures return and volume, January 2, 2008 - December 31, 2015.

Source : Candidates' own estimation based on GARCH (1,1) model.

1.3 Research Questions

1. How the information flow happened between price changes and trading volume relationship during 2008 Global Financial Crisis and 2014 Oil Crisis periods in WTI and Brent futures markets?
2. Does Information-Driven Trade hypothesis or Liquidity-Driven Trade hypothesis is supported in 2008 Global Financial Crisis and 2014 Oil Crisis periods in WTI and Brent futures markets respectively?

1.4 Research Objectives

1. To investigate the information flow happened between price changes and trading volume relationship during 2008 Global Financial Crisis and 2014 Oil Crisis periods in WTI and Brent futures markets.
2. To determine whether Information-Driven Trade hypothesis or Liquidity-Driven Trade hypothesis is supported during 2008 Global Financial Crisis and 2014 Oil Crisis periods in WTI and Brent futures markets respectively?

1.5 Significance of Study

The contribution of this study is to provide more understanding about the price-volume relationship for WTI and Brent crude oil futures markets towards investors during bull and bear market (high volatile period). The level of volatility is influenced by the information flow regardless to the type of information, whether are good or bad news. Therefore, it is vital for investors to comprehend about the knowledge of the market linkages in the futures market, especially during high-volatile sub-periods. Thus, this will provide an understanding to investors in decision making when invest in the crude oil futures market under different conditions.

Moreover, the trading behaviour of investors would heterogeneity in WTI and Brent crude oil futures markets. During crisis periods, whether Liquidity-Driven Trade hypothesis or Information-Driven Trade hypothesis are supported is important for identify investor. Other than that, crude oil futures markets show that the return may not be solely affected by trading volume in crisis periods. Therefore, investors can make their decision making in trading activities by looking at the trend of Liquidity-Driven and Information-Driven.

1.6 Chapter Layout

There are four remaining chapters in this study. In chapter two, this study emphasize on the Information Flow Hypothesis and relationship between price-volume from past findings. In chapter three, sources of data, data description and methodology are provided. In the chapter four, the interpretation of empirical results emphasize on causality-in-mean and variance, as well as the price-volume relationship. Chapter five provide an outline and recommendation about this study.

CHAPTER 2: LITERATURE REVIEW

2.0 Overview

This chapter provides the review of price and trading volume relationship in financial markets. The past studies has categorized into two aspects which are Information Flow Hypothesis and price-volume relationship.

2.1 Information Flow Hypotheses

When the information flows occur in the markets will bring a significant relationship in price-volume relationship. Many past studies had examined the price-volume relationship by using three hypotheses which are Mixture of Distribution (MDH), Sequential Arrival of Information Hypothesis (SAIH), and Noise Trader Hypothesis.

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2.1.1. Mixture of distribution hypothesis (MDH)

Clark (1973) suggested that Mixture of Distribution Hypothesis (MDH) is one of the hypothesis suggests that information disseminated is contemporaneous and indicates a positive contemporaneous causality from volume to price volatility in response to new information flow. He found a positive correlation by using Bayes' tests and Kolmogorov-Smirnov tests to examine the price-volume relationship for cotton futures market from 1945 to 1958.

Most of the past studies were support Mixture of Distribution Hypothesis. For instance, Harris (1987) has conducted the observations on 479 common stocks from New York Stock Exchange during 1981 to 1983 and found that trading volume is the corresponding factor that reflecting the arrival of new information. Anderson (1996) used full dynamic model to investigate the relationship price and volume for daily New York Stock Exchange on five common stocks from 1973 to 1991. He took asymmetric information into MDH to explain contemporaneous relationship between price and volume that found the dissemination of information will be asymmetric across market participants. Qi (2004) employed Ordinary Least Square (OLS) estimation and Generalized AutoRegressive Conditional Heteroscedasticity (GARCH) model to investigate both variables' relationship for six emerging financial markets with 2,870 observations and concluded that price movement and trading volume are affected by the same underlying information process.

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2.1.2 *Sequential arrival of information hypothesis (SAIH)*

Copeland (1976) has developed Sequential Arrival of Information Model was further enhanced by Jennings (1981). According to Copeland (1976) and Jennings (1981), Sequential Arrival of Information Hypothesis explained that all investors will receive new information in a sequential order. Their decisions will be affected since the arrival of new information is not contemporaneous. SAIH indicates that information flow arrival to market at different point of time so that lagged relationship between price changes and trading volume will exist. Lagged values of volume may use to predict current volatility and vice versa.

McCarthy and Najand (1993) found significant relationship between lagged absolute return and volume in the currency futures market. Fujihara and Mougoue (1997) used daily futures price and trading volume series for crude oil, heating oil, and unleaded gasoline traded at the NYMEX from 1984 to 1993. Total of 2,217 observations and apply into linear and non-linear Granger causality test. The result showed the causality between trading volume and price change is significant in non-linear form. Besides that, the study of Moosa and Silvapulle (2000) was investigate price-volume relationship in WTI crude oil futures market by using linear and non-linear causality tests and daily futures prices and volume from 1985 to 1996. The result is supported to SAIH because of noise trader effects, presence of maturity, and liquidity effects.

