FORECASTING MODEL OF CRUDE OIL PRICE INSTABILITY IN ASEAN-5 COUNTRIES

CHIN JIA HUI

BACHELOR OF ECONOMICS (HONOURS)
GLOBAL ECONOMICS

UNIVERSITI TUNKU ABDUL RAHMAN

FACULTY OF ACCOUNTANCY AND MANAGEMENT
DEPARTMENT OF ECONOMICS

MAY 2023

FORECASTING MODEL OF CRUDE OIL PRICE INSTABILITY IN ASEAN-5 COUNTRIES

BY

CHIN JIA HUI

A research project submitted in partial fulfillment of
the requirement for the degree of

BACHELOR OF ECONOMICS (HONOURS)
GLOBAL ECONOMICS

UNIVERSITI TUNKU ABDUL RAHMAN

FACULTY OF ACCOUNTANCY AND MANAGEMENT
DEPARTMENT OF ECONOMICS

MAY 2023

DECLARATION

I 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 36,888 words.

Name of student:	Student ID:	Signature:
Chin Jia Hui	20UKB03081	

Date: 25 April 2023

ACKNOWLEDGEMENT

Firstly, I would like to take this opportunity to express my appreciation to Universiti Tunku Abdul Rahman (UTAR) for putting in the Final Year Project (FYP) course as one of the compulsory courses in the Bachelor of Global Economics programme. Throughout this research process, I significantly improved both my research expertise and my respect for the subject of research and academia in general. Also, I would like to express my gratitude to the individuals who are members of the Faculty of Accountancy and Management (FAM) of UTAR. They were the ones who helped me coordinate this course and assisted me throughout the programme.

Next, I would like to use this opportunity to express my sincerest thanks and gratitude to my supervisor, Dr. Aye Aye Khin, for providing me with patient advice and guidance throughout this research project. It is the greatest honour of my life to carry out this research under her direction, and her insightful recommendations have been of enormous help to me in surmounting the challenges I faced in my research project. Without her assistance and guidance, I would not have been able to finish this research work without any hiccups.

In the end, I would want to convey my appreciation to my loved ones, particularly my family and friends, who have been there for me every step of the way by providing me with support and inspiration. I will be eternally grateful to them for their thoughtfulness and continuous encouragement they have shown.

DEDICATION

This research project is devoted to the people who have helped me along my path uncompromisingly and inspired me to keep moving ahead. My sincerest thanks go out to Universiti Tunku Abdul Rahman (UTAR), Dr. Aye Aye Khin, my family, and all my friends who have blessed me with their support all the way through my years of study. I am also grateful to my classmates and group mates, who have cooperated together with assignments and courses throughout our studies.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ADF	Augmented Dickey Fuller
ADRL	Autoregressive Distributed Lag
ANN	Artificial Neural Networks
API	American Petroleum Institute
AR	Autoregressive
ARCH	Autoregressive Conditional Heteroskedasticity
ARIMA	Autoregressive Integrated Moving Average
ARMA	Autoregressive and Moving Average
ASEAN	Association of Southeast Asian Nations
BMA	Bayesian model average
BNCCP	Brunei Darussalam National Climate Change Policy
BND	Brunei Dollar
BPLM	Breusch-Pagan Lagrange Multiplier
CGE	Computable General Equilibrium
CNY	Chinese Yuan (Currency of China)
COP	Crude Oil Price
CPI	Consumer Price Index
EMA	Energy Market Authority
EUR	Euro (Currency of European Countries)
EXR	Exchange Rate
FEM	Fixed Effects Model
FIGARCH	Fractionally Integrated Generalized Autoregressive Conditional Heteroscedastic
GARCH	Generalized Autoregressive Conditional Heteroskedasticity

GARCH-GJR	Generalized Autoregressive Conditional Heteroskedasticity Glosten-Jagannathan-Runkle
GARCH-MIDAS	Generalized Autoregressive Conditional Heteroscedasticity Mixed Frequency Data Sampling
GDP per capita	Gross Domestic Product per capita
GDP	Gross Domestic Product
IDR	Indonesia Rupiah
INF	Inflation Rate
ITR	Interest Rate
LSTM	Long Short-term Memory Network
MAE	Mean Absolute Error
MAPE	Mean Absolute Percentage Error
MS-VAR	Markov Regime Switching Vector Auto Regression
MTNARDL	Multiple Threshold Nonlinear Autoregressive Distributed Lag
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary Least Squares
OPEC	Organization of the Petroleum Exporting Countries
PCO	Production of Crude Oil
PMG	Pooled Mean Group
POLS	Pooled Ordinary Least Squares Model
REM	Random Effects Model
RM	Ringgit Malaysia
RMB	Ren Min Bi (Currency of China)
RMSE	Root Mean Squared Error

SARIMA	Seasonal Effect of Autoregressive Integrated Moving Average
SGD	Singapore Dollar
SVAR	Structural Vector Autoregressive
TOCOM	Tokyo Commodity Exchange
TOL	Tolerance
TVP-VAR	Time-varying Parameter Vector Autoregressive
USD	United States Dollar
VAR	Vector Autoregressive
VECM	Vector Error Correction Method
VIF	Variance Inflation Factors
WTI	West Texas Intermediate

PREFACE

Students enrolled in the Bachelor of Global Economics program at Universiti Tunku Abdul Rahman have a duty to take in a research project for a period of seven months, starting in October 2022 and ending in May 2023, as part of the course of study for the subject Research Project offered by the Department of Economics at Universiti Tunku Abdul Rahman. This project serves as the final year project for the bachelor's degree of Global Economics. The topic of this research study is "Forecasting Model of Crude Oil Price Instability in ASEAN-5 Countries".

The main objective of this study is to develop a forecasting model of crude oil price instability in ASEAN-5 Countries. There are five (5) factors have been identified to study on the effect on crude oil price which are: (1) exchange rate, (2) inflation rate, (3) interest rate, (4) GDP per capita, and (5) production of crude oil. This research study examines the relationships among the independent variables with crude oil price.

This study is necessary to be conducted because fluctuations in the price of crude oil in a country are an issue that should be of particular concern to the authorities because of the major impact that they have on the economy. Hence, my supervisor and I are inspired to do research on examining the factors of crude oil price instability and forecast the crude oil price. As a result, this research opens a new path for scholars to consider when doing research on the crude oil price instability in each ASEAN-5 country. Additionally, it serves as a reference for all stakeholders including policymakers, investors, practitioners, and consumers, allowing them to analyse and predict the future trend of crude oil price.

ABSTRACT

Crude oil plays an essential role in our daily life today as it serves as raw materials in the industrial process, fossil fuels for transportation, fertilizers in farming, power generators, etc. Crude oil price instability can have negative economic, social, and political consequences. It affects industries and consumer purchasing power and can cause uncertainty for businesses and investors. It can also increase income inequality and affect geopolitical relationships between nations.

This research study examined the factors affecting crude oil prices by investigating the relationships among the exchange rate, inflation rate, interest rate, GDP per capita, production of crude oil, and crude oil price. This research study focused on ASEAN-5 countries, including Brunei, Indonesia, Malaysia, Singapore, and Thailand. This research study utilized a panel model to determine the relationships among the variables with the crude oil price and the ARIMA model to individually forecast the crude oil price in ASEAN-5 countries. This study used secondary data from the World Bank, Index Mundi, the United States Department of Agriculture, and the U.S. Energy Information Administration. The data period adopted was annual data from 2007 to 2021 for the panel model, while monthly data from January 2017 to September 2022 for the ARIMA model. The empirical results show that the Period Fixed Effect Model is the best panel model. There are significant relationships among exchange rate, inflation rate, GDP per capita, production of crude oil, and crude oil price except for interest rate with the crude oil price. The ARIMA model results show the model specifications for all five countries is ARIMA (1,1, 1) model and the crude oil price in ASEAN-5 countries is volatile and unstable during the estimated period. The ex-post forecast revealed an increasing trend for Brunei, Indonesia, and Malaysia and a decreasing trend for Singapore and Thailand. Therefore, policymakers, businesses, and individuals should monitor and respond to changes in crude oil prices to mitigate their impacts.

CHAPTER 1: RESEARCH OVERVIEW

1.0 Introduction

Chapter 1 will present the background of the research about the forecasting models of crude oil price instability in Association of Southeast Asian Nations (ASEAN-5) countries, the current situation of crude oil price instability in ASEAN-5 countries, and problem statements. Next are research objectives, research questions going to be discussed. After that, the significance of the study in terms of theoretical and empirical will be presented. Finally, this chapter will be explained the layout of each chapter and conclusion.

1.1 Research Background

Crude oil is a natural source liquid mostly made up of hydrogen and carbon that developed from diatoms, which are the leftovers of plants and animals that lived in a sea environment millions of years ago before dinosaurs existed (U.S. Energy Information Administration, 2022b). It is often formed underground and sometimes found near the earth’s surface in tar sands. Crude oil is one of the essential primary commodities in the global economy as it is necessary as a raw material in the production process, fossil fuel for transportation, fertilizers and used to generate energy such as electricity and heat by all nations (Millia et al., 2020). Due to the fact that commodities are needed as raw materials in industrial production, primary commodity prices have a positive impact on aggregate price levels (Bloch, Dockery, & Sapsford, 2006). Crude oil is a key component of contemporary industry and economic growth since it is a major energy resource and financial investment tool. Hence, the most recognized indication of commodity prices globally is the price of crude oil (Zhao, 2022). The demand for crude oil is crucial for humankind since it is needed by every economic sector of a nation, including services, trading, transportation, industry, and agriculture (Muthalib, Adam, Rostin, Saenong, & Suriadi, 2018). The need for crude oil also rises yearly as a country's economic activity increases. Crude oil price instability could be high due to significant instabilities in the price of oil in terms of increasing and declining crude oil prices (Becken, 2011). Crude oil is one of the main benchmarks in derivative trading, such as option instruments; therefore instability in the crude oil price is a risk measure in investing and trading in crude oil in the financial markets.

Due to the significant importance of crude oil, crude oil commodities' prices are more unpredictable and unstable than those of other commodities. In light of the inelastic demand, the price of crude oil directly affects investments, global trade, various types of production, manufacturing output, and sometimes even family purchasing power. Additionally, the rising in the oil price will directly affect consumer goods and services, posing unpredictability for the future (Ahmad et al., 2022). Different countries experience the effects of oil price instability differently. The revenue from crude oil trade is essential to the economies of crude oil-exporting countries. Crude oil-exporting countries' governments are stronger and more powerful because they receive crude oil revenue from the oil-importing countries. As a result, the government's organizational structure and policies are crucial to the country's economic development. Therefore, in this aspect, crude oil price is crucial for crude-oil exporting countries since they can maximise their revenue and utilise it to further their country's economic development. Therefore, the volatility of crude oil prices has a significant impact on the outcome of monetary and fiscal policy (Saddiqui, Jawad, Naz, & Niazi, 2018). Crude oil is a key component of industrial goods. Therefore, its instability significantly impacts employment and investment of a country (Rafiq, Salim, & Bloch, 2009).

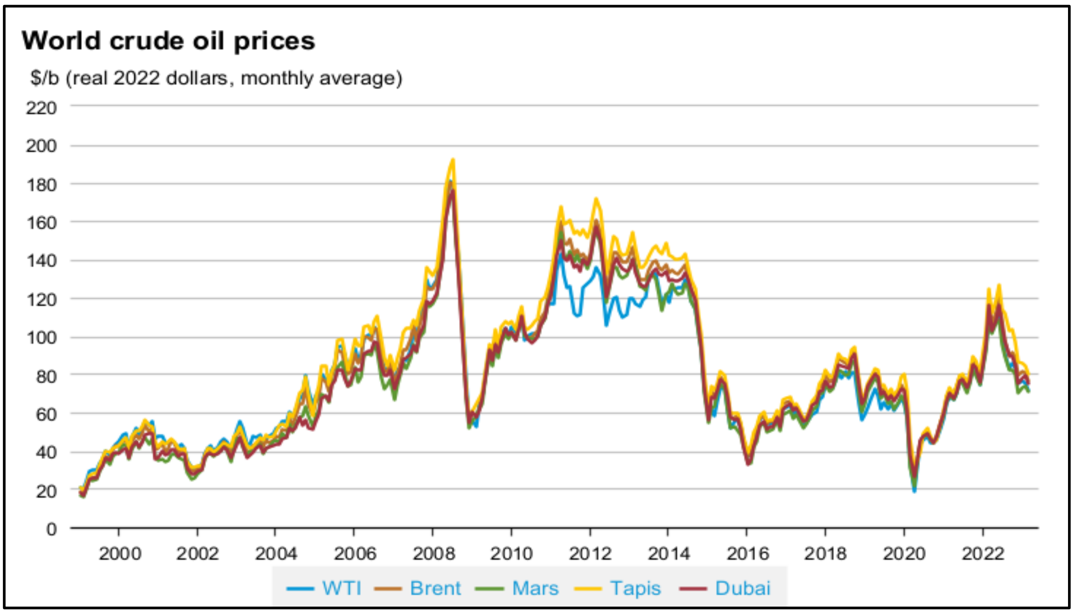
Crude oils are available in a variety of densities in terms of American Petroleum Institute (API) gravity and sulphur concentrations, depending on how much consumers and industry needs. Consequently, the market prices of crude oil vary. The fundamentals of world supply and demand, as well as specific economic and geopolitical situations, can influence crude oil prices. Trading participants make use of standard crude oil baskets, also known as benchmarks or indicators, to represent all such factors. Due to variations in shipping costs and characteristics of markets, there is typically a gap between the markers. Brent, West Texas Intermediate (WTI), and Dubai/Oman are three (3) major benchmarks in the world's crude oil markets.

The first common type of crude oil is Brent crude oil, a low sulphur content and low density, with approximately two-thirds of the world's physical oil trading based on Brent, which is produced in the North Sea (Dunn & Holloway, 2012).Pipeline transportation is used to deliver Brent Crude oil to the Saloomwoo oil terminal in Britain for extraction and refinement. The advantages of oil drilling and exploration may be attributed to Brent Crude's excellent quality and the North Sea region's stability. It is mostly utilised in Australia, Africa, the Mediterranean, European, and a few Asian nations (U.S. Energy Information Administration, 2014). Brent Crude is favoured for refining oil to create fuel, gasoline, and other finished goods because of its light and "sweet" quality.

The second benchmark used by crude oil markets is West Texas Intermediate (WTI) crude oil, one kind of light and sweet crude oil extracted in the United States (U.S.). At the hub for trading crude oil in Cushing, Oklahoma, WTI oil will be delivered and priced (U.S. Energy Information Administration, 2014). WTI oil is brought to the crude oil trading hub by rail and a vast pipeline network. For imported crude oil made in Mexico, South America, and Canada, WTI also serves as a benchmark. WTI is valued as light oil, similar to Brent; however, it is not as widely available as Brent. One factor is that the United States generally forbids the export of crude oil (Alberta Energy, 2015). An additional factor is that majority of refineries are now concentrated around the coast, whereas WTI supplies are now generated in landlocked regions. There is an excess of oil supply in the American Midwest due to rising oil output in the U.S. As a result, WTI currently trades at a lower price compared to Brent oil.

Another frequently utilized benchmark is Dubai/Oman, which is generally used to determine the crude oil price that exports from the Middle East to Asian countries. Dubai/Oman crude oil, unlike Brent and WTI, this type of crude oil is medium and sour. The price of crude oil supplied for export to Asia is set by Saudi Aramco, using the Dubai/Oman benchmark (U.S. Energy Information Administration, 2014). The Tokyo Commodity Exchange (TOCOM) is where the Dubai/Oman oil is traded. Figure 1.1 shows the world spot crude oil prices for five (5) types of crude oil that traded in the oil market. Although these five (5) types of crude oil are shown in different values in dollars per barrel, all of them move closely together in the same direction. The quality difference between the contractual and benchmark crude oils, travel costs, and the differing refining yields from converting the contractual and benchmark crudes into different oil products are some of the reasons contributing to these pricing differences (Dunn & Holloway, 2012). Figure 1.1 shows the trend of world crude oil prices were fluctuated overt the time. According to U.S. Energy Information Administration (2023), over the last few decades, crude oil prices have been influenced by various geopolitical and other occurrences. Whenever events cause a disturbance in oil supply or create uncertainties regarding future oil supplies, it tends to result in an increase or decrease in oil prices. For example, starting from year 2000s, the events such as 9-11 attacks in 2001, global financial crisis in 2008, reduction of oil production in OPEC in 2009, no changes in OPEC production quota in 2015, reduction of oil demand during COVID-19 pandemic in 2020 to 2021, and Russia-Ukraine war in 2022 had eventually caused the crude oil price fluctuated and became unstable.

Figure 1.1: World Spot Crude Oil Prices ($/barrel)



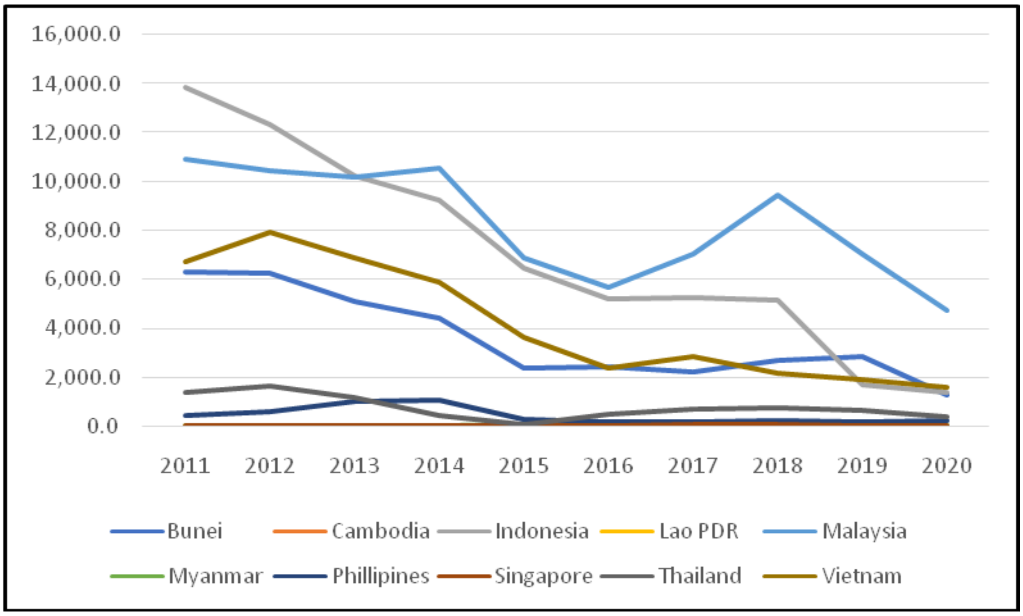
Source: U.S. Energy Information Administration (2023)

Given the crucial role that crude oil plays in the global economy, rises in crude oil price instability have raised concerns among consumers, businesses, and governments throughout the years (Baumeister & Peersman, 2013; Wang & Wu, 2012). Crude oil price instability has significant effects on economic activity, and volatility is a fundamental input into macroeconomic analysis and option pricing methods (J. D. Hamilton, 1983). In order to better comprehend changes of uncertainty in the crude oil market, which are usually reflected upon unexpected instability in the price of crude oil, it is crucial to examine the instability of the crude oil price. Undoubtedly, the instability of crude oil prices comprises information directly related to changes in the actual and future crude oil market (Chatziantoniou, Filippidis, Filis, & Gabauer, 2021). As a result, this information might be useful for energy traders looking to manage their investment portfolios and devise hedging instruments properly. Hence, the research group has been paying close attention to crude oil price instability in recent years. Furthermore, instability in crude oil prices may temporarily lower total production and output levels since it hinders investment by increasing uncertainty or causing costly industry resource reallocation (Guo & Kliesen, 2005).

This research will focus on the ASEAN-5 countries: Brunei, Indonesia, Malaysia, Singapore, and Thailand. Crude oil demand in the ASEAN is predicted to rise rapidly in the future. The Economic Research Institute for ASEAN and East Asia predicted that ASEAN's crude oil demand would be expected to rise by 4.1 percent annually, 12.2 million barrels per day in 2040 from 4.4 million barrels per day in 2015 (Kimura & Phoumin, 2016). Furthermore, the current global oil price shocks have been significantly influenced by the demand for oil in emerging Asia (J. D. Hamilton, 2013; Kilian & Hicks, 2013). In 2012, East Asia accounted for nearly 30 percent of the world's energy consumption, a 45.2 percent rise in the ASEAN-5 region's oil demand since 2000 (Raghavan, 2015). The ASEAN-5 economies are potentially more sensitive to oil shocks since their economies use twice as much oil as average OECD countries as a percentage of GDP (Downes, 2007).

Furthermore, ASEAN countries such as Brunei, Indonesia, Malaysia and Thailand are used to be main exporters of crude oil. However, because of rising crude oil demand and declining crude oil production caused the exports of crude oil in ASEAN countries slightly declined. Figure 1.2 shows crude oil exports in ASEAN from 2011 to 2020. Figure 1.2 shows that ASEAN countries, especially Brunei, Indonesia, Malaysia, Thailand, and Vietnam, are highly dependent on crude oil exports. Therefore, the crude oil price instability in ASEAN countries is significantly important as crude oil is widely traded in the global market. When the crude oil price is unstable, this will have an impact on terms of trade, such as the import and export prices of crude oil and other products made by crude oil. For instance, in response to the rise in the price of crude oil, chemical producers may attempt to raise the export price of synthetic rubber, which is derived from crude oil (Inagaki & Matsuura, 2018). The tighter supply-demand balance could make it simpler to charge a higher price, especially for popular products in oil-producing nations. Export prices will increase if exporters are successful in transferring prices, which might result in more favourable trading conditions.

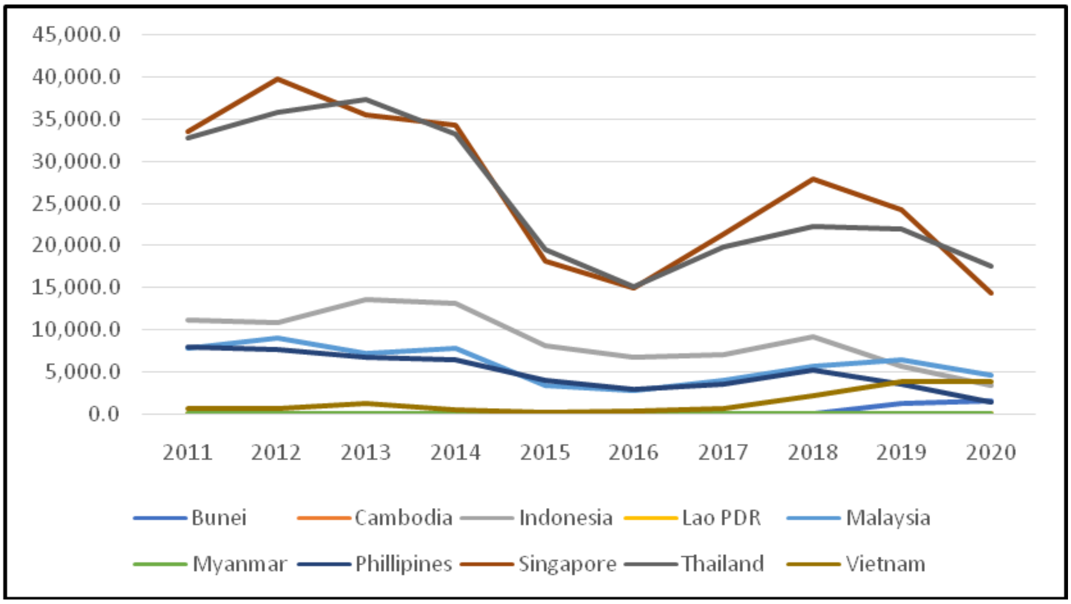
Figure 1.2: Export Values of Crude Oil in ASEAN (millions in US$), 2011-2020



Source: ASEAN Stats (2021)

In the 5th ASEAN Energy Outlook, several ASEAN countries such as Singapore, Philippines, Laos, and Cambodia have the minor reserves of oil, and there have been no large oil discoveries in recent years. Being a net importer of crude oil, ASEAN is sensitive to supply disruptions and price changes. The highest price of crude oil was reached on May 22, 2018, when it reached US$80.49 per barrel (ASEAN Centre for Energy, 2018). As a result of its dependence on oil, ASEAN must stifle emerging energy issues to avoid a rise in crude oil prices. The member of ASEAN who is net importers of oil will see an increase in their importing expenses because of rising oil prices, which will result in higher petrol prices. However, increasing oil prices resulted in substantial extra income for net exporters nations. The necessity of importing crude oil burdens these countries' economies. Figure 1.3 shows the total imports of crude oil in ASEAN countries from 2011 to 2020. Based on Figure 1.3, Singapore and Thailand have heavily relied on crude oil imports. However, the reduction in ASEAN crude oil production is expected to occur until 2040 at an average of 1.4 percent annually (ASEAN Centre for Energy, 2017). In 2040, the crude oil production of ASEAN regions is predicted to drop to 1.6 million barrels per day.

Figure 1.3: Import Values of Crude Oil in ASEAN (millions of US$), 2011-2020



Source: ASEAN Stats (2021)

Sumatra in Indonesia had the first oil discovery in Southeast Asia in 1883. After that, Brunei, Indonesia, and Malaysia—three of the most prominent players in the ASEAN oil industry extended crude oil exploratory drilling activities and started producing it economically. The ASEAN Member States' need for fuel, such as crude oil, to sustain manufacturing, transportation, and household areas necessitates oil drilling operations (ASEAN Centre for Energy, 2018). Oil-producing countries like Brunei, Indonesia, and Malaysia have the chance to boost their incomes and funding from crude oil exports when there is an increase in the crude oil price. These funds could be invested in local and foreign oil development and exploration.

This effort will contribute to a boost in crude oil production and supply. In the ASEAN area, Indonesia consumes the highest level of crude oil, with demand rising gradually from 1.2 million barrels per day in 2010 to 1.6 million barrels per day in 2015 (Kimura & Morikawa, 2018).

The demand for crude oil in Indonesia is forecasted to achieve 4.8 million barrels per day in 2040 as the rise is anticipated to pick up speed in the coming future. This is because the transportation industry in Indonesia will experience most of the increase in demand for crude oil. Crude oil production reached its peak in the 1990s, and Indonesia produced 0.8 million barrels per day in 2015 as the top crude oil producer in ASEAN. However, Indonesia has begun to import crude oil since 2014, as the import reliance on crude oil was 57 percent in 2015 (Kocoglu, Kyophilavong, Awan, & Lim, 2022). To meet its demand, Indonesia will have to rely on crude oil imports.

As of the end of 2016, Brunei had the fourth-highest recognized oil reserves in ASEAN, estimated at 1.1 billion barrels. Brunei's crude oil production has decreased by almost half to approximately 1.15million barrels per day from a record of 2.21 million barrels per day in 2006 (Kocoglu et al., 2022). Even though the country's total crude oil production is predicted to decline from its present level until 2040, some economists stated that there might also be tendencies to change in the future (ASEAN Centre for Energy, 2017). In Brunei, average yearly production is predicted to remain steady over the forecast period. In Southeast Asia, Malaysia ranks second and fourth in terms of crude oil production and consumption. There were 0.6 million barrels per day of demand in 2015, primarily for transportation in Malaysia (Kimura & Morikawa, 2018). Malaysia has been among the region's several nations with net oil exports. Nevertheless, due to Malaysia's strong market growth and falling local output, the country started to import crude oil by 2020 (Raghavan, 2015). By 2040, 65 percent of the country's consumption will likely be imported.

Furthermore, Singapore ranks third in the ASEAN region for crude oil consumption. However, Singapore has significant refining capacity. With a capacity of 1.5 million barrels per day for crude oil refining, Singapore was identified to be one of the top three crude oil trading and refining centres in the world (International Trade Administration, 2023). Despite having abundant refinery capacity, Singapore produces less crude oil domestically. For many years, Singapore served as the area's centre for commerce and crude oil processing. Singapore's oil consumption is expected to increase rapidly in the coming years, even though it declined from 2000 to 2015 as natural gas substituted crude oil for generating electricity (Yeo, Chalmers, Hunter, & Tanjanco, 2017). Moreover, the demand for crude oil is forecasted to increase significantly by 2030, when Singapore's market is mainly focusing on petrochemical feedstock (Kimura & Phoumin, 2016). Thailand also highly consumes crude oil and ranks third in terms of crude oil producer in Asia. In 2015, it used around 1.1 million barrels per day, primarily for non-energy purposes and transportation usage (U.S. Energy Information Administration, 2017). The largest consumption industries, transportation and non-energy usage are predicted to grow, reaching 2.3 million per day in 2040(Kimura & Phoumin, 2016).

In 2015, Thailand's local production climbed to 0.5 million barrels per day, and nearly all of it was used locally. It is also predicted that oil production will begin to decrease in 2030 and stay at roughly 0.4 million barrels per day after 2030. Therefore, increasing import reliance is unavoidable, similar to Malaysia and Indonesia. By 2040, Thailand's reliance on crude oil imports is predicted to increase to 83 percent (Kocoglu et al., 2022). Not only that. ASEAN-5 countries are chosen because they are potential to be involved in regional cooperation. According to the ASEAN Economic Community (AEC), ASEAN is aimed as an integrated marketplace and production base with wide-ranging trade in goods, services, and investments along with more open skill and capital markets (InvestASEAN, 2023). If the crude oil price is very volatile and unstable, the investment in crude oil and the plan of AEC might be delayed. Therefore, the crude oil price will highly affect the related investment to be attracted to ASEAN.

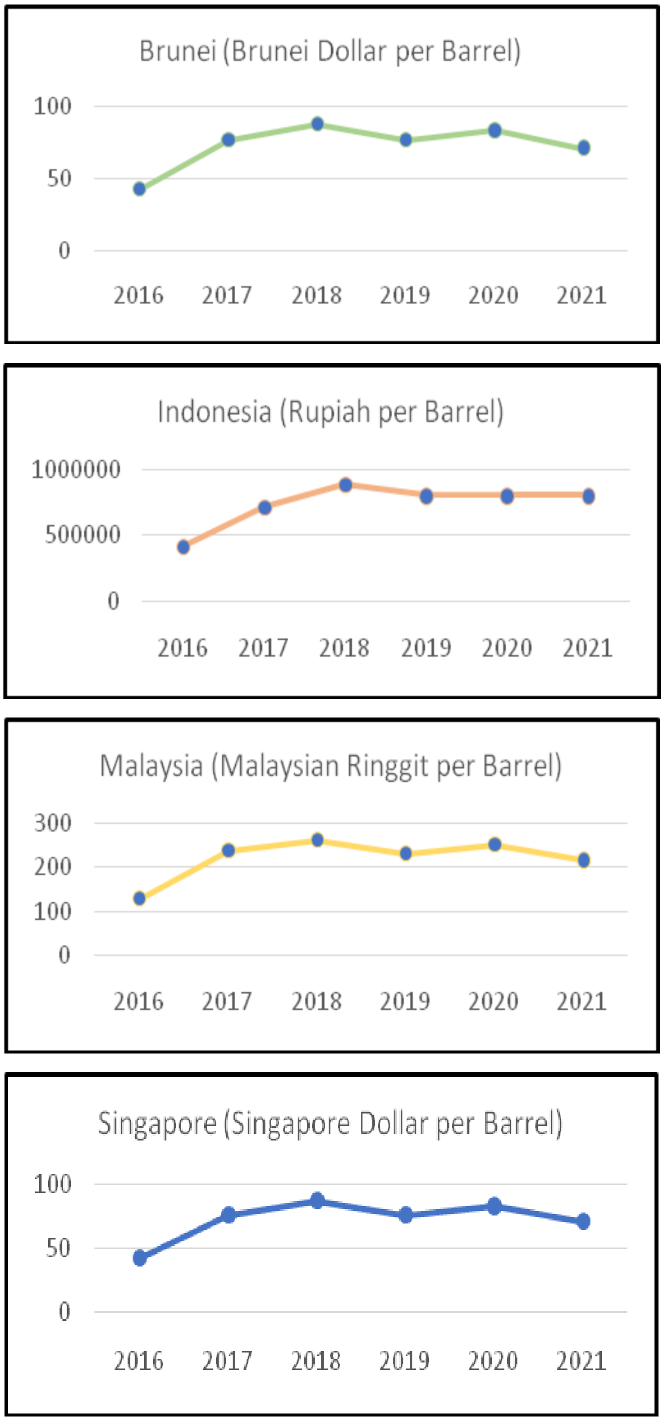
1.2 Current Situation of Crude Oil Price Instability

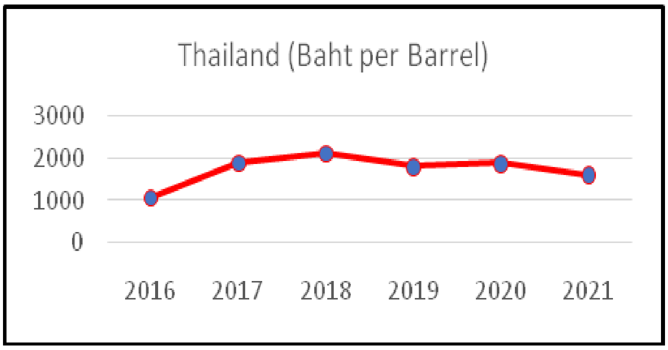
1.2.1 Crude Oil Price

Figure 1.4 shows the average crude oil spot price for Brent, Dubai, and WTI in ASEAN-5 countries, Brunei, Indonesia, Malaysia, Singapore, and Thailand, from 2016 to 2021. In 2018, all five countries recorded the highest average crude oil spot price. For Brunei, the average spot crude oil price in 2018 charted as BND88 per barrel. Meanwhile, Indonesia recorded IDR886,240 per barrel, and Malaysia recorded RM262 per barrel in 2018. Within these six years, Brunei has relied heavily on oil revenues to build the country into one of the highest living standards in the world due to the sharp fluctuations in crude oil prices. This fluctuation trend in Brunei is mainly due to Brunei entered into an agreement with OPEC and non-OPEC countries in 2016 to adjust and cut down the oil production in order to control the global crude oil price, unscheduled maintenance on oil facilities in 2018 also impeded the production of crude oil and the implementation of Brunei Darussalam National Climate Change Policy (BNCCP) on oil and gas industry in 2020 also resulted in higher costs and low production of oil (IMF, 2019, 2021; OPEC, 2021). Consequently, this has led to the price of crude oil in Brunei being unstable.

While the average spot crude oil price for Singapore and Thailand in 2018 was SGD88 per barrel and Baht2,113 per barrel respectively. The first reason the high price happened in 2018 is due to sanctions on Iran which escalated expectations that demand growth is doomed, as well as the worsening scenario in Venezuela are all factors influencing the crude oil market (Rapiah, 2018). Furthermore, another reason that 2018 recorded the highest price for these ASEAN-5 countries is due to 'The Trump Effect'. In 2018, the previous President of the U.S. out of Iran's nuclear agreement unilaterally, resulting in a market decline that digested Iran's crude oil exports. Iran's oil production accounts for about 4% of the world's crude oil supply (Vaughan, 2018). As a result, the crude oil price in 2018 was recorded as the highest. In 2018, there were uncertainties all around the world, which led the price of crude oil to fluctuate and become unstable. Overall, the crude oil price in the ASEAN-5 countries except for Indonesia have slightly decreasing trend in 2020 to 2021 due to the COVID-19 pandemic's lockdowns reduced the economic activities and travels caused the global oil demand decreased significantly and led to a decrease in crude oil price in these ASEAN-5 countries (Gharib, Mefteh-wali, Serret, & Ben, 2020).

Figure 1.4 Average Spot Price of Brent, Dubai, and WTI in ASEAN-5 Countries,2016-2021





Source: Index Mundi (2022)

Table 1.1: Average Spot Price of Brent, Dubai, and WTI in ASEAN-5 Countries, 2016- 2021

Brunei	
Year	**COP (Brunei Dollar per barrel)**
2016	42.6800
2017	76.6100
2018	87.6000
2019	76.7400
2020	83.2700
2021	71.0400

Indonesia	
Year	**COP (Rupiah per barrel)**
2016	413550.2000
2017	715959.3000
2018	886240.2000
2019	802321.8000
2020	802321.8000
2021	802321.8000

Malaysia	
Year	**COP (Malaysian Ringgit per barrel)**
2016	129.3900
2017	239.1400
2018	262.1300
2019	232.8900
2020	251.5000
2021	216.3800

Singapore	
Year	**COP (Singapore Dollar per barrel)**
2016	42.6800
2017	76.6100
2018	87.6000
2019	76.7400
2020	83.2600
2021	71.0400

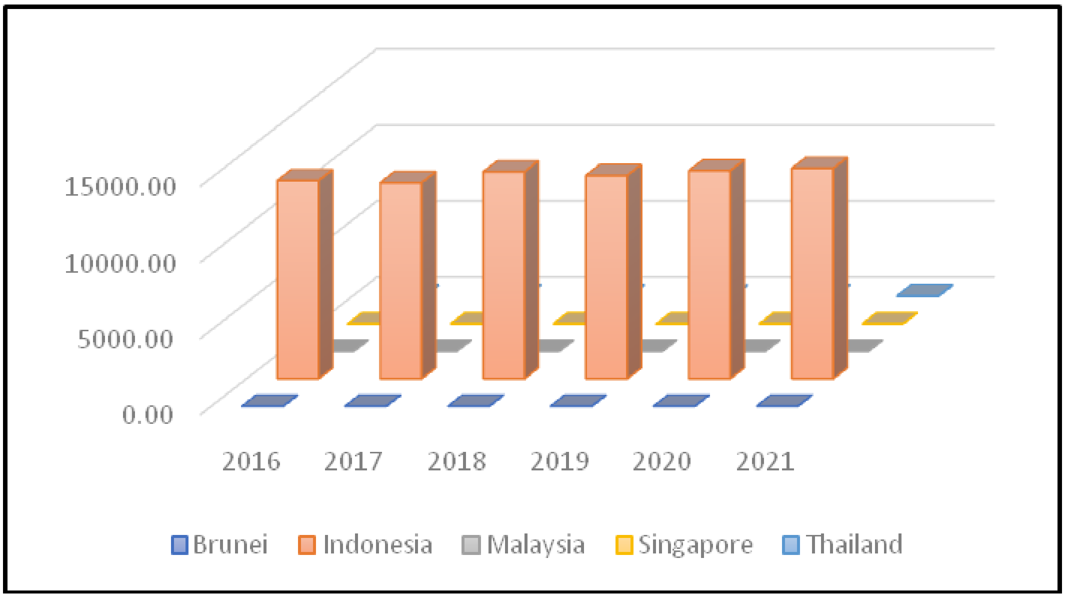
Thailand	
Year	**COP (Baht per barrel)**
2016	1076.6500
2017	1900.5500
2018	2113.0500
2019	1800.1900
2020	1876.1600
2021	1608.0200

Source: Index Mundi (2022)

1.2.2 Exchange Rate

Figure 1.5 shows the exchange rates based on local currency per U.S. dollar of selected ASEAN-5 countries from 2016 to 2021. Here, Indonesia had the highest exchange rate from 2016 to 2021 compared to the other four (4) ASEAN countries. Indonesia recorded the highest exchange rate at IDR13,829.65 per U.S. dollar in 2021. Thailand charted the second-highest exchange rate among the ASEAN-5 countries, and the highest exchange rate was Baht35.67 per U.S. dollar in 2016. In addition, Malaysia was ranked third highest in the exchange rate of these five countries and reached the highest rate at RM4.34 per U.S. dollar in 2021. Meanwhile, the average exchange rate of Brunei and Thailand were BND 1.36 per U.S. dollar and SGD 1.45 per U.S. dollar respectively.

Figure 1.5: Exchange Rates (Local currency per U.S. dollar) of ASEAN-5 Countries, 2016-2021



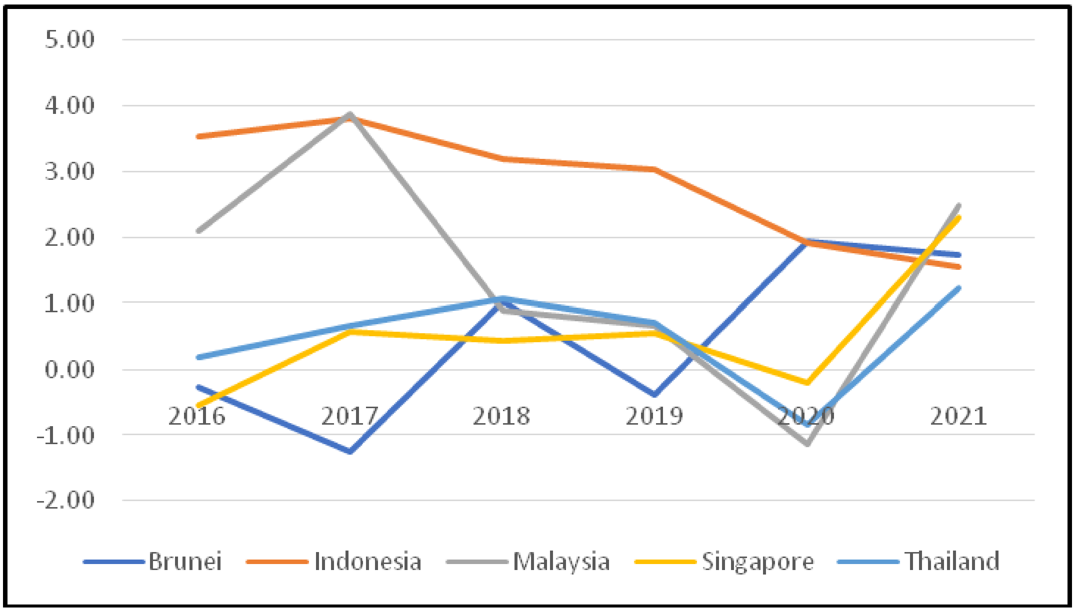
Source: U.S. Department of Agriculture (2022)

Note: Brunei (BND/USD); Indonesia (IDR/USD); Malaysia (RM/USD); Singapore (SGD/USD); Thailand (Baht/USD)

1.2.3 Inflation Rate

Figure 1.6 shows the inflation rate in percentage of the selected ASEAN-5 countries from 2016 to 2021. Here, Indonesia had the highest inflation rate from 2016 to 2021. Indonesia's highest inflation rate reached 3.81% in 2017, and the lowest inflation rate at 1.56% in 2021. The high inflation in Indonesia is due to the rise in transportation costs, as the fuel price in Indonesia has increased since 2015, causing commodity prices to rise (The Star, 2022). However, Indonesia experienced low inflation during 2020 to 2021 due to the government was putting effort to control the inflationary pressure in lowering inflation rate due to Indonesia's weak purchasing power (Yuniarti, Rosadi, & Abdurakhman, 2021). For Malaysia, the country experienced the most fluctuating inflation rate from 2016 to 2021, where the highest inflation rate reached 3.87% in 2017, and the lowest rate was -1.14% in 2020. The negative inflation in Malaysia in 2020 is due to the COVID-19 pandemic happened and caused a few sectors in Malaysia to be affected, such as fuels and gas, electricity, water, housing, and transport (Mahidin, 2021). Meanwhile, the inflation rate trend in Brunei fluctuated over time where the lowest inflation rate was -0.28% in 2016, and the peak rate was 1.94% in 2020, especially on prices of services due to COVID-19 pandemic outbreak had caused the travel restrictions in Brunei (The Scoop, 2020). For the other countries, the inflation rate averaged 0.53% for Singapore and 0.50% for Thailand.