Moosa et al. (2003) used daily price of the three-month and six-month futures contracts and volumes of WTI crude oil futures market, which consist of 2651 observations from 1985 to 1996. They found that the futures price lead trading volume and bi-directional causality between changes of price and trading volume in

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symmetric model and asymmetric model respectively through Granger causality test. Chiang et al. (2010) had support the hypothesis with the strong evidence by explaining it is beneficial to use lagged values of trading volume to forecast return-volatility.

2.1.3 Noise trader hypothesis

De Long et al. (1990) has developed the noise traders' hypothesis and found a significant causal relationship from movement of prices to volume due to noise trading. According to such hypothesis, traders did not make decisions regarding their preferences in trading based on the economists' advice and relevant information. Their actions caused the stock prices temporary mispricing in the short run due to their unpredictable behaviour in trading. They traded the stocks was based on their own research or preference whether to hold a small amount of number of stocks or single stock.

Besides that, Campbell and Kyle (1993) found that the presence of the noise traders did not maximize the utility but instead traded exogenously. This action would affect the stock prices to have high volatile movement. Furthermore, Fujihara and Mougoue (1997) used linear causality tests and showed that lagged trading volume does not cause price changes. Meanwhile, the non-linear causality test indicated bi-directional causality between the variables, which led the author to conclude market inefficiency during 1984-1993. However, Bhar and Hamori (2005) found one-way causal effect from price to volume in the investigation of crude oil futures market from 1990 to 2000. This causality demonstrated that the existence of noise traders in the market.

2.2 Relationship between Price and Volume

In financial markets, investors' behaviours are always not consistent due to the market is not efficient. Theoretically, the homogeneity behaviour of investors occurs when markets are efficiency but it may not suitable to apply in real life. Heterogeneity behaviour of investors can be explained by two different hypotheses, known as Liquidity-Driven Trade (LDT) hypothesis and Information-Driven Trade (IDT) hypothesis.

2.2.1. *Liquidity-driven trade hypothesis (LDT)*

According to Wang (1994), the traders who are trading without information as to balance their portfolios purpose namely “liquidity trader”. Uninformed traders are willing to trade by following informed investors since that informed investors are information motivated. When uninformed traders short their financial assets due to exogenous reasons, if they are willing to take over those financial assets require compensation will loss for liquidity. Exogenous reason can be explained by investment opportunity outside the financial market. Wang has mentioned that limitations of liquidity driven trade approach may not preferable for reader to study about investors' behaviour in volume since the non-informational (liquidity) component is exogenous. Llorente et al. (2002) has mentioned that liquidity-driven traders also known as hedging investors and it will shows a positive correlation between current volatility and lagged trading.

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Wang (2002) has studied mentioned that if liquidity-driven trader has change of investment opportunities outside the market, a consecutive return will occur. For example, when investors short their financial assets for portfolio reasons, volume will be accompanied by a change in price to attract other investors to purchase from it. Besides, the liquidity-driven traders are usually trade by reflect a price movement. Most important is uninformed investors are willing to take the other side of the trading at favourable prices and from that to make an abnormal return.

Besides, Sankaraguruswamy et al. (2013) examine how strong intensity on trading behaviour when the uninformed traders noticed the released of news. They have found a significant increase in trading volume by uninformed traders with more news release. For their study, 1031 stocks data are obtained from New York Stock Exchange in the 2014. They are also used Wilcoxon rank-sum test statistic and get a significant result that supports Liquidity-Driven Trade. Moreover, uninformed traders have strongly intensity when frequent news release.

To examine the dynamics relationship between price changes and trading volume studied the Malaysian futures market, Go and Lau (2014) used the Liquidity-Driven Trade hypotheses The daily data of futures price and trading volume are obtained from 2000 to 2008. They applied two-step procedures of cross-correlation function and found that past trading volume has positive correlation with subsequent volatility of returns. Hence, their finding suggested that the price-volume relationship in the case of Malaysia supported the Liquidity-Driven Trade hypothesis.

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2.2.2. *Information-driven trade hypothesis (IDT)*

According to Wang (1994) found that trading with information in their portfolios namely as “informational trade”. Information-driven traders are using private information like price, macroeconomic information, and so on as a guide to trade. Llorente et al. (2002), suggested that information-driven investors also knew as speculative investors and a negative correlation between current volatility and lagged trading are interpreted the Information-Driven Trade hypothesis.

Information-driven trading is closely related to the behaviour of investors. The information received by the investors will affect the trading behaviour. According to Wang (2002), the way investors interpret or overreacted to the information will generate large volatility to price and trading volume. Moreover, the behaviour of the informed or not informed investors will be different.

Wang (2012) also mentioned that uninformed investor attempt to filter private information from current prices. However, the price changes are due to private information or liquidity demand is uncertain. Therefore, uninformed investor will lead to different dynamic relation between return and volume. Informed traders have access to private information will trade with more confidence. Nevertheless, Wang and Huang (2012) are using one minute high-frequency data from 2007 to 2010. After several deducted the missing data of trading days, it still contains of 947 days. The result had supported Information-Driven Trade hypothesis. It is due to the negative relationship was observed in result.

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According to Liu et al. (2015), the informed investors have aggressive trading style. It is because the informed investors have received private information. For example, traders buy the stock based on the good news that gave rise to the price. The research had concluded that the investor with no private information occupied the majority and only minority of investor with private information. The investors with private information will take a higher price to buy and sell at lower price. The transactions are always more than one to affect the price-volume relationship.