Figure 1.6: Inflation rate (%) of ASEAN-5 countries, 2016-2021

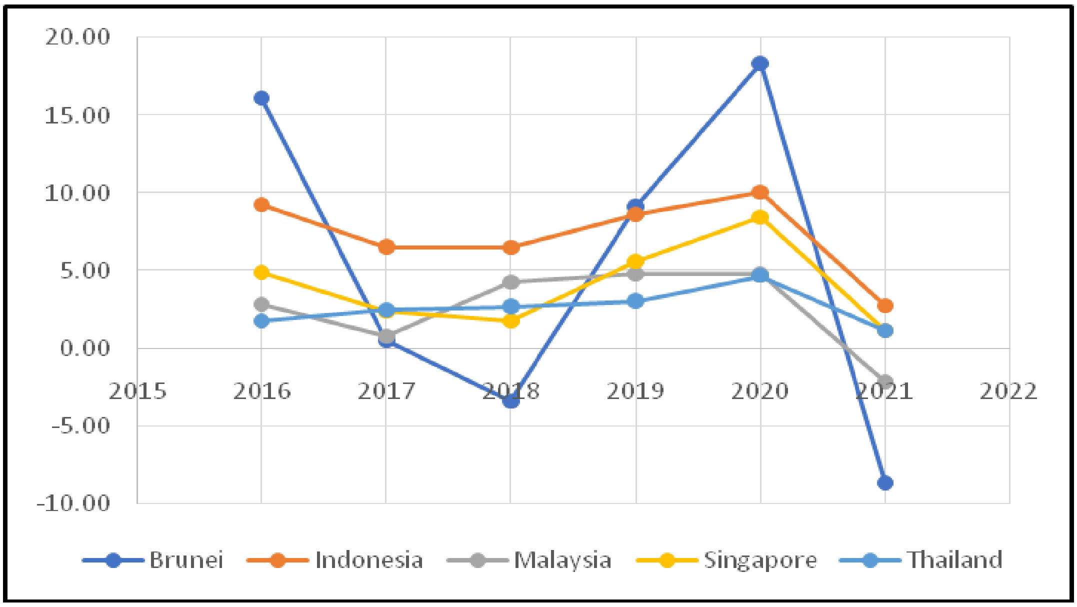


Source: World Bank (2022)

1.2.4 Interest Rate

Figure 1.7 shows the interest rate for selected ASEAN-5 countries from 2016 to 2021. Here, Brunei's interest rate shows the most fluctuating trend from 2016 to 2021 compared to the other four countries. Brunei recorded the highest interest rate at 18.36% in 2020 and reached its lowest value at -8.64% in 2021. According to International Monetary Fund (2021), the central bank of Brunei provided incentives for the private sector by offering lower-interest loans, especially for small and medium-sized enterprises sectors, as these sectors are crucial in supporting the economy in Brunei during the COVID-19 pandemic in order to mitigate the effects of the pandemic. In general, the interest rate trend for the rest of the four countries was considered stable and did not fluctuate as much as Brunei. For Indonesia, the country's interest rate charted at an average of 7.26%. Meanwhile, Malaysia and Singapore marked 2.55% and 4.05% on average respectively. For overall, all five countries reduced their interest rate in 2021. This is due to the government of these countries wanted to minimize the negative effect of the lockdown caused by the COVID-19 pandemic. Hence, these governments utilized interest weapons to assist and support the real economy. For instance, some central banks, such as Brunei and Malaysia, even cut the interest rate to negative rates to create low borrowing costs for firms and households (Hack & Nicholls, 2021).

Figure 1.7: Interest Rate (%) of ASEAN-5 Countries, 2016-2021

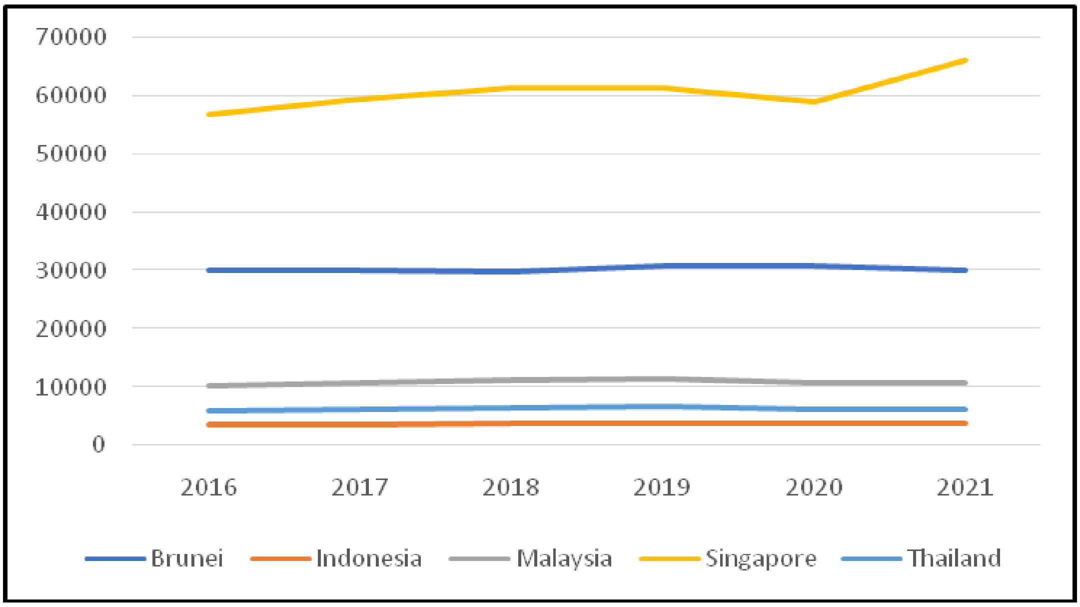


Source: World Bank (2022b)

1.2.5 GDP per capita

Figure 1.8 shows the GDP per capita (in terms of constant 2015 US$) for ASEAN-5 countries from 2016 to 2021. Here, Singapore has the highest GDP per capita among the ASEAN-5 countries from 2016 to 2021 at US$60707.18 on average. Due to its comparatively lower population and highly developed economy, which depends heavily on the export of electrical and electronic products, pharmaceutical, maritime activities, and financial products and services. Also, Singapore is in the way of rapidly transition to high value-added activities compared to other four countries to attract investments in Industry 4.0 (Medina, 2022). Next, Brunei has the second highest GDP per capita among the countries, with an average of US$30202.18. This is due to Brunei greatly enhancing its country to become a main transport and shipping hub for commodities in ASEAN to gain a competitive advantage for country development (Joyce, 2017). Besides that, the Brunei government also established many halal-certified businesses with the goal of dominating the worldwide market for premium halal food products. Malaysia had an average GDP per capita of US$10819.13, while Thailand had an average of US$6304.54. Meanwhile, Indonesia had the lowest GDP per capita at US$ 3711.64 on average.

Figure 1.8: GDP per capita (constant 2015 US$) ofASEAN-5 countries, 2016-2021



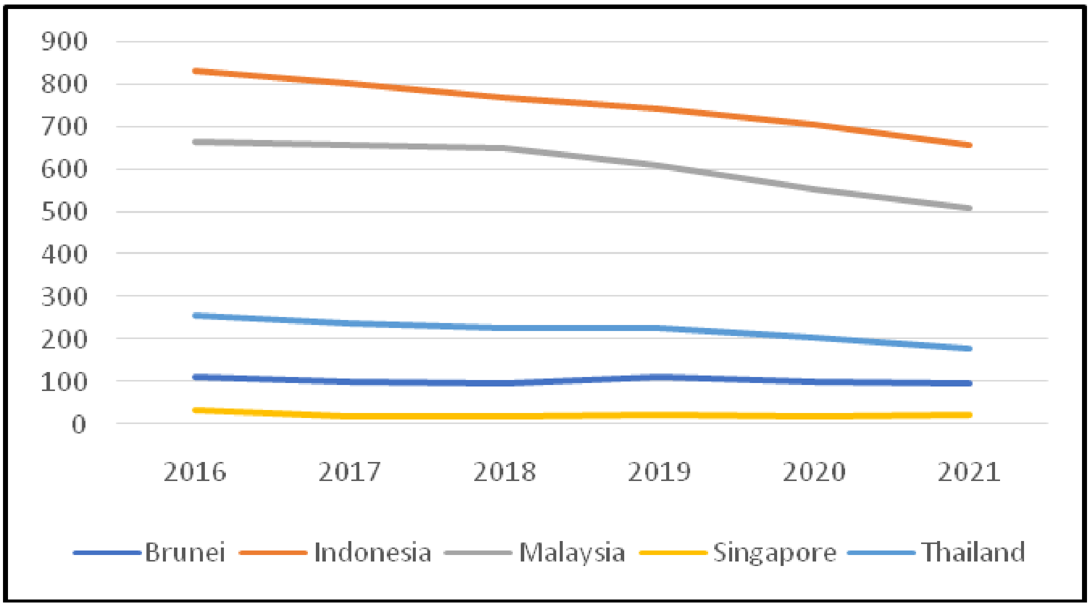
Source: World Bank (2022a)

1.2.6 Production of Crude Oil

Lastly, Figure 1.9 shows the production of crude oil in thousand barrels per day for selected ASEAN-5 countries from 2016 to 2021. Here, Indonesia and Malaysia had a significant decreasing trend in crude oil production over time. For Indonesia, crude oil production dropped from 832 thousand barrels per day in 2016 to 659 thousand barrels per day in 2021. The reduction of crude oil production in Indonesia is due to weak administrative management, corruption, uncertain government regulation, and policy uncertainties are to cause by the lack of development and other investments in the oil and gas industry that have caused to a decrease in Indonesia's crude oil production (Faisol, Indriastuti, & Trihartono, 2020).

This results in an unattractive investment environment, especially for expensive and long-term investments in oil and gas. For Malaysia, the oil production also reduced from 667 thousand barrels per day in 2016 to 511thousand barrels per day in 2021. This is because weather problems and the COVID-19 pandemic affected operations and drilling activities. On the other hand, Brunei marked an average of 102 thousand barrels per day, and Thailand marked 222 thousand barrels per day on average for crude oil production from 2016 to 2021. Meanwhile, Singapore has the lowest crude oil production among the five countries at 21 thousand barrels per day on average, as the country has limited hydrocarbon resources.

Figure 1.9: Production of Crude Oil (thousand barrels per day) for ASEAN-5 countries, 2016-2021



Source: U.S. Energy Information Administration (2022b)

1.3 Problem Statement

Crude oil price instability has been a major concern throughout the globe, especially in those nations that import, or export crude oil commodities regularly will have a much more significant impact on the nation’s economic performance. Products made from crude oil are essential to human societies since they are needed for a variety of daily functions, including industry and common domestic chores. In both exporting and importing nations, the instability in the price of oil may have a considerable macroeconomic effect. It impacts on energy prices, industrial expenses, and shipping costs, creating uncertainties in the global economy (Abdelsalam, 2020).

Based on Figure 1.1, the world spot prices for crude oil have been considered fluctuated since 2008 after Global Financial Crisis. The first oil shock triggered more chronic instability in the price of oil on a global scale. Due to the growing financialization of crude oil, there has been a progressive rise in the number of economic variables impacting oil price volatility (Razek & Michieka, 2019). Following the global COVID-19 pandemic in 2020 and 2021, concerns about volatility dominated the financial markets, and crude oil prices fell dramatically due to drastic dropped in oil demand. The unexpected war between Russia and Ukraine, which occurred in February 2022, increased global uncertainties, and caused crude oil prices to surge again. The uncertainty caused by unstable crude oil price movements can hinder economic growth by increasing the cost of production, changing investment preferences, and impairing economic activity (Difeto, van Eyden, Gupta, & Wohar, 2019).

Moreover, the importance of researching crude oil price instability towards the ASEAN-5 economies should be noticed occasionally. For Brunei, the economy relies mostly on crude oil revenue, and the nation's GDP is mainly contributed by the petroleum industry (Fox, 2022). According to International Trade Administration (2022), the revenue in the oil and gas industry accounts for 90% of the total exports from Brunei and 62% of its GDP. Hence, the crude oil price instability will affect the revenue and budget of the government to develop the country in terms of funding for infrastructure development in Brunei. Indonesia is the only Asian country that joined OPEC and significantly influences global crude oil prices (U.S. Energy Information Administration, 2015). By embracing OPEC, Indonesia will be able to improve its collaboration with countries that produce oil, have better access to supplies of crude oil, and position itself as a connection between countries that produce energy and those that consume it. As a OPEC member, the oil-producing countries will need to adjust their crude oil production to maintain the demand and supply of the global market (World Economic Forum, 2022).

Hence, Indonesia has a significant influence on the fluctuations of global crude oil prices, and the volatility of crude oil prices in Indonesia should always be paid attention to monitor the global crude oil price trend. Besides, Malaysia's crude oil price instability is also highly concern. One of the reason is that Malaysia provides subsidies for petroleum such as RON95, which lead to the price of petrol being lower than the market price (Sulaiman, Harun, & Yusuf, 2022). This is due to the Malaysian government wanting to reduce consumer burdens when the crude oil price is fluctuating and unstable. However, when the crude oil price is highly unstable and rises significantly, this means that the Malaysian government has to increase the budget for petroleum subsidies and increase pressure on Malaysian government finances and cause an economical budget deficit. In 2022, the government spent RM50.8 billion on subsidies for fuel, liquefied petroleum gas, and diesel (CNA, 2023; Ministry of Finance Malaysia, 2022). Therefore, the crude oil price instability in Malaysia significantly influences budget allocation, which might pressure the government in finance.

Furthermore, when the crude oil price fluctuates and is unstable, the energy demand will shift to the crude oil substitutes such as renewable energy instead of fossil fuel for power generation. Since Singapore is one of the major crude oil importers, the volatile crude oil price will highly affect the side of businesses and consumers and cause them to be aware of renewable energy and shift their demand towards it. The government of Singapore is trying to find ways to lower the nation's carbon emissions. The Carbon Pricing Act of Singapore, which included a carbon tax, took effect in 2019. The Energy Market Authority (EMA) of Singapore has unveiled proposals called "4 Switches" to promote the production of greener energy, such as solar energy (EMA Singapore, 2022; U.S. Energy Information Administration, 2021). As a result, the dynamic of supply and demand of crude oil has been affected, with Singapore's exports of petrochemicals and refined petroleum-related goods falling by 5% and 14%, correspondingly in 2019. For Thailand, the instability in crude oil prices will negatively impact farmers' revenue as crude oil is used as a crop's primary fertilizer. Hence, when the crude oil price is fluctuating, the cost of fertilizer rises which might reduce crop production or increase food prices. According to IRENA (2017), the government is encouraging farmers to adopt renewable energy in farming to improve the return of farmers and investments in energy crops as renewable energy will not be depleted, and the price is more stable and suitable to control the food price. Therefore, the crude oil instability will shift the demand and supply of crude oil and cause the global supply chain to be affected, and this might create oil shocks where the crude oil may not be able to be sold.

Next, macroeconomic variables are utilised to investigate the factors of crude oil price instability in selected ASEAN-5 countries. According to Beckmann, Czudaj, & Arora (2020) and Kocoglu et al. (2022), capital investment in crude oil will be affected by the exchange rate's movements. As a result, it increases the cost of crude oil, widens the trade deficit, depletes foreign currency reserves, distorts the balance of payments, and drives up inflation. Hence, the exchange rate is taken as an independent variable in examining its relationship with the crude oil prices in this study. In addition, studies by Castillo, Montoro, and Tuesta (2020) and Olofin and Salisu (2017) show that the inflation rate is shown to have a significant positive effect on the instability of crude oil prices. Therefore, the inflation rate is included in investigating its relationship with the crude oil price. Moreover, Kilian and Zhou (2022) and Mofema and Mah (2021) found that interest rate is identified to have a negative impact on the crude oil price. Hence, the interest rate is included in this study as the independent variable. Other than that, the study of Sha (2022) shows GDP per capita is positively influence crude oil price. Lastly, Chatziantoniou et al. (2021) and Yang, Yang, Chen, and Tong (2022) found that crude oil production negatively influenced oil prices. This research study will use these empirical studies' results as a guide to validate the results for the selected ASEAN-5 countries on the crude oil price.

Last but not least, the study's research gap can be reflected in the study of Ahmad et al. (2022), who examined the relationship between major macroeconomic indicators and crude oil price volatility. In this study, Ahmad et al. (2022) utilised time-series data from eight (8) South Asian nations such as Sri Lanka, Pakistan, Nepal, Maldives, India, Bhutan, Bangladesh, and Afghanistan, for the period 2000 to 2020. Hence, not many studies on this subject targeted the ASEAN countries. Other than that, most past researchers, such as Togonidzea & Kočenda (2022) and Zhao (2022), have focused on oil price shocks in developed nations like Canada, the United Kingdom, and the U.S. These past studies employed high-income level, wide datasets on developed and developing countries, which are constrained in their extent and cannot be used to investigate various economic areas in detail. Thus, it is essential to conduct this study to understand the relationship between exchange rate, inflation rate, interest rate, GDP per capita, and production of crude oil in ASEAN countries such as Brunei, Indonesia, Malaysia, Singapore, and Thailand. Therefore, this is met with the study's general objective, such as developing forecasting models of crude oil price instability in ASEAN-5 countries.

In addition, most researchers like Shah & Kiruthiga (2020) and Vu & Nakata (2018) used the crude oil price benchmarks in terms of U.S. dollars per barrel to examine the relationship instead of using local currency per barrel. However, this study will use each country's crude oil price in terms of local currency per barrel to explore the relationships between the independent variables and crude oil price. This also meets the specific objectives of 1, 2, and 3. Besides, most of the researchers investigated how crude oil price impact inflation, interest rate, and GDP and conducted Granger Causality to examine the relationship but seldom studied the opposite side, which investigated relationships of inflation, interest rate, and GDP on the crude oil price. Additionally, there are rare past studies (Chatziantoniou et al., 2021; Vu & Nakata, 2018)carried out their study by combining to investigate factors of crude oil price instability and forecasting crude oil price instability in the future using the ARIMA model. Therefore, it is necessary and important to recognize the factors of crude oil instability in the context of the ASEAN economies by applying panel model analysis, and the ongoing study carried out using the ARIMA model will enable the researcher to predict the direction of the price of crude oil in the future. Here, this will meet specific objective 4 to predict the ex-post forecast of crude oil prices among ASEAN-5 countries.

1.4 Research Objectives

The research study's general objective and specific objectives are listed below to support the research study and as a guide of direction in this research study.

1.4.1 General Objective

The general objective of the study is to develop forecasting models of crude oil price instability in ASEAN-5 countries.

1.4.2 Specific Objectives

1. To identify the factors affecting crude oil price instability among ASEAN-5 countries.

2. To analyse the combined effects among exchange rate, inflation rate, interest rate, GDP per capita, production of crude oil, and crude oil price of ASEAN-5 countries.

3. To examine how is crude oil price instability in each ASEAN-5 country.

4. To predict the ex-post forecast of crude oil price among ASEAN-5 countries.

1.5 Research Questions

There have been many research studies done to investigate the variables that influence crude oil price instability, but there are still several unclear questions that might affect the instability of the crude oil price in the selected ASEAN-5 nations. The following are the questions:

1. What are the factors affecting crude oil price instability among ASEAN-5 countries?

2. How are the combined effects among exchange rate, inflation rate, interest rate, GDP per capita, production of crude oil, and crude oil price of ASEAN-5 countries?

3. How is crude oil price instability in each ASEAN-5 country?

4. How is the ex-post forecast of crude oil price among ASEAN-5 countries?

1.6 Significance of Study

Since crude oil is a crucial component of practically all contemporary activities, it is important to recognise and understand the main factors influencing its price. Therefore, it's vital to pursue this study subject analytically to assure that the results are substantial and relevant for consumers, investors, and policymakers to take into account in making the decision, forecasting, and planning. The theoretical and empirical significance of the study is highlighted below.

1.6.1 Theoretical Significance of Study

There are two main theories involved in this research study. First and foremost, the theory of supply and demand combines supply and demand changes to influence crude oil prices. Hamilton (2009) examined the factors influencing oil prices and claimed that the increase in crude oil prices in 2007–2008 was mostly caused by the rising demand for oil on a worldwide scale. Crude oil supply shock, global demand shocks for all industrial goods, and the crude oil market were the three main aspects that made up the crude oil price. Yet, crude oil's global supply and demand dynamics have altered recently due to the growth of other energy sources. Besides that, some studies reported that increased crude oil production will lower the price of crude oil generally and will diminish the global demand for oil (Kilian, 2017; Lu, Sun, Duan, & Wang, 2021). Hence, this theory will look into the changes in crude oil prices determined by the equilibrium of demand and supply of crude oil. Secondly, the theory of one price will be discussed on the effect of the exchange rate on the crude oil price.

This theory states that an identical commodity's price will be the same everywhere, regardless of geographic location. Due to the relatively homogeneous nature of commodities like crude oil and the global nature of their trading, exchange rate changes can impact the price of crude oil based on theory of one price. Since crude oil price including WTI, Brent and Dubai/Oman is denominated in U.S. dollar, hence demand for U.S. dollar will change when there is a change in crude oil price

(Basher, Haug, & Sadorsky, 2012). As a result, consumers in different countries will be paying different crude oil prices due to the local currency exchange rate movement against the U.S. dollar. Therefore, the theory of supply and demand and the theory of one price are important in showing the significance of this research study.