2.3 Conclusion

The aim of this study is to identify price-volume relationships in different period and different crude oil markets. After summarized several relevant past studies, it is found that all of the evidences provided were enough for this research and there are only lack of LDT hypothesis's study. However, the methodologies and results obtain by previous studies for price-volume relationships are summarized in table form at end of this chapter.

2.4 Summarized of the Previous Research

Author(s) (year)	Journal	Market	Period	Method	Result
Fujihara, & Mougoue (1997)	An Examination of Linear and Nonlinear Causal Relationships Between Price Variability and Volume in Petroleum Futures Markets	Petroleum	1984 - 1993	GARCH model, Granger causality test, Wald chi-square CLRI test, Box-Pierce Q-statistic	P \longleftrightarrow V
Moosa, & Silvapulle (2000)	The Price-Volume Relationship in The Crude Oil Futures Market: Some Results Based on Linear and Nonlinear Causality Testing	Crude Oil	1985 - 1996	Augmented Dickey-Fuller (ADF) test, Engle Lagrange Multiplier test, Phillip and Perron(PP) test, Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test	P \longleftrightarrow V
Wang (2002)	The effect of net positions by type of trader on volatility in foreign currency futures markets	Foreign Currency Futures Markets	1993 - 2000	ARIMA model, Schwert Volatility Estimation	P \longleftrightarrow V
Moosa et. al (2003)	Testing For Temporal Asymmetry in The Price-Volume Relationship	Crude Oil	1985 - 1996	Dickey-Fuller (ADF) test, Phillip and Perron(PP) test, Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test	P \longleftrightarrow V
Qi (2004)	Return and Volume Relation in the Tail: Evidence from Six Emerging Markets	Stock	1990-2000	ARMA model, Bivariate threshold model, GARCH model, Ordinary Least Square (OLS) test,	P \longleftrightarrow V
Andersen (2010)	Return Volatility and Trading Volume: An Information Flow Interpretation of Stochastic Volatility	Stock	1973 - 1991	Descriptive Statistic, GARCH model, Stochastic Autoregressive Volatility (SARV) model, Generalized method of moments (GMM) model, Ljung-Box test, Quasi-Maximum Likelihood (QML)	P \longleftrightarrow V
Go, & Lau (2014)	Asymmetric Information Spillovers between Trading Volume and Price Changes in Malaysian Futures Market	Kuala Lumpur Options and Financial Futures Exchange	2000 - 2008	Cross-correlation function (CCF) by Cheung and Ng	V \longrightarrow P

CHAPTER 3: DATA AND METHODOLOGY

3.0 Overview

In this chapter, data of this study is stated and described. Cross-Correlation Function (CCF) is employed to examine the causality-in-mean and causality-in-variance and determine the relationship between return and trading volume.

3.1 Data

This study uses daily data for closing price and trading volume of New York Mercantile Exchange (NYMEX) West Texas Intermediate (WTI) Crude Oil Futures and Intercontinental Exchange (ICE) Brent Crude Oil Futures. These data are collected from Bloomberg, where daily closing prices for both markets are recorded in Dollar, while trading volume is equals to 1,000 barrels per contract.

The sample period of WTI futures price and trading volume is from January 2, 2008 to December 31, 2015 which consists of 2,016 observations. While, daily data of Brent futures price and trading volume are covered from January 2, 2008 to December 31, 2015 with 2,024 observations. The sample period used for both futures markets are similar, however the number of observations are different. This is due to different scheme of market holidays. Both data of prices and volume are converted into natural logarithmic form in order to reduce variation and stationary movement of series. The daily crude oil prices and volume is divided into two periods. The first crisis period started from June 2, 2008 to August 31, 2009 and

second crisis period started from August 1, 2014 to December 31, 2015 for both markets.

3.2 Cross-correlation functions of standardized residual and standardized squared residual (CCF)

There is a two-step procedure of residual cross-correlation function (CCF) being developed by Cheung and Ng (1996), which is able to test for causality-in-mean and causality-in-variance. The CCF was being further developed by Hong (2001), as the S-statistic assumes each of the lag term is uniform in weight, with no differentiation between the recent cross-correlations and distant ones. The Hong's version of CCF has enhanced the assumption of the S-statistic, which has modified the uniform weighting for each lag term into non-uniform weighting. He stated that "non-uniform weighting is better against the alternatives whose cross-correlations decay to zero as the lag order increases."