1.6.2 Empirical Significance of Study

Next, the empirical significance will be presented. First and foremost, the exchange rate has been shown to have short-term and long term negative impact crude oil prices (Hlongwane, 2022). Since most investors want to invest in an economy that is stable and would yield a greater return on their investment, this circumstance will have an impact on foreign direct investment in the country. When the exchange rate movement fluctuates in high volatility, the crude oil price will become unstable, creating more uncertainties for the country. Consequently, a country's ability to expand economically will be constrained. Changes will influence oil-exporting and oil-importing countries in terms of the price of crude oil.

Besides that, some studies found that inflation rate and crude oil price are positively related (Castillo et al., 2020; Olofin & Salisu, 2017). This is due to the costs incurred in goods and services increasing, including labour costs, capital costs, and transportation costs will lead to higher inflation; thus, the price of commodities such as crude oil will also be affected. As a result, the consumers will suffer from inflation's consequences. Therefore, this research will give consumers a clearer picture of the relationship between the inflation rate and crude oil price.

In addition, the interest rate is identified to impact crude oil price negatively (Chatziantoniou et al., 2021; Mofema & Mah, 2021).When interest rate increases, this will increase the cost of borrowings and inhibit investment. The worldwide markets become unstable due to high borrowing costs and low investment, which lowers crude oil demand. As a result, when crude oil demand drops, this will cause a fall in crude oil prices, raising the volatility of oil prices.

Fourthly, economic growth in GDP per capita is evidenced to have a positive relationship with crude oil price (Sha, 2022). Investors and entrepreneurs will hesitate to make investments in the manufacturing sector when the crude oil price is volatile and unstable. Further, the reduction in manufacturing and other economic activity has negative influence on the country's economic growth in terms of GDP.

Lastly, several studies proved that crude oil production negatively affects crude oil price (Chatziantoniou et al., 2021; Yang, Yang, Chen, & Tong, 2022). Crude oil production can be defined as oil supply as well, when oil production reduces and means that the supply of oil is reduced. As a result, the crude oil price will increase based on the theory of supply and demand because the quantity of crude oil produced is limited in the oil market. Hence, crude oil price instability will become higher as crude oil prices are very volatile when there are changes in crude oil production.

1.7 Chapter Layout

There are five chapters will be included in this research project to be discussed:

Chapter 1: Research Overview

The first chapter provides an overview of the research project. It started by discussing the issue of global crude oil price instability as well as the ASEAN-5countries. Following that, the problem statement, research objectives, research questions, and study significance were developed. Lastly, the overall research chapter layout was provided.

Chapter 2: Literature Review

Chapter 2 will cover the relevant theories that explain crude oil price instability. This chapter will go into more detail about literature reviews in order to show how the dependent and independent variables relate to one another. Furthermore, empirical reviews of the research method on the panel data analysis model and Autoregressive Integrated Moving Average (ARIMA) model will also be presented.

Chapter 3: Research Method

Chapter 3will outline the method of data collection and the methods employed in the research project. Following that, a conceptual framework and hypothesis development will be proposed. The chapter will also cover definitions of variables, research methods, residual diagnosis, model evaluation, and data analysis.

Chapter 4: Data Analysis and Results

The data analysis and empirical results from the research study will be performed in Chapter 4. This chapter will discuss descriptive analysis, preliminary analysis, research estimation methods as well as major findings of results.

Chapter 5: Discussion, Conclusion, and Implications

The statistical analyses performed in Chapter 4 will be summed up and discussed further in chapter 5, which will then analyse the implications of the study. Following that, the research study's limitations will be identified, and suggestions for further investigation will be presented. The chapter will be ended with a conclusion that summarise the entire research study.

1.8 Conclusion

In summary, Chapter 1 provided the background of crude oil price instability in ASEAN-5 countries and covered the current situation of crude oil price instability in the ASEAN countries. Following the problem statement, the research objectives and questions were stated. After that, economic theories, and previous empirical studies relevant to the research study were in terms of importance of study. Finally, the chapter layout was provided, followed by a conclusion. The next chapter, Chapter 2 will provide the literature review covering theoretical framework and empirical reviews of the factors affecting crude oil price instability and research methods.

CHAPTER 2: LITERATURE REVIEW

2.0 Introduction

This chapter will discuss the literature review, which covers theories applied and reviews of existing past studies on the relationships among independent variables and crude oil prices. This chapter will present a general review of crude oil prices and the determinants that influence crude oil price instability.

2.1 Reviews of Relevant Theoretical Models

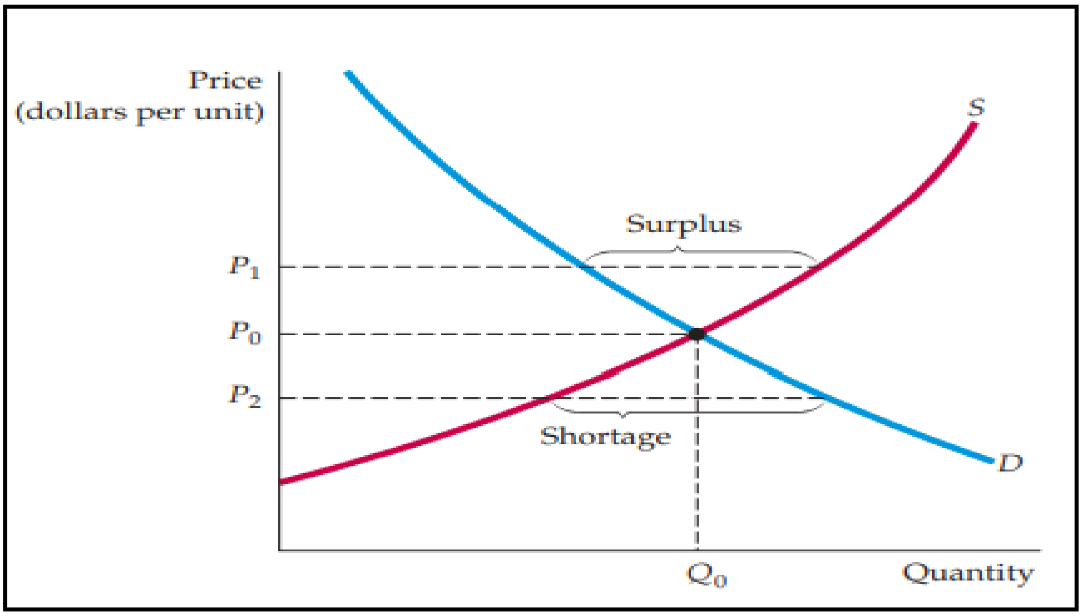
It is important to assure that every study is appropriately supported and explained by theoretical framework. The theories supporting this research are presented in the following discussion, which includes the Theory of Supply and Demand for Commodity Price, Theory of One Price Changes and Effect of Exchange Rate, and Conceptual Theory of Changes of Other Factors on Crude Oil Price.

2.1.1 Theory of Supply and Demand for Commodity Price

Supply refers to the quantity of a good or service that is provided at each price, demand is the quantity that consumers are able and willing to pay and purchase at different prices. The theory of supply and demand indicates that whenever a commodity's demand increases, its supply will also increase and vice versa. The link between a commodity's supply and demand is described by the theory of supply and demand. For example, if a commodity has a high demand and a low supply, this means that the commodity is not enough of the quantity to satisfy the want of people, and which will result in a higher price and vice versa. In a free market, the price of every product is determined by how much demand it has from consumers.

This theory also describes the relationship of supply and demand to achieve market and price equilibrium. Equilibrium price of the product possesses effect of empowering suppliers to sell their products at a price that consumers are willing to pay (Whelan, Forrester, & Msefer, 2001). When the quantity of supply and demand is equal, the market will achieve at equilibrium. Equilibrium is achieved when a supplier is willing to sell the product at a set price at all units and consumers are willing to pay for the price at all units. A market's equilibrium price is created when supply and demand balance out one another. Businesses or firms typically look for ways to achieve equilibrium; they commonly look for ways to maintain a balance between the quantity of goods produced and consumer demand. To illustrate, Figure 2.1 presents the market equilibrium of price and quantity when both demand curve (D) and supply curve (S) intercept together.

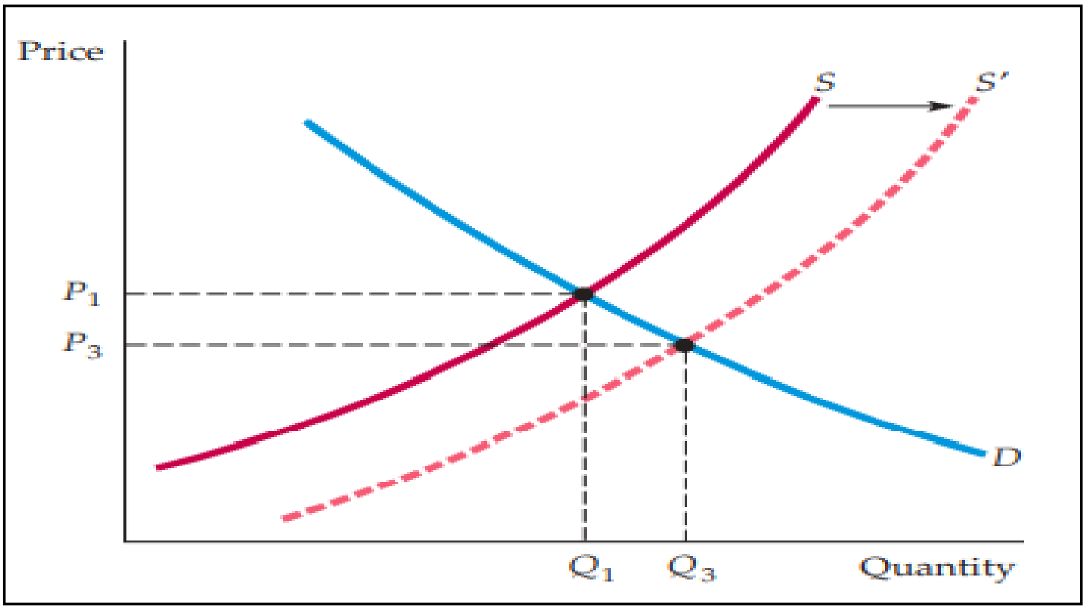
Figure 2.1: Market Equilibrium of Price and Quantity



Source: Pindyck & Rubinfeld (2018)

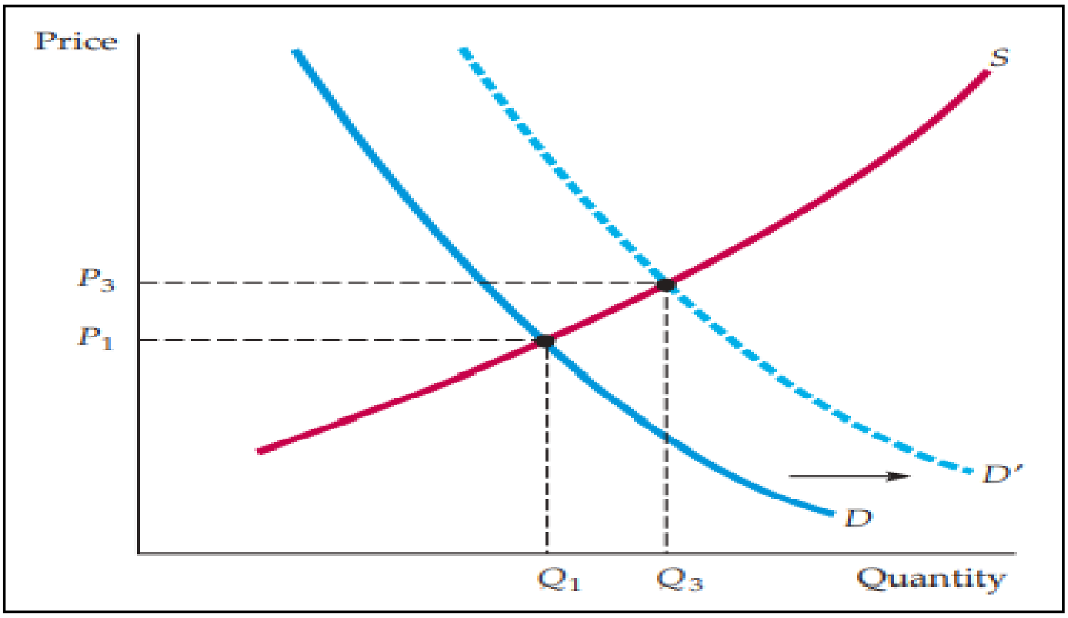
Typically, the price of the commodity will reduce when there is an increase in supply of commodity and supply curve will shift rightward. Figure 2.2 illustrates the changes when increasing in supply. On the demand side, when the demand of commodity increase, demand curve will shift rightward from D to D’ and causing the price and quantity increase. Figure 2.3 illustrates the changes when increasing in demand.

Figure 2.2: Equilibrium Changes Following Shift in Supply



Source: Pindyck & Rubinfeld (2018)

Figure 2.3: Equilibrium Changes Following Shift in Demand



Source: Pindyck & Rubinfeld (2018)

The oil market's dynamics fluctuate over time as it is a commodity that is influenced by demand and supply just like every other good or service. The fluctuation in oil prices can be explained by the theory of supply and demand of commodity price. The tremendous growth of the automotive industry and other technical infrastructures is the driving factor behind the rise in demand for crude oil or petroleum products (Bekkeheien, Håland, Klovening, & Stokholm, 1999). The economy and "unabated consumer demand" have widely been discussed as causes of the rise in oil prices (J. D. Hamilton, 1996).

Thus, this proved that supply of crude oil has a negative relationship with crude oil price. When the oil supply or oil production increases, this means that oil price will reduce. For instance, people in oil-rich nations such as Saudi Arabia can indeed fill up their tanks for a cheap price because there is a sufficient supply of oil there (Tverberg, 2012). The balance between supply and demand is clearly indicated by spot market prices (U.S. Energy Information Administration, 2022a). A need for more supply is indicated by increasing prices, while a surplus of supply relative to demand is shown by decreasing in prices. As a result, futures markets reflect the supply and demand equilibrium as well as market expectations.

2.1.2 Theory of One Price Changes and Effect of Exchange Rate

Theory of one price by Jevon is an economic theory stating that the price of identical items in the same open market must be the same at any time (Pippenger, 2016).The relative domestic product prices might be used to determine the exchange rate In the chapter “International Parity Conditions” of “Fundamentals of Multinational Finance” authored by Moffett, Stonehill, and Eiteman (2021), exchange rate defined in equation (2.1).

$$S^{\frac{A}{B}} = \frac{P^A}{P^B} \quad \text{..................................} \quad (2.1)$$

Where,

$S^{\frac{A}{B}}$ = Exchange rate of Country A per Country B

P^A = Price of product in Country A

P^B = Price of product in Country B

The theory of one price considers a market that is free from transaction costs, transportation costs, and trade restrictions such as tariffs and quotas. The rule of one price is present because the arbitrage opportunity would ultimately remove differences in asset values in different regions. The theory of one price fundamental underlying concept is the perfect commodity arbitrage. It eliminates price discrepancies by causing prices of identical commodities to converge in different marketplaces (Chance & Brooks, 2015). Arbitrage opportunities are the main reason why the theory of one price is valid. Arbitrage possibilities occur when the prices of identical commodities vary across marketplaces so a trader can purchase a commodity at a lower price in a particular market and after that sell it in another market to earn a profit in high price. According to the dynamics of supply and demand will eventually bring on prices to converge across markets, which will result in the elimination of arbitrage possibilities.

The fact that the price of crude oil is expressed in US dollars serves as the theoretical basis for the causal relationship between exchange rates and crude oil prices. Based on the theory of one price, the logarithms of the crude oil price denominated in a local currency and the US dollar while transaction costs not considered in equation (2.2).

$$S^{\frac{F}{\$}} = \frac{P^F}{P^\$} \quad \text{..} \quad (2.2)$$

Where,

$S^{\frac{F}{\$}}$ = Exchange rate of local currency per US dollar

P^F = Price of crude oil in local currency

$P^\$$ = Price of crude oil in US dollar

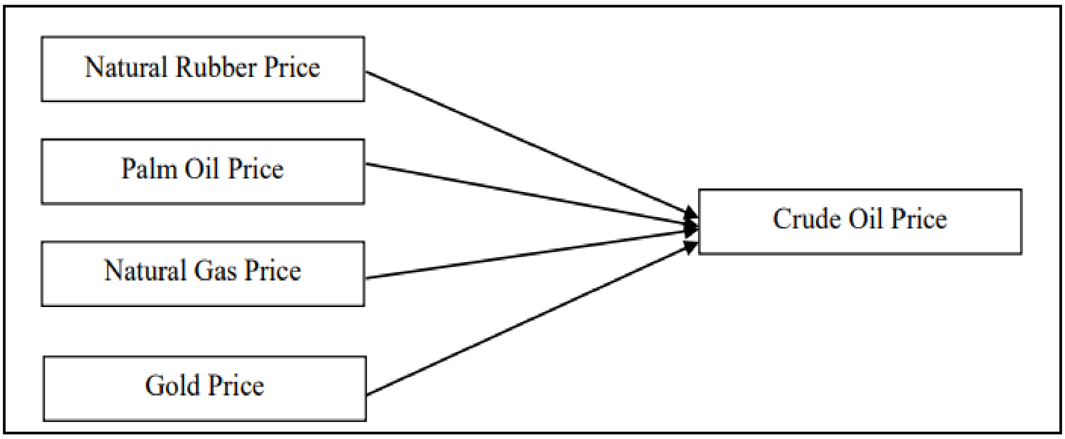
Movements in the global oil markets cause fluctuations in oil prices. According to equation (2.2), an appreciation in US dollar (a rise in the $S^{\frac{F}{\$}}$) raises the price of oil when expressed in terms of the local currency and the price of crude oil declines as demand for oil outside of the US reduces (Akram, 2009; Blomberg & Harris, 1995). Foreign oil producing countries may increase crude oil prices or reduce supply if the US dollar depreciates, and vice versa (Fratzscher, Schneider, and Robays, 2014). Instead, if they are using a pricing to market technique, they may maintain a fixed price for crude oil in US dollars, despite of fluctuations in the exchange rate of the

US dollar. Hence, the difference between two currencies will induce a change in crude oil price based on theory of one price.

2.1.3 Conceptual Review Theory of Changes of Other Factors on Crude Oil Price

Other factors like other different commodities' prices also have an impact on crude oil price. According to Khin, Chiun, Chun, Qian, & Yee (2017), the researchers investigated on the relationship between the crude oil price and four chosen other commidties price: gold price, natural gas price, palm oil price, and natural rubber price that shown in Figure 2.4.

Figure 2.4: Other (Commodity Prices) Factors Affecting the Price of Crude Oil on the Global Market



Source: Khin et al. (2017)

The research' results of Khin et al. (2017) showed that the prices of natural gas, palm oil and natural rubber are correlated with the price of crude oil, and the gold price is not correlated with the price of crude oil. From the results, the researchers also found that threre is a long-term negative relationship and conintegrated between crude oil price, natural rubber price and palm oil price while natural gas price has a inverse short-term relationship with crude oil price. In short, the results indicates that all studied commodities prices except for gold price was negatively affect crude oil price. The fluctuations in commodities prices will contribute to instability of crude oil price.

2.2 Empirical Reviews of the Study

There are five factors selected to study the relationship with crude oil price instability: exchange rate, inflation rate, interest rate, GDP per capita and oil production in ASEAN-5. This part will emphasize on the important empirical studies that includes the five factors selected and crude oil price.

2.2.1 Crude Oil Price

In order to have a sustainable macroeconomic environment, the country's policy makers are also highly concerned about crude oil price fluctuations. Thus, it is crucial for these economies to identify the factors influencing instability in the price of crude oil. A study by Raghavan (2015) highlighted the key drivers of oil price shocks during 2000-2013 for Thailand, Singapore, Philippines, Malaysia, and Indonesia. This study applied Structural Vector Autoregressive (SVAR) methodology to study the link among crude oil price and macroeconomic factors.

It evaluates how the oil shocks influence the macroeconomic variables of the ASEAN countries and looks at how monetary policy reacts to these changes. This study specified that oil production, global activity, and oil demand instabilities are the three (3) major causes of price fluctuations in crude oil. The results found that increases in production costs due to oil price shocks will cause falling in output levels and higher inflation. In response to rising inflation, the central banks of these countries should tighten their monetary policy in order to attain stable prices and long-term economic growth.

Lee and Huh (2017) proposed an alternative method for forecasting oil prices with accuracy and taking oil market’s structural changes into account by employing a

Bayesian framework. In order to determine how accurately it predicts the future oil price, Lee and Huh (2017) used the method by comparing the models of neural network model and linear ordinary least squares model. The findings indicated that the price of crude oil is predicted to rise by 2040.

According to Khin et al. (2017), the researchers studied on the relationship between prices for major agricultural commodities and crude oil price fluctuations in the global market. The selected commodities prices included in the model are gold price, natural gas price, palm oil price, and natural rubber price. This study applied Vector Error Correction Method (VECM) to study the relationship from January 2000 to December 2016. The results of Khin et al. (2017) revealed that there was relationship between natural gas price and crude oil price in short term in world market while other variables have relationships with crude oil price in long term.

In the study by Vu and Nakata (2018) examined economic influence of crude oil price fluctuations on six countries in Southeast Asia from 1999 to 2013. Vector autoregressive (VAR) model with block exogeneity was used in the study. The variables involved in the study include industrial production index, consumer price index (CPI), exports, imports, interest rate, and exchange rate. First, the oil-importing nations like Thailand, Singapore and Philippines are more responsive to the condition of the global oil price compared to the nations that export oil, Vietnam, Malaysia, and Indonesia. These countries' financial institutions have reacted to changes in oil prices that due to shocks in the demand for oil specifically.

The study by Ahmad et al. (2022) investigated on the relationship between the volatility of crude oil prices and four macroeconomics indicators: GDP, interest rate, inflation rate, and exchange rate. The authors collected data from 2000 to 2020 for eight South Asian countries which are Sri Lanka, Pakistan, Nepal, Maldives, India, Bhutan, Bangladesh, and Afghanistan. This study adopted VAR model to investigate the link between the four chosen macroeconomics indicators and crude oil price volatility. The results of the study showed that there is positive relationship between GDP, inflation rate, and interest rate of South Asian countries and crude oil price. The results also indicted that exchange rate is negatively correlated to crude oil price. However, the study also found out that the economies of South Asia have little effect on the price of oil globally based on Granger Causality test results.

Moreover, Togonidzea and Kočenda (2022) studied on the impacts of oil price shocks on the underlying financial and economic fundamentals of growing economies in three geographical areas with various resource endowments on 28 countries in Latin America and the Caribbean, Europe and Central Asia, and East Asia and Pacific for period 2000 to 2019 by using VAR model. The literature revealed that oil exports in Central Asian and European countries are more dependent on oil than exports in East Asia and the Pacific, and they argue that policymakers in those regions need to be focused about exchange rate appreciation after a positive oil shock to help reduce economic loss in the non-oil export market. Then, the significant short-term differences in consumption can be attributed to oil prices. Real GDP and interest rates are primarily affected in the medium term by fluctuations in oil prices.

Another study by Zhao (2022) investigated on main factors of crude oil price volatility by utilizing the method of generalized autoregressive conditional heteroscedasticity mixed frequency data sampling model (GARCH-MIDAS) with Lasso-adaptive method. This study examined the key factors of crude oil price volatility for period 1997 to 2021. Inventory and exchange rate are identified as the key elements influencing the stability of oil prices. Additionally, crude oil price volatility is still primarily driven by supply and demand of the oil in the long term. Alternative energy sources and the unpredictability of economic policy can also affect fluctuations in the crude oil price, but this effect is in short term.

Therefore, based on above previous studies, the researchers provided the macroeconomic variables show different relationships with crude oil price in different countries and regions. This study will undertake the variables into account to further examine the links among the chosen independent variables and crude oil price for selected ASEAN-5 countries in this study.

2.2.2 Exchange Rate

Exchange rate is critical in an economy as it will have an impact on financial transactions and international trade between countries. Exchange rate refers to the price of exchanging one currency for another currency or a collection of currencies (Hamilton, 2018). Individuals, corporations, and the government are all influenced by changes in the exchange rate in making decisions. The exchange rate will cause the difference in price of commodities such as crude oil price in different countries based on the global crude oil price. Zhang, Fan, Tsai, and Wei (2008) examined on the impact of the US dollar's exchange rate on global crude oil prices from a trading viewpoint for period 2000 to 2005. The methods applied in this study including VAR model, Autoregressive conditional heteroskedasticity (ARCH) model, and Granger Causality test. The results revealed that the increase in the price of crude oil on the global market during the periods examined was significantly influenced by the depreciation of US dollar. This study also indicates that the relationship of volatility between the two markets is statistically insignificant. As a result, the volatility of the exchange rate of US dollar has a small influence on the fluctuation in the oil price on a global scale.

Yan (2012) systematically analysed the previous course of the fluctuations in the oil price on an international market, thoroughly examined the factors that impact it, and then suggested solutions and recommendations to deal with it. The findings revealed that increase in the price of global oil at that time is significantly influenced by the depreciation of the US dollar. Hence, the value of other currencies increases dramatically in buying power as a result of the US dollar's depreciation, and investors in non-dollar regions are attracted to crude oil futures trading as an investment tool. Yet, purchasing oil futures in large amount will cause the price of crude oil on the global market to shoot up. Hence, exchange rate is a major driver in the fluctuation in the price of oil at the time.

Moreover, another study by Brahmasrene, Huang, and Sissoko (2014) investigated the dynamic relationship between exchange rates and the price of crude oil into the United States over both the short and long terms. Brahmasrene et al. (2014) used the methods of VAR model and Granger causality test from 1996 to 2009 for the five countries of Canada, Mexico, Colombia, the United Kingdom, and Venezuela. According to their findings, the exchange rates Granger-caused the short-term rise in crude oil prices whereas the long-term increase in crude oil prices Granger-caused the exchange rates. Besides, crude oil price fluctuations have a significant medium and long run effect on changes in exchange rates. Crude oil prices are significantly influenced by exchange rate fluctuations.

According to Adam, Rosnawintang, Saidi, Tondi, and Sani (2018), the study examined on the relationships among rice price, exchange rate of Indonesian rupiah against Euro (EUR) and crude oil price. The authors employed VAR model and Granger Causality and utilised dataset from January 2000 to September 2017 to examine the relationships. The results revealed that there were only short-term relationships exist among crude oil price, exchange rate and rice price. Additionally, Adam et al. (2018) revealed that the exchange rate of Indonesian Rupiah against EUR has a positive impact crude oil price.

Next, Beckmann, Czudaj, and Arora (2020) studied on the both theoretical and empirical research that has been conducted on the relationship between crude oil prices and exchange rates. Strong evidence demonstrates a long-term relationship between crude oil prices and exchange rates. In addition, there is a lot of studies indicates various short-run relationships and indirect effects between the two markets. The association between US dollar depreciations and crude oil price increases tends to manifest on a daily basis or over the span of several months. Additionally, it was discovered that, in the short term, both price of crude oil and exchange rates could reliably predict the other variable, but that the effects are time-varying.

Furthermore, a study by Huang, Lee, Chang, and Lee (2021) investigated on the dynamic relationship between crude oil prices and exchange rates from a worldwide standpoint. This study adopted pooled mean group (PMG) approach and used data from January 1997 to July 2015 for 81 oil exporting and importing countries. Overall, the findings show that exchange rates and real oil prices have long-term relationships but is specific to a certain of countries. Despite the fact that the results of Huang et al., (2021) show a considerably negative bidirectional correlation between the variables based on the assumption of free-floating settings, the direction, effect, strength, and significance varied for different nations depending on the level of their net oil imports, as well as their exchange rate regime.

In addition, Hlongwane (2022) studied on the relationship between exchange rates and crude oil price over the years 1970 to2021 for South Africa. The Autoregressive Distributed Lag (ADRL) model was used in the study along with Granger Causality test to investigate the relationships in the model. According to the results and analysis, the researchers found that a negative association existed between South African exchange rates of the Rand against the US dollar and crude oil prices. This implied that depreciation in exchange rate of the South African Rand against the US Dollar will cause the crude oil price to go up in South Africa.

Next, Jalal and Gopinathan (2022) examined on the effect of exchange rate on crude oil prices in India. The authors applied a Multiple Threshold Nonlinear Autoregressive Distributed Lag model (MTNARDL) and used a dataset of India from January 2004 to July 2022 in their study. According to their results, the sample's exchange rate depreciation has a significant effect on crude oil prices in negative way, moving them from the lower to the higher quintiles in long term. Crude oil prices are affected by exchange rate changes differently depending on how minor and major they are. The results conclusively show that exchange rate depreciation rather than appreciation has a higher effect on crude oil prices in India.

Lastly, study of Sun, Zhan, Peng, and Cai (2022) investigated whether there is a shift in the links between the local crude oil price, exchange rate, and global price of crude oil before and after Shanghai International Energy Exchange launched crude oil futures for China. This study employed Markov Regime Switching Vector Auto Regression (MS-VAR) model from March 2017 to October 2019 to examine the relationship between the variables. The findings show that although the global crude oil market has a significant influence on crude oil price in China, but the effect of China domestic crude oil price on the global crude oil price is slightly weak. The volatility in the exchange rate has a significant positive relationship with China's crude oil prices since the introduction of crude oil futures by Shanghai International Energy Exchange under the new regime.

Hence, the results of these empirical findings show that those changes in the exchange rate can influence changes in oil prices. Thus, this study aimed to see if the results are consistent with the previous empirical findings when applying to the sample countries that chosen in this study.

2.2.3 Inflation Rate

The increase in the general price of commodities or the increase in a country's cost of living are two instances of how inflation is frequently measured (Oner, 2017). When there is inflation in an economy, money loses its value as a given amount now buys lesser goods and services than previously. The price index for a given time compared to that reported in a prior period denotes the inflation rate as a percentage change and often computed annually. Numerous studies have empirically shown the relationship between inflation rate and crude oil price. Lescaroux and Mignon (2008) investigated on the relationship between inflation in terms of CPI and crude oil price. The study employed the methods of Granger Causality and Hodrick-Prescott filter and used data from 1962 to 2005 period. The results indicated that the relationship between crude oil prices and CPI is cointegrated for all nations. Organization of the Petroleum Exporting Countries (OPEC) and the countries that export oil are significantly affected by the causality between oil prices and CPI. The results Granger Causality tests, CPI leads real oil prices in a countercyclically manner. For most countries, inflation, and the erosion in crude oil prices are found to correlate with each other.

A study conducted by Olofin and Salisu (2017) the association between the price of crude oil and inflation in some OPEC and European countries. The data of study from 2000 to 2014 was examined using the Linear Symmetric Autoregressive Distributed Lag (ARDL) and Nonlinear Asymmetric ARDL. According to the findings, there the price of oil and inflation are positively linked. The results revealed that all OPEC countries have both short and long-term relationships in the oil price-inflation nexus. EU countries such as Sweden, Spain, Italy, Germany, France, Finland, Czech Republic, and Belgium only showed a short-term inflationary response to fluctuations in oil prices. As a result, oil exporting countries have a greater connection between the price of crude oil and inflation than oil importing countries.

Next, Castillo, Montoro, and Tuesta (2020) analysed on relationship between inflation and the volatility of the crude oil price. The authors estimated by using VAR model and utilised monthly data from 1973 to 2019 in their model. From the results, the authors identified there is a positive relationship between inflation and the price of crude oil in their study. When marginal costs regarding crude oil are greater and crude oil has few substitutes and substitutes are rare, this relationship founded become stronger.

In addition, Ekananda (2022) studied on how macroeconomic factors such as exports, human capital, GDP growth, inflation rate and foreign direct investment affect natural resource price volatility in Indonesia. This study adopted ADRL model to examine on the relationships between the variables from 1971 to 2020. According to the results of Ekananda (2022), bidirectional causality hinders a significant relationship between macroeconomic factors such as inflation rate and crude oil price volatility from being established in a variety of circumstances. Hence, this study concludes that there is no significant relationship between inflation rate and crude oil prices.

Furthermore, a part of the study by Philips, Akinseye, and Oduyemi (2022) examined how the cyclical relationships between the price of crude oil and stock returns is affected by inflation rate. The authors employed a nonlinear panel ARDL approach to estimate the relationship. The results show that the inflation rate has little impact on the association between crude oil prices and returns of stock when asymmetry is taken into consideration. The instability in the price of crude oil is attributed for the deviation from the results generated in the symmetric scenario. As a result of the initial increase in inflation rate being cancelled out by a decline in crude oil prices, inflation has no effect on the cyclical relationship between crude oil prices and stock returns.

Finally, study by Zhang, Hyder, Baloch, Qian, and Berk Saydaliev (2022) studied on relationship between inflation and the volatile crude oil price on Australia, Norway, and Canada by applying VAR, Generalized Autoregressive Conditional Heteroskedasticity Glosten-Jagannathan-Runkle (GARCH-GJR), and General Equilibrium model in their study from 2010 to 2020. and Share of the market in the United States typically acts as a catalyst in the short term, and crude oil prices tend to follow. Thus, short-term changes in the price of oil throughout the world are mostly caused by inflation. If the amount of money in circulation was limited, fluctuations in the price of oil would eventually be transmitted to the price index and raise inflation. However, oil price fluctuations will also lead to CPI volatility in their long-term relationship with inflation. Other firms that depend on oil are hampered by rising oil costs, which are also driving up the cost of energy and raw materials.

Therefore, some of the empirical findings provided by previous studies show inflation rate has a positive relationship with crude oil price, but some studies indicate that there no significant relationship between inflation rate and crude oil price.

2.2.4 Interest Rate

Interest rate is known as cost of borrowing or the profit of lending and this rate often expressed in percentage amount (OECD, 2022). When the central bank of a country implements either contractionary or expansionary monetary policy, it usually focuses in adjusting interest rates in order to have an impact on money supply. The actual production of commodities and services can be affected by changes in the money supply. Another intriguing aspect to take into account is interest rate, where the study by Leduc and Sill (2004) analysed monetary policy variables in terms of interest rate in examining the response to a crude oil price change. This study adopted VAR model and quarterly data from 1972 to 2000 were used in their estimation. The findings of Leduc and Sill (2004) showed that monetary policy leads to a 40 percent decline in crude oil production with an rise in crude oil prices from 1979.

Next, Yoshino and Taghizadeh-Hesary (2014) investigated the link between crude oil prices and monetary policy following the subprime mortgage crisis. The study employed SVAR method to examine the relationship between monetary policy and crude oil prices from 2007 to 2013. The authors included the interest rate which is factor of monetary policy in the crude oil price function. The results of the study revealed that there is a negative relationship interest rate. Oil prices will increase when central bank implements quantitative easing policy by lowering the interest rate. As a consequence, this will have a negative impact on global economic circumstances. This study conclusively highlights the important impact of monetary policy on global oil prices.

In another study of Taghizadeh-Hesary and Yoshino (2014) examined the characteristics of oil markets and the drivers that affect crude oil prices from 1960 to 2011 by using regression model. In the study, interest rate was accounted to the monetary policy. The results illustrated interest rate has a negative link with crude oil price. This shown by the average oil price increase from $35/barrel in 1981 with 16.7 percent of interest rate to $111/barrel in 2011 with 0.1 percent of interest rate. The authors concluded that stabilisation of the crude oil market requires careful management of monetary policy in order to significantly raise real interest rates.

Furthermore, Shangle and Solaymani (2020) studied on monetary policy response to fluctuations in global oil prices in Malaysia. This study collected data from 2014 to 2018. The financial computable general equilibrium (CGE) model was developed to estimate the effects of monetary policy in response to instability in global oil prices. The study results indicated that no relationship exists between interest rate and price of crude oil.

Next, Chatziantoniou, Filippidis, Filis, and Gabauer (2021) examined on factors influencing the volatility of oil price from 1990 to 2019 by applying time-varying parameter vector autoregressive (TVP-VAR) model. Interest rate is included as an independent variables and crude oil price as dependent variable. The results of study revealed that interest rate shock has a negative relationship with crude oil price. Crude oil price volatility is increased by interest rate shocks while it is decreased by shocks to the global economy activities. A rise in borrowing costs and a disincentive to investment are the results of a positive global interest rate shock. The worldwide markets become uncertain because of this change, which lowers overall crude oil demand. Consequently, it is anticipated that crude oil prices would decline, escalating crude oil price volatility.

Mofema and Mah (2021) investigated on the impact of interest rate on crude oil price changes and volatility in South Africa. This study employed GARCH model to estimate the effects between interest rate and crude oil price as well as other macroeconomics factors such as money supply growth, inflation, and GDP growth from years 2000 to 2020. According to the results of Mofema and Mah (2021), interest rates have a positive influence on crude oil prices changes in South Africa. Theoretically, when there is a rise in interest rates due to a tight monetary policy will reduce long-term output, which would lead to lower investment.

In addition, Urom, Guesmi, Abid, & Dagher (2021) studied on the association between crude oil price shocks and interest rates for 12 Asian economies, Europe area, and United States. This study adopted TVP-VAR model to estimate the dynamic integration between crude oil price shocks and interest rate and the authors used the data from 1999 to 2018. The findings showed that the fluctuations of interest rates caused oil shocks changed drastically over time. and was influenced by how stable the political and economic environment was. Urom et al. (2021) found that high levels of interest rate shocks that have spilled over into the area from countries like the United States and the oil market, considering the significance of crude oil in the economic process of production.

Moreover, study of Kilian and Zhou (2022) discussed on the “Did monetary policy have an impact on the price of oil in United States? ”. The study applied VAR model to test the results by using data from 1973to 2018. The findings showed that a negative relationship existed between interest rate and the price of crude oil. According to the study result, the actual price of crude oil dropped due to rising in interest rates resulting from tightening monetary policy. The study highlighted that tightening monetary policy with higher interest rate contributed 4 percent to late 2008's overall decrease in the actual oil price.

Hence, the results of previous studies present two outcomes where Chatziantoniou et al., (2021); Kilian & Zhou (2022); Taghizadeh Hesary & Yoshino (2014); Yoshino & Taghizadeh-Hesary (2014) indicates that there is negative relationship between interest rate and crude oil price. Mofema and Mah (2021) shows interest rate is positive affect crude oil price while Shangle & Solaymani (2020) shows no relationship exist between interest rate and crude oil price.

2.2.5 GDP per Capita

The elimination of poverty is closely related to sustained economic growth, which raises average incomes. GDP per capita, which acts as an auxiliary measure of per capita income, provides a fundamental measure of output value per individual(Federal Statistical Office, 2022). Economic growth and performance is often measured by the GDP per capita. Prasad, Narayan, and Narayan (2007) investigated the link between GDP and oil prices for Fiji Islands. The study adopted unit root test, cointegration test, OLS regression, and Granger Causality test to study the relationship between GDP and oil prices during the period of 1970 to 2005. The findings imply that GDP and oil prices have a short-term causal association between each other. In other words, the researchers discover that the two variables they both cause one another.

In the study of Yoshino and Taghizadeh-Hesary (2014), real GDP is taken into account to examine the relationship with crude oil price. The authors used data from 2007 to 2013 and the SVAR methodology in their study. The influence of GDP growth on the crude oil market's crude oil prices are one of the other results of this study. The results revealed that crude oil price is statistically significantly affected positively by a positive shock to the real Organisation for Economic Co-operation and Development (OECD) GDP.

Nyangarika, Mikhaylov, and Tang (2018) investigated the relationship between crude oil price and GDP in major developed nations such Saudi Arabia and Russia. This study applied Fractionally Integrated Generalized Autoregressive Conditional Heteroscedastic (FIGARCH) model to examine the relationship between crude oil prices and GDP by using data from 2004 to 2008. The findings of Nyangarika et al. (2018) showed the significant correlation between crude oil prices and GDP. The authors also observed that there is a positive relationship between crude oil prices and GDP in Saudi Arabia and Russia. Therefore, the countries will have the opportunity to restructure their own economies and become less dependent to changes in oil prices by developing alternative energy sources.

In addition, Jarrett, Mohaddes, and Mohtadi (2019) analysed the relationship between crude oil price volatility and economic growth. This study employed a synthetic control methodology and panel ARDL approach and collected data from 1980 to 2016 for thirty (30) oil producing countries. Variable of real GDP was used to measure economic growth in this study. From the findings of study, a relationship between the crude oil price and the GDP and per capita is identified. The results demonstrated that the vital role played by economic growth particularly during periods of unexpectedly severe negative crude oil price shocks.

Next, Maheu, Song, and Yang (2020) examined on the association between the growth of the economy and crude oil price shocks in the United States. The authors measured the economic growth by using real GDP growth in the United States. This study employed Autoregressive (AR) model and GARCH model to examine the relationship between real GDP growth and crude oil price shocks from 1974 to 2018. The results of study indicated that there is significant relationship between GDP growth and crude oil price fluctuations.

Moreover, Mofema and Mah (2021) studied and assessed on the effect of GDP per capita growth on crude oil price volatility in South Africa. This study adopted GARCH model to estimate the effects between GDP per capita growth and crude oil price in South Africa. According to Mofema and Mah (2021), the results of their study revealed that there is no significant relationship between growth in GDP per capita and crude oil price changes.

Adeosun, Tabash, and Anagreh (2022) investigated the link between the economic performance measured by GDP and price of crude oil in seven chosen emerging economies from 1985 to 2021. The researchers used time-varying Granger causality to identify and assess changes in the direction of the causal association between the crude oil price and the sample nations' GDP. Results revealed that there is bidirectional causality for at least a month between the economic performance and price of crude oil across all the selected countries in this study. The study also identified that economic performance and crude oil prices are long term associated.

Finally, study by Sha (2022) examined the associations between global economic performance, crude oil prices, and total natural resources. In this study, GDP is a proxy for global economic performance. This study adopted time series approaches to analyse the data from period 1960 to 2020 and Granger Causality test to causal relationships. The empirical findings revealed that a bidirectional causal relationship between economic performance and crude oil prices. The findings also demonstrated a positive relationship between the oil price and economic performance. Besides that, the study also identified there is two-way positive relationship among price of crude oil, performance of economic performance and total natural resources.

Therefore, mostly of the empirical findings of previous studies on relationship between GDP and crude oil price are significant positively related and bidirectional causality exists between these two variables. However, only the study conducted by Mofema and Mah (2021) indicates an insignificant relationship between GDP and crude oil price.

2.2.6 Production of Crude Oil

Crude oil prices are significantly influenced by production of crude oil. Crude oil markets frequently react to shifting predictions about current and future supply and demand (U.S. Energy Information Administration, 2022d). The demand and supply of crude oil will highly influence the crude oil price in the oil market. A study conducted by Horn (2004) utilised a simple utility function crude oil market model in the study to examine the relationship between GDP, oil production capacity, and crude oil price. According to the Horn (2004), during January 1999 and January 2000, the price of crude oil increased from 10 USD per barrel to 30 USD per barrel as a result of OPEC's decrease in the production capacity of crude oil. Hence, the results of the study found out that there is negative relationship between crude oil production capacity and crude oil price.