This study adopted Hong (2001) version of CCF procedure. In the first step, univariate time series model is being estimated which consists of conditional means and variances of time variation. The conditional mean for both return and volume are generated by Autoregressive (AR) model, as shown in Equations (1) and (3) that could be applied to examine the movement of the price change and trading volume for both crude oil futures markets. However, conditional mean is not able to capture the volatility of return and volume, therefore conditional variance is required. Conditional variance for return is computed by Generalized Autoregressive Conditional Heteroscedasticity (GARCH) model, as shown in Equations (2) and (4). It is found that GARCH model is not able to capture the volatility of trading volume during the first step. Hence, GARCH-in-mean model is being used to compute the conditional variance of trading volume for Brent and

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WTI futures market. The equation of GARCH-in-mean is shown in Equation (5). The equations are written as below:

$$R_t = \beta_0 + \beta_1 R_{t-1} + \varepsilon_{R,t} \quad (1)$$

$$\sigma_{R,t}^2 = \lambda_0 + \lambda_1 \varepsilon_{R,t-1}^2 + \lambda_2 \sigma_{R,t-1}^2 + V_t \quad (2)$$

$$V_t = \alpha_0 + \alpha_1 V_{t-1} + \varepsilon_{V,t} \quad (3)$$

$$\sigma_{V,t}^2 = \delta_0 + \delta_1 \varepsilon_{V,t-1}^2 + \delta_2 \sigma_{V,t-1}^2 + V_t \quad (4)$$

$$V_t = \mu + \lambda \sigma_t + a_t \quad (5)$$

According to Equations (1) and (3), it shows conditional mean dynamics for return and trading volume respectively and can be specified as AR model. R_t represents return, while V_t is the trading volume at t period respectively. Besides that, Equations (2) and (4) are conditional variance for return at t period respectively that specified as a GARCH (x_1, x_2) model. x_1 represents ARCH terms number and x_2 is GARCH terms number. $\varepsilon_{R,t}$ and $\varepsilon_{V,t}$ represent the variables that are unpredictable and omitted in the equations for return and volume respectively.

In Equation (5), V_t represents the trading volume value at period t. Whereas, μ and λ is the mean of GARCH model and the volatility coefficient for the mean respectively. a_t represents the residual at period t for the model, it can be derive in as $a_t = \sigma_t \times \varepsilon_t$, where σ_t is the conditional standard deviation at period t.

The second step is required to examine the causal relationship in mean and variance for WTI and Brent futures market. CCF is used to analyse standardized

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residuals and the standardized residuals squared estimated from AR-GARCH models in this stage. Causality-in-mean is tested using cross correlation coefficients between standardized residuals, while standardized residuals squared used to determine the causality-in-variance. The significance of the cross correlation shows the pattern of causality. Cheung and Ng (1996) have developed the S-statistic that able to detect the direction of causality whereas in Q-statistic are able detected for one-sided causality developed by Hong (2001).

The conditional mean and variance in first step are then used to compute standard residual and standard residual squared for both return and trading volume respectively. The equations are written as below:

$$\sqrt{\frac{\varepsilon_{Vt}}{\sigma_{Vt}^2}} \quad (6)$$

$$\frac{\varepsilon_{Vt}^2}{\sigma_{Vt}^2} \quad (7)$$

$$\sqrt{\frac{\varepsilon_{Rt}}{\sigma_{Rt}^2}} \quad (8)$$

$$\frac{\varepsilon_{Rt}^2}{\sigma_{Rt}^2} \quad (9)$$

Equations (6) and (8) are used to generate the standard residuals for V_t and R_t respectively. Whereas equations (7) and (9) are being used to compute the standard residual squared for V_t and standard residual squared for R_t . In equations (6), (7), (8) and (9), σ_{Rt}^2 and σ_{Vt}^2 are the conditional variance for return and trading volume respectively. While ε_{Rt}^2 and ε_{Vt}^2 represent the squared of error term for return and trading volume respectively.

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S-statistic is used to test the null hypothesis of no causality-in-mean and variance during the first M lags (Cheung & Ng, 1996; p.37). The S-statistic is written as below:

$$S = T \sum_{i=1}^M \hat{\rho}_{uv}^2(i) \quad (10)$$

where

$$\hat{\rho}_{uv}(i) = \{c_{uu}(0)c_{vv}(0)\}^{-\frac{1}{2}}c_{uv}(i) \quad (11)$$

$$c_{uv}(j) = \begin{cases} T^{-1} \sum_{t=1}^{T-j} (\hat{u}_t - \bar{u})(\hat{v}_{t+j} - \bar{v}), & j \geq 0, \\ T^{-1} \sum_{t=1}^{T-j} (\hat{u}_{t-j} - \bar{u})(\hat{v}_t - \bar{v}), & j < 0, \end{cases} \quad (12)$$

$$u_t = (X_t - \mu_{X,t})^2 / h_{X,t} \quad (13)$$

$$v_t = (Y_t - \mu_{Y,t})^2 / h_{Y,t} \quad (14)$$

In Equation (11), the $c_{uu}(0)$ and $c_{vv}(0)$ are the sample variances of disturbances for u_t and v_t , while T is the sample size. Besides that, $h_{X,t}$ and $h_{Y,t}$ represent the conditional variance for GARCH (p,q) model.

This study has used the Q-statistic that developed by Hong (2001). The Q-statistic is adopted from Hong (2001; p.191 &192). The equation is written as below:

$$Q_1 = \left\{ T \sum_{j=1}^{T-1} k^2(j/M) \hat{\rho}_{uv}^2(j) - C_{1T}(k) \right\} / \{2D_{1T}(k)\}^{1/2} \quad (15)$$

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where

$$C_{1T}(k) = \sum_{j=1}^{T-1} (1 - j/T) k^2 (j/M) \quad (16)$$

$$D_{1T}(k) = \sum_{j=1}^{T-1} (1 - j/T) \{1 - (j + 1)/T\} k^4 (j/M) \quad (17)$$

In Equations (16) and (17), $C_{1T}(k)$ and $D_{1T}(k)$ represent the mean and variance respectively. While, $(1 - j/T)$ and $(1 - j/M)\{1 - (j + 1)/T\}$ represent finite sample corrections.