Ratti and Vespignani (2014) investigated how crude oil production capacity in OPEC and non-OPEC nations affected crude oil prices in global market. The SVAR model was employed in the study, and data period from 1974 to 2012 on the crude oil production capacities of OPEC and non-OPEC members were used by the authors. The purpose of the study was to ascertain if the production capacity of OPEC members will significantly influence crude oil prices and whether non-OPEC nations will have an impact on OPEC'S oil production capacity, which will then have an impact on price of crude oil. The empirical finding indicated that the increase of OPEC members' crude oil production capacity demonstrated a positive relationship with the performance of crude oil price.

Apergis, Ewing, & Payne (2016) explored on the link between oil rigs, oil production, and crude oil price in the U.S.'s six main oil-producing regions. The study used data from 2007 to 2014 and applied time series econometric techniques with Generalized Least Squares (GLS) estimator in order to investigate the relationships for the six regions. The results revealed that there is a long-term equilibrium relationship between the variables of oil production and crude oil price. Prices for crude oil show statistically significant positive relationships with total oil production.

Next, study of Amarfio, Marfo, & Gyagr (2017) examined on the variables that influence crude oil prices and their effects individually. The study utilised the method of Logarithmic Multiple Regression using OLS method to study the relationship from 1965 to 2015. The findings of Amarfio et al. (2017) indicated that production rates for both the global and OPEC markets are negatively influence on oil prices. This phenomenon can be described by the supply economic theory, which states that prices of goods and services and supply move opposite direction, when production rise and causing the price to reduce.

In another research by Caldara, Cavallo, and Iacoviello (2019) on title " Oil price elasticities and oil price fluctuations" which examine the comparative significance of supply variable (oil production) in determining changes in the oil market. Caldara et al. (2019) used data from 1985 to 2015 and employed the method of SVAR in their research. The results discovered that supply of oil is significant in explaining changes in oil prices. Approximately 35% of the oil price volatility and 45% of the oil production volatility are attributed to the oil supply shocks, which are the primary factors influencing oil market fluctuations. The results also indicated that the decrease in prices was caused by an increase in global oil production. This study also highlighted that only when triggered by supply shocks will cause a decline in oil prices stimulate the economy in advanced economies.

In addition, Chatziantoniou et al. (2021) investigated the global factors that affect the volatility of the crude oil price. In this study, the selected factors on examining the impact on crude oil price volatility are oil supply, oil demand, financial trend, interbank stress, and financial market instability. The authors used data from 1990 to 2015 and adopted TVP-VAR model to determine the impact of all selected factors on volatility of crude oil price. In this study, oil production is used as a measure to represent the oil supply. The results stated a negative impact on crude oil price exists when oil production increases. A rise in global oil production due to improvements in oil extraction technology or an increase in oil quotas by OPEC is referred to as a positive global oil supply shock. As a result, the price of oil declines and oil price volatility increases.

Furthermore, Lu, Sun, Duan, and Wang (2021) examined on the factors affecting crude oil price and forecasting crude oil price. The study utilized the elastic-net regularized generalized linear model (GLMNET) and Bayesian model average (BMA) to determine the effect of the selected factors on crude oil price and long short-term Memory Network (LSTM) model is employed. In this study, crude oil production is the selected variable to measure the oil supply index. The findings of the study revealed that the changes in oil production or supply will significantly lead to changes in crude oil price. The study indicated that when there is a surge in oil production will causing a rise in crude oil inventories, and this will cause to a decline in crude oil price.

Lastly, Yang, Yang, Chen, and Tong (2022) studied on the effect of crude oil production capacity on crude oil price. This study employed smooth transition autoregressive model to estimate the relationship between the exogenous variables from 1983 to 2021. Based on the results of Yang et al. (2022), the effect on the change in WTI crude oil price will become more significant as the lagged term of the WTI crude oil production increases. The results also revealed that there is a negative relationship between WTI crude oil production capacity and WTI crude oil price. This means that increase in crude oil production capacity will cause to a decline in WTI crude oil price.

Therefore, most of previous studies indicated that there is an inverse relationship between oil production and crude oil price. Most of the literature related the oil production to the crude oil supply and applied the theory of supply on how oil production affect crude oil price.

2.2.7 Research Methodology

The panel model analysis was frequently employed in the study's research methodology. In the study of Khin, Bin, Keong, Yie, and Liang (2019) employed panel model analysis to study the variables that affect instability of natural rubber price. The study used monthly data from January 2008 to December 2016. The research methodology included VECM model and cointegration rank test. The independent variables included in this study are Shanghai natural rubber price, crude oil price, exchange rate, total consumption, and total production, while the dependent variable is natural rubber price in Malaysia. Besides that, forecast method such as ex-post and ex-ante also used to predict the next three months in 2017. The results of Khin et al. (2019) revealed that a significant relationships among Shanghai natural rubber price, crude oil price, total consumption, and total production with Malaysian natural rubber price. However, there is insignificant relationship between exchange rate and Malaysian natural rubber price.

Additionally, Fong, Khin, and Lim (2020) investigated on factors affecting natural rubber prices in four main producing countries in Vietnam, Malaysia, Indonesia, and Thailand. The study employed panel model regression and data from 2008 to 2017 for the four major producing countries. Natural rubber consumption and production, exchange rates, crude oil prices, synthetic polymer prices, and Shanghai natural rubber prices are the independent variables used in the study of Fong et al. (2020). Firstly, the panel unit root test and panel cointegration tests were applied initially, followed by the panel model selection using the Redundant Fixed Effect test, the Breusch-Pagan Lagrange Multiplier (BPLM) test, and the Hausman test. The Fixed Effects Model (FEM) was eventually found to be the best appropriate model for this research based on the results. Following that, the panel Granger Causality test was carried out, and the model was evaluated using the Root Mean Squared Error (RMSE), Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE), and U-Theil statistic.

Besides, the forecasting method using the autoregressive integrated moving average (ARIMA) model is also frequently applied in research study. Selvi, Shree, and Krishnan (2018) utilised ARIMA method to predict crude oil price in 2017 to 2021 by using data from 1946 to 2016. First, this study test for autocorrelation by using autocorrelation and partial autocorrelation function were used to develop ARIMA's order. The Box-Jenkins Method commonly called as the Autoregressive (AR) and Moving Average (MA) also known as ARM techniques was used to examine the data for the study. An ARIMA model is defined as a suitable model for analysing the provided time series data since differencing is only performed once to transform data to stationary. ARIMA model for this study is (2,1,1).

Moreover, Shah and Kiruthiga (2020) investigated at the crude oil price's time series and employed an ARIMA model to forecast future prices by using data from July 1987 to March 2020. Findings indicated that the ARIMA model generates the best results. The Augmented Dickey Fuller (ADF) test was used to test stationarity at the beginning and the results showed the differencing time for data to stationary is 1. As a result, ARIMA model for this study is (0,1,4) based on autocorrelation and partial autocorrelation function. Besides, this model also evaluated using mean squared value.

Lastly, Fu and Suhaila (2022) used ARIMA and Exponential Smoothing to predict monthly bulk latex prices in Malaysia. The MAPE and RMSE are used to evaluate the performance of the models. The Box-Jenkins Method was used to analyse the data. In order to test on stationarity of model, ADF test was used to determine the number of differencing in the model. Next, the order of the ARIMA was then identified using the autocorrelation and partial autocorrelation function. The best model was then chosen using the Akaike Information Criterion (AIC), and the residual diagnostic tests were performed after that. The findings shown that the most accurate forecast bulk latex price in Malaysia is given in ARIMA (1,1,0).

2.4 Summary of Empirical Reviews of Forecasting Model of Crude Oil Price Instability

Table 2.1: Empirical Reviews Summary

No.	Authors & Years	Title	Methodology	Novelty & Findings
Crude Oil Price				
1	Lee and Huh (2017)	Forecasting Long-Term Crude Oil Prices Using a Bayesian Model with Informative Priors	Bayesian approach and OLS model	The findings indicated that by 2040, the price of crude oil is predicted to rise to $169.3/Bbl.
2	Vu and Nakata (2018)	Oil price fluctuations and the small open economies of Southeast Asia: An analysis using vector autoregression with block exogeneity	VAR model with block exogeneity	Oil-importing nations are more responsive to the condition of the oil price compared to the nations that exporting oil.
3	Ahmad et al. (2022)	Macroeconomic effects of crude oil shocks: Evidence from South Asian countries	VAR model and Granger Causality	There is positive relationship between GDP, inflation rate, and interest rate of South Asian countries and crude oil price. Exchange rate is negatively correlated to crude oil price.

4	Togonidze and Kočenda (2022)	Macroeconomic responses of emerging market economies to oil price shocks: An analysis by region and resource profile	VAR model	The literature reveals that oil exports in Central Asian and European countries are more dependent on oil than exports in East Asia and the Pacific.
5	Zhao (2022)	Exploring the influence of the main factors on the crude oil price volatility_ An analysis based on GARCH-MIDAS model with Lasso approach	GARCH-MIDAS with Lasso-adaptive method	Crude oil price fluctuations are driven by supply and demand of the oil, inventory and exchange rate.
Exchange Rate				
6	Beckmann, Czudaj, and Arora (2020)	The Relationship between Oil Prices and Exchange Rates: Revisiting Theory and Evidence	Pseudo out-of-sample	Strong evidence demonstrates a long-term relationship between oil prices and exchange rates.
7	Huang et al. (2021)	Dynamic linkage between oil prices and exchange rates: new global evidence	PMG approach	There is a negative bidirectional correlation between exchange rate and crude oil price.
8	Hlongwane (2022)	The relationship between oil prices and exchange rates in South Africa	ARDL model and Granger Causality	There is a negative relationship between South African exchange rates and crude oil prices.

9	Jalal and Gopinathan (2022)	Time-varying and asymmetric impact of exchange rate on oil prices in India: Evidence from a multiple threshold nonlinear ARDL model	MTNARDL Model	The sample's exchange rate depreciation has a significant positive impact on oil prices.
10	Sun et al. (2022)	Crude oil price and exchange rate: Evidence from the period before and after the launch of China's crude oil futures	MS-VAR model	Exchange rate has a significant positive impact on China's crude oil prices.
Inflation Rate				
11	Olofin and Salisu (2017)	Modelling oil price-inflation nexus: The role of asymmetries and structural breaks	Linear Symmetric ARDL and Nonlinear Asymmetric ARDL	There are positive relationships between the price of oil and inflation.
12	Castillo et al. (2020)	Inflation, oil price volatility and monetary policy	VAR model	A positive relationship exists between inflation and the price of oil.
13	Ekananda (2022)	Role of macroeconomic determinants on the natural resource commodity prices: Indonesia futures volatility	ADRL model	There is no significant relationship between inflation rate and crude oil price.

14	Philips, Akinseye, and Oduyemi (2022)	Do exchange rate and inflation rate matter in the cyclicality of oil price and stock returns?	Nonlinear panel ARDL model	Inflation rate has insignificant influence on the cyclical relationship between oil prices.
15	Zhang et al (2022)	Nexus between oil price volatility and inflation: Mediating nexus from exchange rate: Evidence from global data	VAR, GARCH-GJR, General Equilibrium model	Short-term changes in the price of oil throughout the world are mostly caused by inflation.
Interest Rate				
16	Shangle and Solaymani (2020)	Responses of monetary policies to oil price changes in Malaysia	CGE model	There is no relationship between interest rate and crude oil price.
17	Chatziantoniou et al. (2021)	A closer look into the global determinants of oil price volatility	TVP-VAR model	Interest rate shock has a negative relationship with crude oil price and positive relationship with crude oil price volatility.
18	Mofema and Mah (2021)	An empirical analysis of volatility in South African oil prices	GARCH model	Interest rates have a positive influence on crude oil prices changes in South Africa.

19	Urom et al. (2021)	Dynamic integration and transmission channels among interest rates and oil price shocks	TVP-VAR model	Thefluctuations of interest rates caused oil shocks changed drastically over time.
20	Kilian and Zhou (2022)	Oil prices, exchange rates and interest rates	VAR model	Interest rate has a negative relationship with the price of crude oil.
GDP per Capita				
21	Jarrett, Mohaddes and Mohtadi (2019)	Oil price volatility, financial institutions and economic growth	Synthetic control methodology and panel ARDL approach	A relationship between the oil price and the GDP and per capita is revealed in the findings.
22	Maheu et al. (2020)	Oil price shocks and economic growth: The volatility link	AR and GARCH model	There is significant relationship between economic growth (GDP growth) and crude oil price fluctuations.
23	Mofema and Mah (2021)	An empirical analysis of volatility in South African oil prices	GARCH model	There is no significant relationship between growth in GDP per capita and crude oil price changes.

24	Adeosun, Tabash, and Anagreh (2022)	Oil price and economic performance: Additional evidence from advanced economies	Time-varying Granger causality	There is a bidirectional causality for at least a month between the economic performance and price of oil.
25	Sha (2022)	Total natural resources, oil prices, and sustainable economic performance: Evidence from global data	Time series approaches and Granger Causality	The findings also demonstrated a positive relationship between the oil price and economic performance.
Production of Crude Oil				
26	Amarfio, Marfo, & Gyagr (2017)	Determining the Key Factors Affecting Global Pricing of Crude Oil Using Trend Analysis and Numerical Modelling	Logarithmic Multiple Regression using Ordinary Least Squares (OLS) method	Production rates for both the global and OPEC oil markets are negatively influence on oil prices.
27	Caldara, Cavallo & Iacoviello (2019)	Oil price elasticities and oil price fluctuations	Structural vector autoregressions (VAR)	The decrease in prices was caused by an increase in global oil production.
28	Chatziantoniou et al. (2021)	A closer look into the global determinants of oil price volatility	TVP-VAR model	There is a negative impact on crude oil price when oil production increases

29	Lu et al. (2021)	Analysis and forecasting of crude oil price based on the variable selection-LSTM integrated model	GLMNET method, BMA method and LSTM model	Oil production will negatively influence on crude oil price.
30	Yang et al. (2022)	Exploring the non-linearity of West Texas Intermediate crude oil price from exchange rate of US dollar and West Texas Intermediate crude oil production	Smooth transition autoregressive model	There is an inverse relationship between the rate of change in WTI crude oil production capacity and change in WTI crude oil price.
Research Methods				
31	Selvi, Shree, & Krishnan (2018)	Forecasting Crude Oil Price Using ARIMA Models	ARIMA model	ARIMA model for this study is (2, 1, 1).
32	Khin et al. (2019)	Critical Factors of The Natural Rubber Price Instability in The World Market	Panel model regression	Panel model such as VECM, Cointegration Rank Test, and Ex-post and Ex-ante Forecast Method were used to study factors of instability of natural rubber price.
33	Fong et al. (2020)	Determinants of Natural Rubber Price Instability for Four Major Producing Countries	Panel model regression and Granger causality	FEM is the best model in this study and model evaluation is based on RMSE, MAE, and MAPE.

34	Shah & Kiruthiga (2020)	Crude Oil Price Forecasting using ARIMA model	ARIMA model	ARIMA model for this study is (0, 1, 4).
35	Fu and Suhaila (2022)	Forecasting Malaysia Bulk Latex Prices Using Autoregressive Integrated Moving Average (ARIMA) and Exponential Smoothing	ARIMA model	ARIMA (1,1,0) provides the most accurate prediction.

2.5 Conclusion

This chapter explained on theoretical framework and empirical analysis using past research journals. This chapter provides a review of a few variables that influence the crude oil price instability. The next Chapter 3 will discuss on the methodology of the research study.

CHAPTER 3: METHODOLOGY

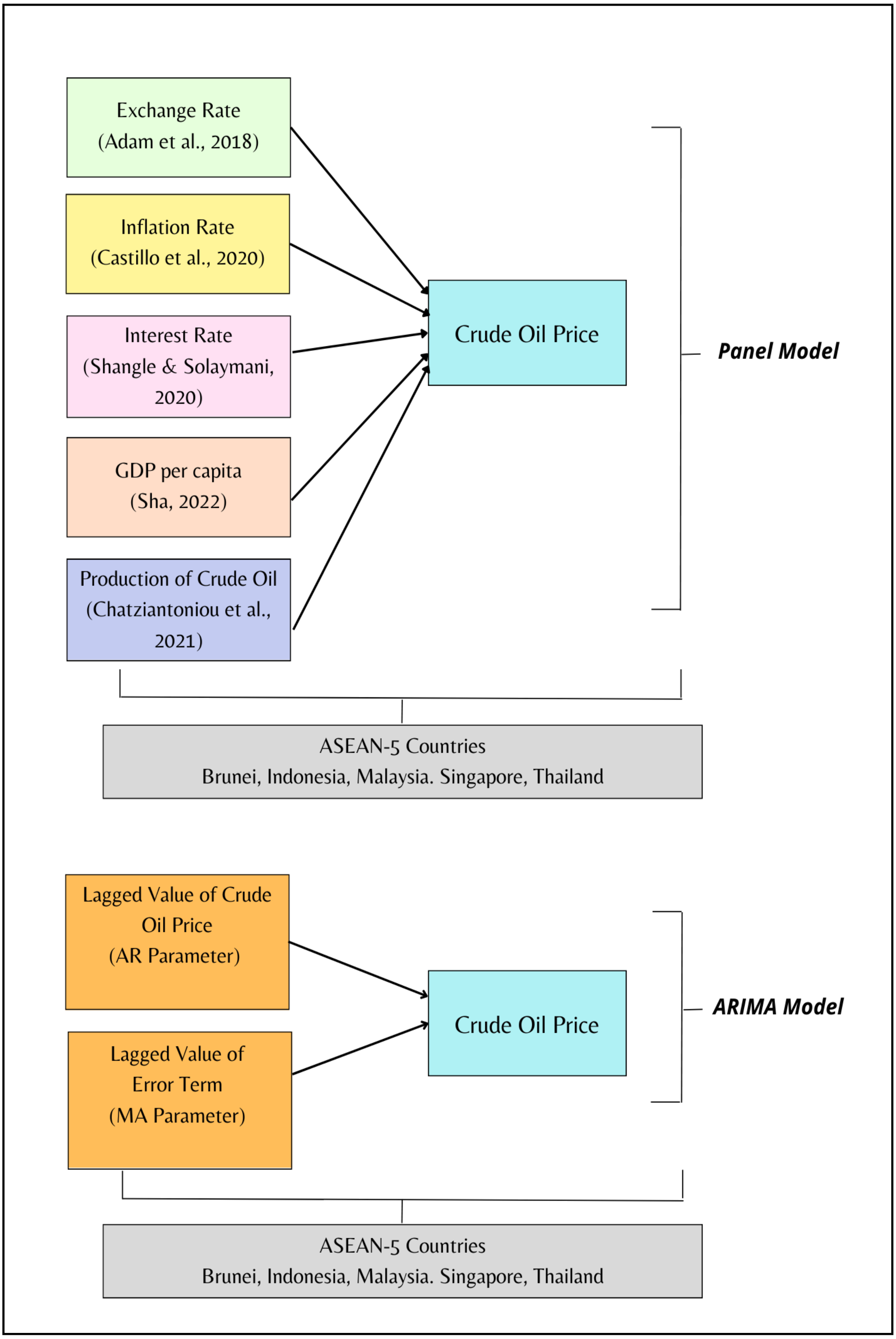
3.0 Introduction

Chapter 3 will discuss the research methodology that applied to the research study which will cover conceptual framework, development of hypotheses, data collection and sources, research methods, residual diagnosis, model evaluation, data analysis, as well as model estimation procedure. This research study will employ a secondary research methodology. In this study, the crude oil price is chosen as dependent variable and the exchange rate, inflation rate, interest rate, GDP per capita, and production of crude oil as independent variables. The panel data analysis and ARIMA model analysis will be conducted on the selected ASEAN-5 countries (Brunei, Indonesia, Malaysia, Singapore, and Thailand). Then, the conclusion will be justified.

3.1 Conceptual Framework

Figure 3.1 shows the proposed research framework of crude oil prices for ASEAN-5 countries. The figure below illustrates the research framework:

Figure 3.1: Research Framework of Crude Oil Price for ASEAN-5 Countries



Source: Author's Own Creation

The proposed conceptual framework for this research study is shown in Figure 3.1. The dependent variable for the panel model is crude oil price measured as local currency per barrel. The independent variables of panel model are (1) exchange rate as local currency per US$, (2) inflation rate as annual percentage, (3) interest rate as annual percentage, (4) GDP per capita as constant 2015 US$ and (5) production of crude oil as thousands barrel per day. For the ARIMA model, the dependent variable is the crude oil price, while the independent variables are the lagged value of crude oil price (AR parameter) and the lagged value of error term (MA parameter).

There will be two (2) parts to the model specifications: (1) the panel model and (2) the ARIMA model.