Q-statistic tests the alternative hypothesis of causality-in-variance means that there is significant of past lags affected in the current return. If the result of test statistic is more than upper-tailed critical values, the null hypothesis of no causality-in-variance during the first M lags term will be rejected. The normal distribution for Q-statistic is shown as below:

$$Q_1 \rightarrow N(0,1) \text{ in distribution}$$

When Q-statistic is further modified become to truncated kernel approach, test statistic can be form as:

$$Q_{1TRUN} = (S - M)/(2M)^{1/2}$$

Q-statistic truncated kernel test is also asymptotically equivalent to a Granger (1969) type regression-based test for H_0 . Furthermore, Q-statistic has weighting scheme, $k(\cdot)$, which there no fixed each of all lag term as a uniform weight but it is given a different rating weight to different lag term. In order words, the smaller lag term the higher weighting would be and vice versa. Argument by Hong (2001) stated that, current output have a strongly impact from a previous results, but most of the past results stated weaker impact to current output.

CHAPTER 4: EMPIRICAL RESULTS

4.0 Overview

In this chapter presents empirical results based on the cross-correlation function (CCF) method. The empirical tests are implemented in order to test causality-in-mean and causality-in-variance. After that, both causalities in each crisis period from respective crude oil futures market are compared in order to identify the causal directional between price changes and trading volume.

4.1 Descriptive Statistic

Table 4.1 shows results of descriptive statistics for return and trading volume for Brent and WTI crude oil futures markets in 2008 Global Financial Crisis and 2014 Oil Crisis, respectively. The table shows negative mean value for return in both markets. While there is positive mean value for trading volume in both markets. The standard deviation for return in 2008 Global Financial Crisis is higher than 2014 Oil Crisis for both markets. This indicates that the price movement in 2008 shows a higher volatility compare to 2014 for both markets.

Skewness for trading volume in both markets is found to have negative values. These negative values indicate that there is a longer right tail in the asymmetry of the probability distribution. However, the skewness values for return in both markets are positive, which indicates a longer left tail. This results show a

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positive kurtosis value, this indicates that the distribution for both series is leptokurtic. In addition, the Jarque-Bera (JB) test statistic indicates that the null hypothesis of normal distribution is rejected for all series. This rejection suggests that the existence of volatility clustering in return and trading volume series due to the asymmetric information among market participants.

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Table 4.1: Descriptive Statistic for return and trading volume in Brent and WTI futures markets

	2008 Global Financial Crisis				2014 Oil Crisis			
	Brent		WTI		Brent		WTI	
	R	V	R	V	R	V	R	V
Mean	-0.0020	11.3652	-0.0019	12.3361	-0.00285	12.1011	-0.0027	12.6010
Median	-0.00249	11.51274	-0.0027	12.4822	-0.00388	12.24608	-0.0036	12.7510
Maximum	0.1271	11.9900	0.1641	13.1585	0.0975	12.9265	0.0977	13.5323
Minimum	-0.1095	8.9203	-0.1307	9.8864	-0.0886	9.4927	-0.1079	9.8482
Std.Dev	0.0374	0.5283	0.0434	0.5697	0.0251	0.6038	0.0272	0.6598
Skewness	0.0558	-2.8474	0.2680	-2.7688	0.3366	-2.5965	0.0563	-2.4497
Kurtosis	3.8584	11.3799	4.4564	11.0216	4.3534	10.3393	4.3010	9.6375
Jarque-Bera	9.6161	1317.379	31.7088	1250.9750	34.9407	1236.075	25.4380	1015.2380
P-Value	0.0082	0.000000	0.000000	0.000000	0.000000	0.000000	0.000003	0.000000

Notes: R represents the daily futures return of oil markets. V represents the daily trading volume of oil markets.

Std.Dev represents as Standard Deviation.

P-Value represent probability of null hypothesis to reject normal distribution.

2008 Global Financial Crisis period: June 2, 2008-August 31, 2009.

2014 Oil Crisis period: August 1, 2014-December 31, 2015.

4.2 Univariate Time Series Estimations

In this study, AR-GARCH model is presented as in the table for return and trading volume in Brent and WTI futures markets. In respect of return, AR-GARCH (1, 1) model is selected to conduct the test. However, AR-GARCH (1, 1) is not able to capture the volatility of trading volume in the crisis periods. Therefore, AR-GARCH-in-mean is selected for trading volume.

The persistence of volatility is measured by parameters β and γ in AR-GARCH model. In Table 4.2, the coefficients ARCH ($\beta_{(i)}$) and GARCH ($\gamma_{(i)}$) term for return and trading volume (0.0933, 0.1267, 0.0588, 0.0517) are significant during 2008 Global Financial Crisis and 2014 Oil Crisis for both markets.

As shown in the Table 4.3, during 2008 Global Financial Crisis in WTI futures market, the coefficient of ARCH and GARCH terms (-0.1199, 0.6360) for trading volume are significant. However, there is no empirical result for trading volume in AR-GARCH model in Brent futures market, because there is no GARCH effect in trading volume. To proceed from Ordinary Least Square (OLS) to AR-GARCH model, the model have to fulfil two conditions which the model consist of heteroscedasticity and autocorrelation. However, log trading volume cannot fulfil these two conditions. During 2014 Oil Crisis, the ARCH and GARCH terms for Brent (-0.0075, 0.0796) and WTI (-0.1713, 0.7404) futures markets are significant.

During both crisis periods, the coefficients of GARCH term in conditional mean in for WTI futures markets are positive. This indicates that that there is a positive volume-risk relationship during crisis period. In other words, high risk causes high volatility in trading volume. However, during 2014 Oil Crisis the

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coefficient in Brent futures market is -4.6124, which shows a negative volume-risk relationship.

During 2008 Global Financial Crisis and 2014 Oil Crisis, Ljung-Box statistics show there are no autocorrelation up to lag 20 for standard residual squared. However during 2008 Global Financial Crisis, there is autocorrelation problem for trading volume in Brent futures market.

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Table 4.2: AR-GARCH Model for Return

	2008 Global Financial Crisis				2014 Oil Crisis			
	Brent		WTI		Brent		WTI	
	<i>ARMA(2,1)-GARCH(1,1)</i>		<i>ARMA(1,1)-GARCH(1,1)</i>		<i>ARMA(1,1)-GARCH(1,1)</i>		<i>ARMA(2,2)-GARCH(1,1)</i>	
	Coefficient	S.E	Coefficient	S.E	Coefficient	S.E	Coefficient	S.E
Return Equation								
<i>c</i>	-7.24×10^{-05}	0.0001	-0.0016	0.0035	-0.0054	0.0015	-0.0057	0.0089
<i>a</i> ₁	0.8714	0.0876	-0.9111	0.1926	-0.5158	0.2180	-0.5841	1.7076
<i>a</i> ₂	0.0962	0.0642	-	-	-	-	-0.0757	0.8710
<i>b</i> ₁	-0.9437	0.0627	0.9042	0.2012	0.3699	0.2375	0.4183	1.7096
<i>b</i> ₂	-	-	-	-	-	-	0.0640	0.6098
Variance Equation								
<i>C</i>	2.24×10^{-05}	2.23×10^{-05}	2.63×10^{-05}	1.95×10^{-05}	8.71×10^{-06}	5.09×10^{-06}	1.56×10^{-05}	8.97×10^{-06}
<i>β</i> ₁	0.0933	0.0461	0.1267	0.0381	0.0588	0.0260	0.0517	0.0241
<i>γ</i> ₁	0.8896	0.0534	0.8619	0.0404	0.9321	0.0264	0.9304	0.0286
Log-likelihood	602.0307		583.7415		869.7924		808.4491	
ARCH-LM	2.582927 (0.2749)		0.979616 (0.3223)		1.272687 (0.2593)		0.755126 (0.3849)	
Q ² (20)	16.8980 (0.5970)		21.1130 (0.3310)		16.1120 (0.6500)		4.7341 (0.9990)	

Notes: Persistence of volatility is measured through $\gamma_{(i)}$ in ARMA-GARCH (1, 1) model.

Q² (20) is the Ljung-Box statistic for the null hypothesis that there is no autocorrelation up to order 20 for standard residual squared.

All the P-value are reported in the ().

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Table 4.3: AR-GARCH Model for Trading Volume

	2008 Global Financial Crisis				2014 Oil Crisis			
	Brent		WTI		Brent		WTI	
	Coefficient	S.E	Coefficient	S.E	Coefficient	S.E	Coefficient	S.E
	<i>Return Equation</i>							
C	-	-	11.4469	0.3312	14.8765	0.0359	11.8985	0.1997
A	-	-	2.4024	0.6291	-4.6124	0.1659	1.4671	0.3475
b_1	-	-	0.5141	0.0135	0.4611	0.0102	0.4104	0.0185
b_2	-	-	0.2152	0.0097	0.2565	0.0196	-	-
b_3	-	-	-	-	0.0485	0.0104	-	-
	<i>Variance Equation</i>							
C	--	-	0.0898	0.0195	0.3309	0.0150	0.1107	0.0177
β_1	-	-	0.1514	0.0451	-0.0520	0.0030	0.1761	0.0513
β_2	-	-	-0.1199	0.0363	-0.0180	0.0020	-0.1713	0.0488
β_3	-	-	-	-	-0.0075	0.0022	-	-
γ_1	-	-	0.6360	0.0468	0.07960	0.0163	0.7404	0.0395
Log-likelihood	-	-	-95.8027		-147.2277		-196.6546	
ARCH-LM	-	-	0.006770 (0.9344)		2.051766 (0.1520)		0.000541 (0.9814)	
$Q^2(20)$	34.4320 (0.0160)		0.1784 (1.0000)		17.6960 (0.4080)		7.2351 (0.9930)	

Notes: "A" represent the coefficient of GARCH in conditional mean.

Persistence of volatility is measured through $\gamma_{(i)}$ in ARMA-GARCH (1, 1) model.

$Q^2(20)$ is the Ljung-Box statistic for the null hypothesis that there is no autocorrelation up to order 20 for standard residual squared.

All the P-value are reported in the ().