3.1.1 Panel Model Specification for ASEAN-5 Countries Crude Oil Price

For panel data model, all the test and regression procedures are conducted using the data in the form of natural logarithm (ln). The countries covered in the Equation (3.1) are Brunei, Indonesia, Malaysia, Singapore, and Thailand, which are shown in Equation (3.1) below:

$$lnCOP_{it} = \beta_0 + \beta_1 lnEXR_{it} + \beta_2 \ln INF_{it} + \beta_3 lnITR_{it} + \beta_4 lnGDP_{it} + \beta_5 lnPCO_{it} + \beta_6 \varepsilon_{1it} \quad \text{...(3.1)}$$

Where,

$lnCOP_{it}$	= Average Spot Crude Oil Price of Brent, Dubai, and WTI in ASEAN-5 Countries in natural logarithm (local currency per barrel)
$lnEXR_{it}$	= Real Exchange Rate in natural logarithm (local currency per US$)
$lnINF_{it}$	= Inflation Rate in natural logarithm (annual %)
$lnITR_{it}$	= Interest Rate in natural logarithm (annual %)
$lnGDP_{it}$	= GDP per capita in natural logarithm (constant 2015 US$)
$\ln PCO_{it}$	= Production of Crude Oil in natural logarithm (thousand barrels per day)
ε_{1it}	= Error term
β_0	= Intercept
$\beta_1 \dots \beta_5$	= Coefficients of independent variables
β_6	= Coefficients of error term
Period	= 2007 to 2021 annual data (75 observations)

3.1.2 ARIMA Model Specification for Crude Oil Price in Brunei

The ARIMA model specification for Brunei is shown in Equation (3.2) below:

$$\Delta COPBrunei_t = \beta_7 + \underbrace{\phi_1 \Delta COPBrunei_{t-1}}_{\text{AR Parameter}} + \underbrace{\theta_1 \varepsilon_{t-1}}_{\text{MA Parameter}} + \varepsilon_{2t} \quad \text{.......................} \quad (3.2)$$

$\Delta COPBrunei_t$	= Crude oil price time series of Brunei after stationary at first differencing, I(1)
ϕ_1	= Coefficient of autoregressive parameter (AR) of order 1 representing the fit to the crude oil price time series actual value
θ_1	= Coefficient of moving average (MA) parameter of order 1
β_7	= Intercept
ε_{t-1}	= Random error of MA of order 1
ε_{2t}	= Random disturbance
Period	= January 2017 to September 2022 (69 observations)

3.1.3 ARIMA Model Specification for Crude Oil Price in Indonesia

The ARIMA model specification for Indonesia is shown in Equation (3.3) below:

$$\Delta COPIndonesia_t = \beta_8 + \underbrace{\phi_2 \Delta COPIndonesia_{t-1}}_{\text{AR Parameter}} + \underbrace{\theta_2 \varepsilon_{t-1}}_{\text{MA Parameter}} + \varepsilon_{3t} \quad \ldots\ldots\ldots\ldots\ldots (3.3)$$

$\Delta COPIndonesia_t$	= Crude oil price time series of Indonesia after stationary at first differencing, I(1)
ϕ_2	= Coefficient of autoregressive parameter (AR) of order 1 representing the fit to the crude oil price time series actual value
θ_2	= Coefficient of moving average (MA) parameter of order 1
β_8	= Intercept
ε_{t-1}	= Random error of MA of order 1
ε_{3t}	= Random disturbance
Period	= January 2017 to September 2022 (69 observations)

3.1.4 ARIMA Model Specification for Crude Oil Price in Malaysia

The ARIMA model specification for Malaysia is shown in Equation (3.4) below:

$$\Delta COPMalaysia_t = \beta_9 + \underbrace{\phi_3 \Delta COPMalaysia_{t-1}}_{\text{AR Parameter}} + \underbrace{\theta_3 \varepsilon_{t-1}}_{\text{MA Parameter}} + \varepsilon_{4t} \quad \text{.................. (3.4)}$$

$\Delta COPMalaysia_t$	= Crude oil price time series of Malaysia after stationary at first differencing, I(1)
ϕ_3	= Coefficient of autoregressive parameter (AR) of order 1 representing the fit to the crude oil price time series actual value
θ_3	= Coefficient of moving average (MA) parameter of order 1
β_9	= Intercept
ε_{t-1}	= Random error of MA of order 1
ε_{4t}	= Random disturbance
Period	= January 2017 to September 2022 (69 observations)

3.1.5 ARIMA Model Specification for Crude Oil Price in Singapore

The ARIMA model specification for Singapore is shown in Equation (3.5) below:

$$\Delta COPSingapore_t = \beta_{10} + \underbrace{\phi_4 \Delta COPSingapore_{t-1}}_{\text{AR Parameter}} + \underbrace{\theta_4 \varepsilon_{t-1}}_{\text{MA Parameter}} + \varepsilon_{5t} \quad \ldots\ldots\ldots\ldots (3.5)$$

$\Delta COPSingapore_t$	= Crude oil price time series of Singapore after stationary at first differencing stationary, I(1)
ϕ_4	= Coefficient of autoregressive parameter (AR) of order 1 representing the fit to the crude oil price time series actual value
θ_4	= Coefficient of moving average (MA) parameter of order 1
β_{10}	= Intercept
ε_{t-1}	= Random error of MA of order 1
ε_{5t}	= Random disturbance
Period	= January 2017 to September 2022 (69 observations)

3.1.6 ARIMA Model Specification for Crude Oil Price in Thailand

The ARIMA model specification for Thailand is shown in Equation (3.6) below:

$$\Delta COPThailand_t = \beta_{11} + \underbrace{\phi_5 \Delta COPThailand_{t-1}}_{\text{AR Parameter}} + \underbrace{\theta_5 \varepsilon_{t-1}}_{\text{MA Parameter}} + \varepsilon_{6t} \quad \text{………..... (3.6)}$$

$\Delta COPThailand_t$	= Crude oil price time series of Thailand after stationary at first differencing, I(1)
ϕ_5	= Coefficient of autoregressive parameter (AR) of order 1 representing the fit to the crude oil price time series actual value
θ_5	= Coefficient of moving average (MA) parameter of order 1
β_{11}	= Intercept
ε_{t-1}	= Random error of MA of order 1
ε_{6t}	= Random disturbance
Period	= January 2017 to September 2022 (69 observations)

3.2 Hypotheses Development

3.2.1 Panel Model Hypotheses

The panel data model hypotheses proposed for ASEAN-5 countries are stated as follows:

H_{01}: There are no significant relationships among exchange rate, inflation rate, interest rate, GDP per capita, production of crude oil, and crude oil price of ASEAN-5 countries.
H_{A1}: There are significant relationships among exchange rate, inflation rate, interest rate, GDP per capita, production of crude oil, and crude oil price of ASEAN-5 countries.

ASEAN-5 countries: Brunei, Indonesia, Malaysia, Singapore, and Thailand
H_{011}: There is no significant relationship between exchange rate and crude oil price.
H_{A11}: There is a significant relationship between exchange rate and crude oil price.
H_{012}: There is no significant relationship between inflation rate and crude oil price.
H_{A12}: There is a significant relationship between inflation rate and crude oil price.
H_{013}: There is no significant relationship between interest rate and crude oil price.
H_{A13}: There is a significant relationship between interest rate and crude oil price.
H_{014}: There is no significant relationship between GDP per capita and crude oil price.
H_{A14}: There is a significant relationship between GDP per capita and crude oil price.
H_{015}: There is no significant relationship between production of crude oil and crude oil price.
H_{A15}: There is a significant relationship between production of crude oil and crude oil price.

3.2.2 ARIMA Model Hypotheses

The ARIMA model hypotheses proposed for Brunei are as follows:

Brunei

H_{02}: There is no relationship between AR parameter (lagged value of COP of Brunei) and COP of Brunei.

H_{A2}: There is a relationship between AR parameter (lagged value of COP of Brunei) and COP of Brunei.

H_{03}: There is no relationship between MA parameter (lagged value of error term of Brunei) and COP of Brunei.

H_{A3}: There is a relationship between MA parameter (lagged value of error term of Brunei) and COP of Brunei.

The ARIMA model hypotheses proposed for Indonesia are as follows:

Indonesia

H_{04}: There is no relationship between AR parameter (lagged value of COP of Indonesia) and COP of Indonesia.

H_{A4}: There is a relationship between AR parameter (lagged value of COP of Indonesia) and COP of Indonesia.

H_{05}: There is no relationship between MA parameter (lagged value of error term of Indonesia) and COP of Indonesia.

H_{A5}: There is a relationship between MA parameter (lagged value of error term of Indonesia) and COP of Indonesia.

The ARIMA model hypotheses proposed for Malaysia are as follows:

Malaysia

H_{06}: There is no relationship between AR parameter (lagged value of COP of Malaysia) and COP of Malaysia.

H_{A6}: There is a relationship between AR parameter (lagged value of COP of Malaysia) and COP of Malaysia.

H_{07}: There is no relationship between MA parameter (lagged value of error term of Malaysia) and COP of Malaysia.

H_{A7}: There is a relationship between MA parameter (lagged value of error term of Malaysia) and COP of Malaysia.

The ARIMA model hypotheses proposed for Singapore are as follows:

Singapore

H_{08}: There is no relationship between AR parameter (lagged value of COP of Singapore) and COP of Singapore.

H_{A8}: There is a relationship between AR parameter (lagged value of COP of Singapore) and COP of Singapore.

H_{09}: There is no relationship between MA parameter (lagged value of error term of Singapore) and COP of Singapore.

H_{A9}: There is a relationship between MA parameter (lagged value of error term of Singapore) and COP of Singapore.

The ARIMA model hypotheses proposed for Thailand are as follows:

Thailand

H_{010}: There is no relationship between AR parameter (lagged value of COP of Thailand) and COP of Thailand.

H_{A10}: There is a relationship between AR parameter (lagged value of COP of Thailand) and COP of Thailand.

H_{011}: There is no relationship between MA parameter (lagged value of error term of Thailand) and COP of Thailand.

H_{A11}: There is a relationship between MA parameter (lagged value of error term of Thailand) and COP of Thailand.

3.3 Data Collection and Sources of Data

The secondary quantitative research methodology was employed in this study since the results could be globally evaluated and generalized due to the data's standardisation. To analyse the relationship between the variables, the data of selected variables are collected from Index Mundi, the United States Department of Agriculture, the World Bank, and the U.S. Energy Information Administration. This study will use annual data from 2007 to 2021 for the panel model and monthly data from January 2017 to September 2022 for the ARIMA model. Table 3.1 provides detailed information on the data sources.

Table 3.1: Variable, Description, Unit, Definition, Source, and Link

Variable	Description	Unit	Definition	Source	Link
COP	Average Spot Crude Oil Price of Brent, Dubai, and WTI in ASEAN-5 Countries	Local currency per barrel	Spot prices for different crude oil barrels	Index Mundi	https://www.indexmundi.com/commodities/?commodity=crude-oil&months=60
EXR	Real Exchange Rate	Local currency per US$	Price of exchanging one currency for another currency or a collection of currencies	United States Department of Agriculture	https://www.ers.usda.gov/data-products/agricultural-exchange-rate-data-set/
INF	Inflation Rate	Annual %	Increase in the general price of commodities or the increase in a country's cost of living	World Bank	https://data.worldbank.org/indicator/FP.CPI.TOTL.ZG

ITR	Interest Rate	Annual %	Cost of borrowing or the profit of lending	World Bank	https://data.worldbank.org/indicator/FR.INR.RINR
GDP	GDP per capita	Constant 2015 US$	An auxiliary measure of per capita income provides a fundamental measure of output value per individual	World Bank	https://data.worldbank.org/indicator/NY.GDP.PCAP.KD
PCO	Production of Crude Oil	Thousands barrel per day	The amount of crude oil that is extracted from the earth after being cleaned of inert substances or contaminants	U.S. Energy Information Administrati-on (EIA)	https://www.eia.gov/international/data/world

3.4 Research Methods

3.4.1 Panel Model

The combination data of time series and cross-sectional is known as panel data, also called longitudinal data. Panel data is used when observations on the same variables from the same cross-sectional sample are collected over two or more periods (Gujarati & Porter, 2009). A panel data model is the preferred method in most econometric studies is because sample sizes will certainly increase, more effective in studying the dynamic of change, accurately detect and quantifying impacts that unable be seen in times series or cross-sectional data alone, prevent omitting variables that might bias cross-sectional research. There are three methods to estimate the regression model when utilizing panel data: Fixed Effects Model (FEM), Random Effects Model (REM), and Pooled Ordinary Least Squares Model (POLS) (Zulfikar, 2018). FEM implies that individual variations may be addressed by different intercepts. Different intercepts can develop as a result of differences in the outcomes. REM has an intercept taken from a distribution for each cross-sectional unit. The REM has the advantage of eliminating heteroscedasticity. To decide the best model, whether it is REM, FEM, or POLS, the following tests are conducted:

To decide whether POLS and FEM is preferred, the Redundant Fixed Effects Test will be conducted.
H_0: POLS is preferred.
H_A: FEM is preferred.

If the p-value is less than the α-value of 0.05, reject H_0, and FEM is preferred. If the p-value is more than the α-value of 0.05, do not reject H_0, and POLS model is preferred.

To decide whether POLS and REM is preferred, the Lagrange Multiplier Test for Random Effects will be conducted.

H_0: POLS is preferred.

H_A: REM is preferred.

If the p-value is less than the α-value of 0.05, reject H_0, and REM is preferred. If the p-value is more than the α-value of 0.05, then do not reject H_0, and POLS model is preferred.

To decide whether REM and FEM is preferred, the Hausman Test will be conducted.

H0: REM is preferred.

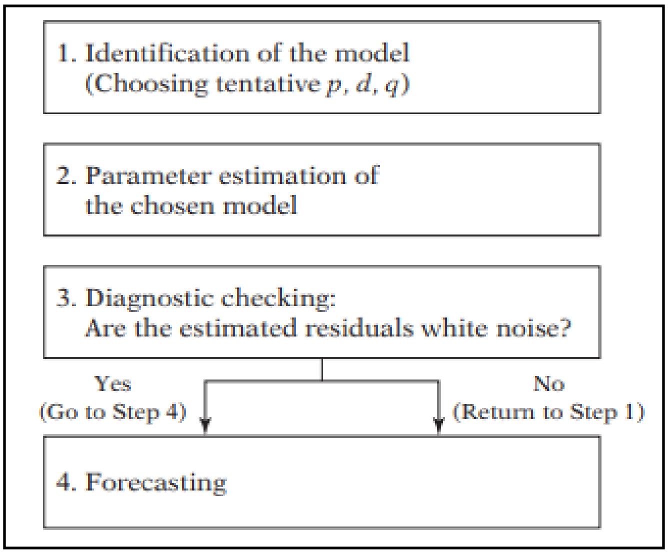
HA: FEM is preferred.

If the p-value is less than the α-value of 0.05, reject H_0, and FEM is preferred. If the p-value is more than the α-value of 0.05, then do not reject H_0, and REM is preferred. The results of all three tests will be collected and analyzed to choose the POLS, FEM, or REM model that is preferred.

3.4.2 ARIMA Model

To forecast future trends in crude oil price, this study will apply the ARIMA model, also known as the Box-Jenkins methodology. As a result, this model is commonly referred to as a univariate model and usually utilizes single time-series. This methodology involves four (4) steps: model specification and identification, model estimation and verification, diagnostic checking, and forecasting (Gujarati & Porter, 2009). Figure 3.2 shows the four (4) steps of the Box–Jenkins methodology.

Figure 3.2: Four (4) Steps in Box–Jenkins Methodology



Source: Gujarati & Porter (2009)

Step 1: Model Specification and Identification

To identify the values of the p, d, and q of an ARIMA model (p, d, q), this step is identified by forming the correlogram and partial correlogram of the time series.

Step 2: Model Estimation and Verification

Once the p and q values have been determined, the model's autoregressive parameter (AR) and moving average parameter (MA)need to be estimated by using statistical inference techniques.

Step 3: Diagnostic Checking

To assess the extent to how precise the model matches the data, diagnostic checks are conducted. We do this by performing tests on residuals and by examining the significance and relationships between the parameters.

Step 4: Forecasting

When the model has been identified, this step is applied to forecast the time series and produce confidence intervals, which reflect the forecast's degree of uncertainty.

The ARIMA model is a stochastic procedure which has been used for the purpose of conducting analyses on time series that are not stationary. The three main elements of an ARIMA model are the autoregressive parameter (AR), moving average parameter (MA) and integrated (I). The format of ARIMA model is determined by ARIMA (p,d,q). By conducting unit root test, the number of differencing to be stationary will decide the value of "d". For example, if the time series are stationary at first differencing, I (1), this means that the value of "d" equals to 1. Next, the number and order of AR and MA parameters are determined by the value of "p" and "q" by performing correlograms. Also, the spike of lags will decide the values for "p" and "d". For instance, if there is only spike on the first lag of correlograms in Partial Correlation (PAC) and Autocorrelation (AC), so takes "p" equals to 1 and "q" also equals to 1. This means that there is one AR and MA parameter of order 1 in the ARIMA model. Time series have to be differentiated employing the AR or MA approach as the majority of time series data has a non-stationary form. The ARIMA equation is presented as below:

$$\Delta X_t = c + \underbrace{\phi_1 \Delta X_{t-1}}_{\text{AR Parameter}} + \underbrace{\theta_1 \varepsilon_{t-1}}_{\text{MA Parameter}} + \varepsilon_t$$

3.5 Residual Diagnosis

3.5.1 Normality Test

The numerical approach used to determine whether the group and sample data fit the normal distribution is the objective of the normality test. Normality test will ensure the model follows the standard normal distribution, ensuring the model is unbiased, has consistency, minimum variance, and residuals are normally distributed (Gujarati & Porter, 2009). Hence, a normality test is necessary because the validity of a model depends on the assumption of normality, which must be evaluated for a range of statistical procedures. The hypotheses of the normality test are shown as follows:

H_0: Residuals are normally distributed.

H_A: Residuals are not normally distributed.

There are three tests to test a model's normality: histogram of residuals, normal probability plot, and the Jarque–Bera test. Using the histogram of residuals, the shape of the histogram will generally show that the residuals have a bell-shaped pattern if the residuals are normally distributed. Secondly, the normal probability plot will be nearly a straight line if the variable is taken from the normal population. Next, normality also can be tested using the formula of Jarque-Bera= $n\left[\frac{S^2}{6}+\frac{(K-3)^2}{24}\right]$. If the value of Jarque-Bera is more than X^2 statistics, reject H_0, and residuals are not normally distributed. If the value of Jarque-Bera is less than X^2 statistics, do not reject H_0, and residuals are normally distributed.

3.5.2 Heteroscedasticity

Heteroscedasticity problem arise when variances are not constant when observed throughout a range of independent variable values. There are several sources to cause heteroscedasticity. Firstly, the existence of outliers might lead to heteroscedasticity and can significantly affect the outcomes of regression analysis (Gujarati & Porter, 2009). A considerably distinct observation from the others in the sample is an outlier. Secondly, the source of heteroscedasticity can be incorrect specification of the regression model. Then, the next source is due to the skewness in the distribution of one or more independent variables. The assumption of the OLS will be violated if a dataset is heteroscedasticity, which indicates that the outcomes produced are inaccurate. The following are the hypotheses of heteroscedasticity:

H_0: Residuals are not heteroscedasticity.

H_A: Residuals are heteroscedasticity.

The decision rule for this test is if the p-value less than the α-value of 0.05, reject H_0, and residuals are heteroscedasticity. If the p-value is more than the α-value of 0.05, do not reject H_0, and residuals are not heteroscedasticity.

3.5.3 Multicollinearity

Multicollinearity occurs when the model's independent variables are highly correlated with each other. For instance, the included independent variables might be unnecessary in the model. The reason of multicollinearity problem occurs might be due to the sample size is too large and over a limited of range, constraints on the model, wrongly specify the model, or the model is overdetermined. Therefore, multicollinearity test needs to be conducted in a research study. Following are the hypotheses of multicollinearity test:

H_0: The time series do not have multicollinearity.

H_A: The time series have multicollinearity.

There are two ways to detect multicollinearity problem which can calculating Variance Inflation Factors (VIFs) and Tolerance (TOL). By using formula of $VIF(\hat{\beta}_i) = \frac{1}{(1 - R_i^2)}$, if the VIF value is greater than 5, reject H_0 and the time series have high multicollinearity. By using $TOL = \frac{1}{VIF}$ to measure multicollinearity, if TOL is smaller than 0.19, reject H_0 and the time series have high multicollinearity.

3.6 Model Evaluation

To measure model accuracy, Root Mean Squared Error (RMSE), Mean Absolute Percent Error (MAPE), Mean Absolute Error (MAE), U-Theil Criterion, Akaike Information Criterion (AIC), and Schwarz Information Criterion (SIC) are used based on the time-series data.

3.6.1 Root Mean Squared Error (RMSE)

The value generated by computing the square root of the MSE is known as the RMSE. It is scaled according to the observations of data. RMSE assesses how much the forecasted value varies from the actual time trend. With increased variability in the distribution of error values, the value of RMSE is larger than the value of MAE(Chai & Draxler, 2014). To calculate RMSE, the formula is $RMSE = \frac{E_{j=T+1}^{h}(P_t - A_t)^2}{T}$.

3.6.2 Mean Absolute Percent Error (MAPE)

MAPE signifies the average multiplicative influence of each projected mean on the observed result. It is designed to examine how accurate the predicted values are. When the actual values are large, the MAPE performs particularly well. To calculate MAPE, the formula is $MAPE = \frac{\frac{\sum(|P_t - A_t|)^2}{A_t} * 100}{T}$.

3.6.3 Mean Absolute Error (MAE)

Another measure in model evaluation is MAE. MAE is applied to determine whether a forecasting approach is biased. The forecasting approach is constantly overestimated if the value of MAE is high in negative percentage. The value of MAE is substantially less than the value of RMSE since RMSE penalizes large errors, but MAE provides equal weight to every error (Chai & Draxler, 2014). To calculate MAE, the formula is $MAE = \frac{\sum(|P_t - A_t|)}{T}$.

3.6.4 U-Theil Criterion

U-Theil Criterion is a measure of accuracy that evaluates the outcomes of predicting historical data. When the U-Theil statistic is near to 0, the model is preferred and whereas when it is close to 1, the model's ability to forecast the future is very poor. To calculate U-Theil statistics, the formula is

$$U - Theil\ Statistics = \frac{\sqrt{\frac{E_{j=T+1}^{h}(P_t - A_t)^2}{T}}}{\sqrt{\frac{E_{j=T+1}^{h}(P_t)^2}{T}} + \sqrt{\frac{E_{j=T+1}^{h}(A_t)^2}{T}}}.$$

3.6.5 Akaike Information Criterion (AIC)

The formula for AIC is AIC = (2k/n) +ln (RSS/n). In the formula, k represents the number of regressors, n represents the number of observations, and RSS represents the Residual Sum of Squares. AIC has the advantage of being effective for a regression model's out-of-sample forecast accuracy in addition to the in-sample forecast. Furthermore, it tends to work effectively with both nested and non-nested models. The lag length in an AR(p) model has also been measured using it. It is preferred to choose the model with the lowest AIC value.