4.3 Causality-in-Mean between Price Changes and Trading Volume in WTI and Brent Futures Markets during Crises

As shown in Table 4.4, during 2008 Global Financial Crisis in Brent futures market shows that there is no Granger causality effect. While in WTI futures market illustrates that the causality from return to trading volume are significant at lag 5 and lag 10 days. It is significant at the 10 per cent and 5 per cent respectively.

During 2014 Oil Crisis, Brent futures market shows the results of Granger causality-in-mean are significant at all lag terms. It indicates that the mean of return cause the trading volume at each of the significance level. The causality effect from return to trading volume at lag 5, 10 and 15 days are significant at the 1 per cent level, lag 20 and 30 days are significant at the 5 per cent level and lag 25 days is significant at the 10 per cent level. Besides that, there is no causal relationship from past trading volume to return. In WTI futures market, only at lag 30 days is significant at the 10 per cent which is the past trading volume affects the return.

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Table 4.4: The empirical results for causality-in-mean testing

M	2008 Global Financial Crisis				2014 Oil Crisis			
	BRENT		WTI		BRENT		WTI	
	V(-1)→R	R→V(+1)	V(-1)→R	R→V(+1)	V(-1)→R	R→V(+1)	V(-1)→R	R→V(+1)
5	0.7876	-1.3938	0.7563	1.5589*	-0.6895	3.6502***	-0.3541	-0.5955
10	0.3113	-1.4938	-0.1222	2.1673**	-0.2093	3.0355***	0.5246	-0.6255
15	-0.1129	-1.9603	0.0408	1.1370	-0.4007	2.4390***	0.4188	-0.8076
20	-0.5831	-1.8929	-0.2691	0.7023	-0.2677	2.1040**	0.5088	0.2327
25	-0.1437	-1.9433	-0.0820	0.8880	-0.2264	1.6442*	1.6247*	-0.1794
30	0.1760	-1.7867	-0.1239	0.4323	-0.0751	1.6846**	1.1603	-0.3770

Notes: This table indicates the value of Q-statistic based on Hong (2001) approach.

The Q-statistic is used to test the null-hypothesis of no causality from lag 1 up to lag M (M = 5,10,15,20,25 and 30 days)

The test statistic is based on one-side tests. Lags are measured in days.

*, ** and *** represent significance at 10%, 5% and 1% respectively when reject null-hypothesis.

V(-1)→R represents past daily trading volume affect current daily return, R →V(+1) represents current daily return affect future daily trading volume

4.4 Causality-in-Variance between Price Changes and Trading Volume in WTI and Brent Futures Markets during Crises

As shown in Table 4.5, during 2008 Global Financial Crisis, there is no causality-in-variance in Brent futures market. In WTI futures market, past trading volume is found to affect return at lag 5, 10 and 15 days. Lag 5 days and lag 10 days are significant at the 1 per cent while lag 15 days is significant at the 5 per cent level.

During 2014 Oil Crisis, in Brent futures market shows the causal relationship from past volume to return at lag 10 and 15 days. It is significant at the 10 per cent. Besides that, most of the low and high order lags are significant in the causal effect which runs from return to trading volume. The causality effect from return to trading volume at lag 10, 20 and 30 days are significant at the 1 per cent level while at lag 15 and 25 days are significant at the 5 per cent level. In WTI futures market, the causal relationship happened from past trading volume to return at high order lags which are at lag 25 and 30 days. It is significant at the 1 per cent level.

As overall, there is only unilateral causality-in-variance. In WTI futures market, there is a volatility movement from past trading volume to return in both crisis periods. During 2014 Oil Crisis, information flow in the Brent futures market is causal from return to trading volume. Thus, it is conclude that the information flow between the return and trading volume affect mean movements and the volatility movements for both crude oil markets during the crisis periods.

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Table 4.5: The empirical results for causality-in-variance testing

M	2008 Global Financial Crisis				2014 Oil Crisis			
	BRENT		WTI		BRENT		WTI	
	V(-1)→R	R→V(+1)	V(-1)→R	R→V(+1)	V(-1)→R	R→V(+1)	V(-1)→R	R→V(+1)
5	-	-	3.1988***	-0.0279	0.4500	-1.0457	-1.1280	-1.1635
10	-	-	3.0211***	-0.9115	1.5684*	3.4829***	-1.8431	-0.9310
15	-	-	1.8323**	-0.8994	1.3643*	2.3082**	-1.8712	-1.5964
20	-	-	1.1941	-1.3623	0.5499	2.3896***	-2.2045	-1.8034
25	-	-	1.1364	-1.4064	-0.0610	1.7944**	17.8772***	-2.1291
30	-	-	0.5629	-1.3269	-0.3695	3.1070***	15.8385***	-2.3590

Notes: This table indicates the value of Q-statistic based on Hong (2001) approach.

The Q-statistic is used to test the null-hypothesis of no causality from lag 1 up to lag M

(M = 5,10,15,20,25 and 30 days)

The test statistic is based on one-side tests. Lags are measured in days.

*, ** and *** represent significance at 10%, 5% and 1% respectively when reject null-hypothesis.

V(-1)→R represents past daily trading volume affect current daily return, R→V(+1) represents current daily return affect future daily trading volume

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As shown in Table 4.6, during 2008 Global Financial Crisis, there is no empirical result in the cross-correlation for Brent futures market. This is due to the standard residual squared is not conducted as the data of trading volume in Brent futures market has no GARCH effect. It is possible that the GARCH model is not able to capture the special trend of trading volume in Brent futures market during the crisis periods. Therefore, the relationship between return and trading volume in Brent futures market is not able to be examined.

Overall in 2008 Global Financial Crisis, there is a negative relationship between return and trading volume for WTI futures market (-0.0347, 0.0244, -0.0320) at lag 5, lag 10 and lag 15days. The empirical results indicate that WTI futures market is under Information-Driven Trade at low order lag days. This may due to the 2008 Global Financial Crisis was begun in United States, when Lehman Brothers Holding Inc declared bankruptcy. The investors in U.S. were possible to obtain information and trade based on it in WTI futures market. Hence, the result supports the Information-Driven Trade hypothesis in WTI futures market.

During 2014 Oil Crisis, Brent futures market shows a positive return-volume relationship from lag 10 to lag 30days. This indicates that Brent futures market is under Liquidity-Driven Trade during whole crisis period. This is possible that the investors were caught in surprise by the sudden oil price drop in oil crisis, and lead to the condition where investors have insufficient information to trade. The cost in obtaining information during crisis period increased, this will make the situation worst. Investors may be forced to trade based on their own prediction in the market. Therefore, the Liquidity-Driven Trade hypothesis is supported.

During 2014 Oil Crisis, WTI futures market is found to have significant causality-in-variance at lag 25 and lag 30 days. However, lag 25 obtains positive empirical result while the result in lag 30 days is negative. There is insufficient

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evidence to identify the hypothesis that is supported with the empirical results in WTI futures market.

As overall, during 2008 Global Financial Crisis the Information-Driven Trade hypothesis is supported in WTI market. While during 2014 Oil Crisis, Liquidity-Driven Trade hypothesis is supported in Brent market.

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Table 4.6: Cross correlation of standard residual squared in causality-in-variance between price changes and volume

M	2008 Global Financial Crisis				2014 Oil Crisis			
	BRENT		WTI		BRENT		WTI	
	V(-1)→R	R→V(+1)	V(-1)→R	R→V(+1)	V(-1)→R	R→V(+1)	V(-1)→R	R→V(+1)
5	-	-	-0.0347	-	-	-	-	-
10	-	-	0.0244	-	0.1507	0.0682	-	-
15	-	-	-0.0320	-	0.0674	-0.0137	-	-
20	-	-	-	-	-	0.0003	-	-
25	-	-	-	-	-	-0.0310	0.6373	-
30	-	-	-	-	-	0.0832	-0.0035	-

Notes: All cross-correlations reported in the table are significant.

V(-1) → R represents past daily trading volume affect current daily return, R → V(+1) represents current daily return affect future daily trading volume

4.4 Conclusion

This chapter analyzes the relationship between price changes and trading volume. All the empirical results are illustrated in the figures and table form with explanation. The objectives of this study have been achieved based on the empirical results.

CHAPTER 5: CONCLUSION

5.0 Overview

This chapter consists of the major findings and implications of the study. Besides, this chapter also provides recommendation for the future researchers to further examine the price-volume relationship.

5.1 Major Findings

The first finding is information flow affects the volatility movement between price and volume relationship in WTI and Brent futures markets during crisis periods. There is causality-in-variance occur in either direction. In Brent market, investors use information flow of return to forecast the volatility movement of trading volume in doing their trading activities during 2014 Oil Crisis. However, there is no causality-in-variance in Brent market during 2008 Global Financial Crisis implies that the information spillover is absence in the price-volume relationship. In WTI market, investors are forecast the return based on the past trading volume in both crisis periods. Therefore, the information flow will provide certain effect for investors in doing their decision making during crisis periods for both markets.

In the second finding is Information-Driven Trade hypothesis holds in WTI market during 2008 Global Financial Crisis while Liquidity-Driven Trade holds in

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Brent market during 2014 Oil Crisis. Uninformed investors may trade by using the public signal information or informed investors obtained the private information in trading activities. They can get the information from other sources during first crisis period. Besides that, high-volatile happened in the crude oil futures market causes the economy become instability during second crisis period. Investors cannot obtain the information because they need to pay high cost. This will bring the adverse impact to the investors and lead them become more caution in trading activities. Therefore, the Liquidity-Driven Trade hypothesis is supported in Brent market during 2014 Oil Crisis.

5.2 Implications

Based on both findings, this study suggests two aspects of investors' implication. First, if investors aim to reduce the asymmetric information due to unexpected external factors, they are suggested to rely on trading volume. The reason is trading volume can provide the information about noisy movement of return.

Second, if the fundamental factors such as supply of inventory and consumption growth that cause the occurrence of oil price bubbles, investors are further suggested to make use of return in predicting trading volume. The reason is trading activities contribute to market liquidity of crude oil. For example, if trading volume is high, the physical stock of such hard commodity can be easily traded and vice versa. This subsequently can allow them to make entry decisions in their transactions or investments related to crude oil products.

5.3 Recommendation

This study suggests that future researchers should examine price-volume relationship by separating futures prices into long and short positions. Therefore, the price-volume relationship for long and short positions in WTI and Brent futures can be compared during the specific high volatile period.

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