3.6.6 Schwarz Information Criterion (SIC)

To calculate SIC, the formula is SIC = k/n (ln n) + ln (RSS/n). The same as the formula AIC, k represents the number of regressors, n represents the number of observations, and RSS represents the residual sum of squares. Similar to AIC, SIC is being applied to make a comparison of in-sample and out-of-sample model forecasting accuracy. It is preferred to choose the model with the lowest SIC value.

3.7 Data Analysis

3.7.1 Descriptive Analysis

Descriptive analysis is a form of data analysis that aids in explaining, presenting, or combining datasets to allow patterns to emerge that satisfy all of the data's requirements (McCarthy, McCarthy, & Ceccucci, 2021). The descriptive analysis also summarizes and lays out the data in a simple way to observe the relationship between the study's variables. The components measured in descriptive statistics included the value of minimum, maximum, mean, median, mode, standard deviation, the value of kurtosis, and skewness. Therefore, researchers will be able to describe the data shown easily by using descriptive analysis.

3.7.2 Unit Root Test

Unit root test is a stationarity test for time series. The accuracy, validity, and significance of the regression are tested using unit root tests. If the data has a unit root, the regression result would be spurious. To determine whether the time series has any unit roots, the Augmented Dickey and Fuller (ADF) and Phillips and Perron (PP) tests are conducted. The ADF test may be used to examine for random walk components in residuals. The PP test has the advantage that the Newey-West correction is applied in this test to avoid the autocorrelation and heteroscedasticity issues because PP test is a non-parametric test. The hypotheses of the unit root test are as follows:

H_0: The time series is non-stationary.

H_A: The time series is stationary.

The decision rule of the unit root test is if the p-value less than the α-value of 0.05, reject H_0, and the time series is stationary. If the p-value is more than the α-value of 0.05, do not reject H_0, and the time series is not stationary. When the data is stationary at the level, it will be denoted by I (0). When the data is stationary at the first difference, it will be denoted by I (1). When the data is stationary at second difference, it will be denoted by I (2).

3.7.3 Cointegration Test

Cointegration test is a type of data analysis that determines if there is a relationship over the long run between two variables. The cointegration test is similar to the unit root test, but the unit root test is conducted on a single time series, while the cointegration test is conducted on a group of variables. The selection of independent and dependent variables is not required for the cointegration test. The hypotheses of cointegration test are as follows:

H_0: The variables are not cointegrated.

H_A: The variables are cointegrated.

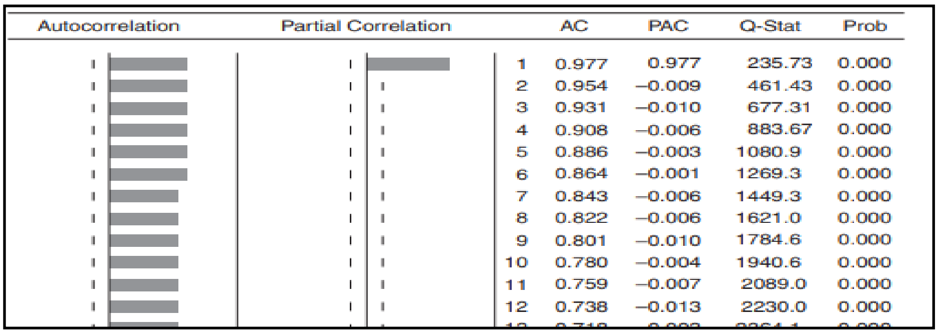
If the p-value less than α-value of 0.05, reject H_0 and the variables are cointegrated and have long term relationship. Given the large sample size in this research and interest in examining the long-term relationship between more than two variables, the equation of cointegration for crude oil price is formulated as below:

$$\beta_1 COP_{t-1} + \beta_2 EXR_{t-1} + \beta_3 INF_{t-1} + \beta_4 ITR_{t-1} + \beta_5 GDP_{t-1} + \beta_6 PCO_{t-1} = 0$$

3.7.4 Correlogram

Another stationarity test of time series is the correlogram. A correlogram is a graph that shows the autocorrelation coefficients and various lags. A correlogram makes it simple to identify periodicities in a time series. Figure 3.3 shows an illustration of the correlogram.

Figure 3.3: Illustration of Correlogram



Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.977	0.977	235.73	0.000
		2	0.954	−0.009	461.43	0.000
		3	0.931	−0.010	677.31	0.000
		4	0.908	−0.006	883.67	0.000
		5	0.886	−0.003	1080.9	0.000
		6	0.864	−0.001	1269.3	0.000
		7	0.843	−0.006	1449.3	0.000
		8	0.822	−0.006	1621.0	0.000
		9	0.801	−0.010	1784.6	0.000
		10	0.780	−0.004	1940.6	0.000
		11	0.759	−0.007	2089.0	0.000
		12	0.738	−0.013	2230.0	0.000

Source: Gujarati & Porter (2009)

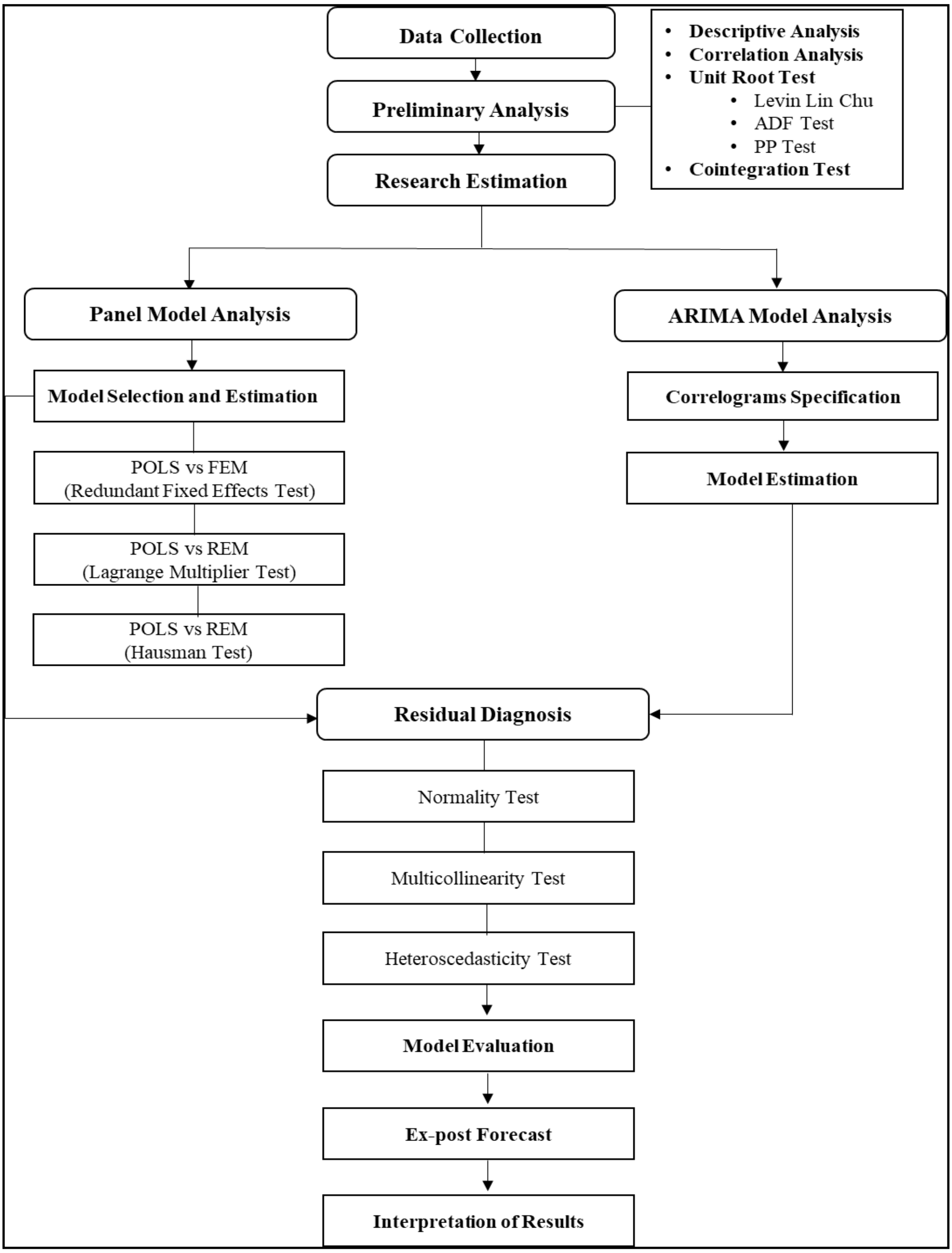
Based on Figure 3.2, there are two important components: autocorrelation function (ACF) and partial correlation function (PACF). The format of the ARIMA (p,d,q) model will depend on the ACF and PAC in the correlogram. The alphabet ‘p’ in ARIMA (p,d,q) model will refer to PAC, while the alphabet ‘q’ will refer to AC in the correlogram. For example, if the PAC indicates the value of 3 and the AC indicates the value of 1 with stationary at the first differencing I (1), the ARIMA model will be the ARIMA (3,1,1) model. Therefore, Chapter 4 will further discuss the correlogram analysis of the crude oil price ARIMA model.

3.8 Research Estimation Procedure

Figure 3.4 below shows the research estimation procedure of this research study. First, the preliminary analysis will be performed, including descriptive analysis, correlation analysis, unit root test, and cointegration test. The procedure of collecting data on each variable will be carried out first. Then, to develop a fundamental understanding of the unprocessed data, a descriptive analysis is conducted. The analyses involve assessing the mean, mode median, and standard deviation. Next, a correlation test will be performed to check the correlation between each variable. After that, the unit root test is conducted by employing the Levin, Lin, Chu test for the panel model and the ADF and PP test for the ARIMA model to test the stationarity of the variables.

For research estimation, two (2) models will be conducted in this research study: the panel model and the ARIMA model. For panel model analysis, model selection will be carried out to identify whether FEM, REM or POLS model is the best model by conducting three (3) tests: Redundant Fixed Effects Test, Lagrange Multiplier Test, and Hausman Test. After identifying the best model, the model estimation will be presented with the estimation outcomes generated by EViews. Then, residual diagnosis and model evaluation will be performed to assess the model's appropriateness. Lastly, the ex-post forecast will be presented to forecast the crude oil price. For ARIMA model analysis, correlograms of each country are going to be presented to check on the order of AR and MA parameters. Next, the estimation outputs will be presented in model estimation on the ARIMA model. Finally, residual diagnosis and model evaluation for each country is going to be performed, and all the estimation outputs will be then interpreted.

Figure 3.4: Research Estimation Procedure for Forecasting Model of Crude Oil Price Instability in ASEAN-5 Countries



Source: Author’s Own Creation

3.9 Conclusion

This chapter has presentedthe conceptual framework, hypotheses development, sources of data, the concept of research methodologies, residual diagnosis, model evaluation, and data analysis. The next chapter, Chapter 4 will discuss data analysis and research estimation outcomes of the research study.

CHAPTER 4: DATA ANALYSIS AND RESULTS

4.0 Introduction

Chapter 4 will describe the results of data analysis, and i.e. two (2) parts. They are the results from the panel model analysis from 2007 and 2021 yearly data with 75 observations and ARIMA model analysis for ASEAN-5 countries from January 2017 and September 2022 monthly data with 69 observations for each country. Using the methodology stated in Chapter 3, this chapter specifies the relationships among the exchange rate, inflation rate, interest rate, GDP per capita, and production of crude oil and crude oil price. The results are generated using the econometrics software EViews, which is mostly used for time-series in econometric research.

For panel model, all the test and regression procedures are conducted using the data in the form of natural logarithm. Panel model analysis will include descriptive analysis, preliminary analysis, research estimation methods, diagnosis analysis, model evaluation, and ex-post forecast for the crude oil price model of ASEAN-5 countries. For ARIMA model, the analysis will include descriptive statistics, unit root test, correlogram analysis, research estimation method, diagnostic analysis as well as model evaluation.

4.1 Results of Panel Model Analysis

4.1.1 Descriptive Analysis of Panel Model

Table 4.1 illustrates the descriptive statistics analysis for the combined ASEAN-5 countries from 2007 to 2021. For crude oil price, the mean value is 7.7637. The median value is 5.8209, maximum value for crude oil price is 14.0341, and the minimum value is 4.1784. The standard deviation is 3.6094. Next, for exchange rate, the mean falls on 3.5909 and the median falls on 1.4337. The value of maximum is 9.5346 and the value of minimum is 0.2120. The standard deviation recorded as 3.6579. Thirdly, for the inflation rate, the mean is 0.6108% with the median of 0.7443%, the values of maximum and minimum are 1.8913% and -2.1913%; while the standard deviation is 0.9529%.

For interest rate, the mean falls on 1.3230% and the median falls on 1.4411%. The value of maximum is 3.5671% and the value of minimum is -1.4142%. The value of standard deviation recorded is 0.8506%. Furthermore, for the GDP per capita, the mean is US$9.2630 with the median of US$8.9630, the values of maximum and minimum are US$11.1001 and US$7.7843; while the standard deviation is US$1.0872. For production of crude oil, the mean value is 5.4112 thousand barrels per day. The median value is 5.4838 thousand barrels per day, maximum value is 6.8606 thousand barrels per day, and the minimum value is 2.8904 thousand barrels per day. The standard deviation is 1.3403 thousand barrels per day.

Table 4.1: Descriptive Analysis Results for Panel Crude Oil Price Model of ASEAN-5 Countries

	lnCOP	lnEXR	lnINF	lnITR	lnGDP	lnPCO
Mean	7.7637	3.5909	0.6108	1.3230	9.2630	5.4112
Median	5.8209	1.4337	0.7443	1.4411	8.9630	5.4838
Maximum	14.0341	9.5346	1.8913	3.5671	11.1001	6.8606
Minimum	4.1784	0.2120	-2.1913	-1.4142	7.7843	2.8904
Std. Dev.	3.6094	3.6579	0.9529	0.8506	1.0872	1.3403
Observations	51	51	51	51	51	51

Source: EViews output

4.1.2 Preliminary Analysis for Panel Model

Preliminary analysis will include correlation analysis, unit root test and cointegration test for panel model on ASEAN-5 countries' data. Correlation test will be to measure the strength of the linear connection between two variables. The panel model unit root test is going to be conducted to test on stationarity of each variable by using Levin, Lin and Chu. The cointegration test will also be performed to test on whether the variables are cointegrated.

4.1.2.1 Correlation Analysis for Panel Model

Table 4.2 presents the correlation analysis output for panel model on ASEAN-5 countries. First and foremost, the exchange rate and crude oil price have correlation coefficient of 0.9948. The relationship between these two variables is positive. Secondly, the inflation rate and crude oil price have correlation value of 0.5061. There is positive relationship between these two variables. Thirdly, the interest rate and crude oil price have a correlation coefficient of -0.1747. There is negative relationship between interest rate and crude oil price. Furthermore, the GDP per capita and crude oil price have correlation value of 0.8182. Therefore, there is positive relationship between GDP per capita and crude oil price. Lastly, the production of crude oil and crude oil price have a correlation coefficient of -0.6565. Therefore, negative relationship exists between production of crude oil and crude oil price.

Table 4.2: Correlation Results forPanel Crude Oil Price Model of ASEAN-5 Countries

	COP	EXR	INF	ITR	GDP	PCO
COP	1.0000	0.9948	0.5061	0.1747	-0.8182	0.6565
EXR	0.9948	1.0000	0.4809	0.1736	-0.8237	0.6660
INF	0.5061	0.4809	1.0000	-0.0083	-0.4070	0.2975
ITR	-0.1747	0.1736	-0.0083	1.0000	0.0680	0.0835
GDP	0.8182	-0.8237	-0.4070	0.0680	1.0000	-0.8805
PCO	-0.6565	0.6660	0.2975	0.0835	-0.8805	1.0000

Source: EViews output

4.1.2.2 Panel Model Unit Root Test

A unit root test detects whether or not a time series has a unit root, which is a non-stationary time series characteristic. When the mean and variance of a time series vary over time in an unpredictable pattern, this is a time series characteristic known as a unit root. When the data is stationary at the level, it will be represented by I (0). When the data is stationary at the first differencing, it will be represented by I (1). When the data is stationary at second differencing, it will be presented by I (2). The following are the unit root test hypotheses:

H_0: The time series is non-stationary.

H_A: The time series is stationary.

For the panel model unit root testing for ASEAN-5 countries, the Levin, Lin, and Chu unit root test is employed. Table 4.3 shows the panel model unit root test outputs for ASEAN-5 countries. The outputs show that crude oil price, inflation rate, and GDP per capita are stationary at level. Next, all variables are stationary after the first differencing. From the outputs of unit root test after second differencing, all variables are stationary except for GDP per capita. The data sample will next be subjected to a cointegration test since the variables are stationary at non-uniform difference levels.

Table 4.3: Unit Root Test Results of Panel Crude Oil Price Model of ASEAN-5 Countries

Levin, Lin & Chu			
	Level	**I (1)**	**I (2)**
lnCOP	-2.6805**	-4.8793***	-4.8257***
lnEXR	0.0406	-2.3803***	-6.0578***
lnINF	-3.3287***	-3.9454***	-5.8431***
lnITR	-1.2017	-1.9627**	-4.3120***
lnGDP	-2.2710**	-2.5866***	1.4678
lnPCO	1.3396	-1.9468**	-5.8998***

Source: EViews output

Note:

*	represents the stationary at $\alpha = 0.10$ significance level.
**	represents the stationary at $\alpha = 0.05$ significance level.
***	represents the stationary at $\alpha = 0.01$ significance level.

4.1.2.3 Panel Cointegration Test (Kao Test)

A cointegration test is used to determine whether two or more non-stationary time series are cointegrated or not. The hypotheses of cointegration test are as follows:

H_0: The time series are not cointegrated.

H_A: The time series are cointegrated.

Table 4.4 presents the cointegration test outputs for crude oil price model of ASEAN-5 countries. The test identified that the t-statistics for ADF is -2.0350, for residual variance is 0.0491, and HAC variance is 0.0447. The results indicate the p-value of ADF is 0.0209 which is less than α 0.05 level and the H_0 is rejected. Therefore, there is cointegration and long-term relationship between the variables in the crude oil price model of ASEAN-5 countries.

Table 4.4: Kao Panel Cointegration Test Results of Panel Crude Oil Price Model of ASEAN-5 Countries

	t-Statistic	**Prob.**
ADF	-2.0350	**0.0209**
Residual variance	0.0491	
HAC variance	0.0447	

Source: EViews output

4.1.3 Panel Model Research Estimation Methods

4.1.3.1 Panel Model Selection for Crude Oil Price Model of ASEAN-5 Countries

The Redundant Fixed Effects Test, Lagrange Multiplier Test for Random Effects, and Correlated Random Effects - Hausman Test were performed in order to decide whether POLS, FEM, or REM is the best suitable model to estimate the crude oil price for the ASEAN-5 countries.

First and foremost, the Redundant Fixed Effects Test was conducted. The hypotheses are:
H_0: POLS is preferred.
H_A: FEM is preferred.

Table 4.5 presents the results of Redundant Fixed Effects Test. The results show the significance of the cross-section fixed, period fixed, and cross-section and period fixed effects are all significant at p-value less than of 0.05. The H_0 is rejected. Therefore, the Fixed Effects Model (FEM) is preferred.

Table 4.5: Panel Redundant Fixed Effects Test Output for Panel Crude Oil Price Model of ASEAN-5 Countries

Effects Test	**Statistic**	**d.f.**	**Prob.**
Cross-section F	3.0671	(4,27)	**0.0332**
Cross-section Chi-square	19.1042	4	**0.0007**
Period F	35.3336	(14,27)	**0.0000**
Period Chi-square	151.0211	14	**0.0000**
Cross-Section/Period F	68.3520	(18,27)	**0.0000**
Cross-Section/Period Chi-square	195.8866	18	**0.0000**

Source: EViews output

Note:
*	represents significant at α = 0.10 significance level.
**	represents significant at α = 0.05 significance level.
***	represents significant at α = 0.01 significance level.

Next, Lagrange Multiplier Test was conducted. The hypotheses of Lagrange Multiplier Test are:

H0: POLS is preferred.

HA: REM is preferred.

Table 4.6 presents the Lagrange Multiplier Test for Random Effects results. The results of LM test show all test are significant at 0.01 level with all p-values less than 0.01 level, and the $H_0$is rejected. Therefore, Random Effect Model (REM) is preferred.

Table 4.6: Lagrange multiplier (LM) test for Panel Crude Oil Price Model of ASEAN-5 Countries

Null (no rand. effect)	Cross-section	Period	Both
Alternative	**One-sided**	**One-sided**	
Breusch-Pagan	1.5387	57.5421	59.0808
	(-0.2148)	(0.0000)	**(0.0000)**
Honda	-1.2404	7.5857	4.4867
	(-0.8926)	(0.0000)	**(0.0000)**
King-Wu	-1.2404	7.5857	2.4060
	(-0.8926)	(0.0000)	**(-0.0081)**
GHM	--	--	57.5421
	--	--	**(0.0000)**

Source: EViews output

Note:
* represents significant at α = 0.10 significance level.
** represents significant at α = 0.05 significance level.
*** represents significant at α = 0.01 significance level.

Then, the Panel Correlated Random Effects – Hausman Test was conducted. The hypotheses of Hausman Test are:

H_0: REM is preferred.

H_A: FEM is preferred.

Table 4.7 shows the Panel Correlated Random Effects – Hausman Test results. The results show period random was significant at 0.0127 which is less than α value of 0.05, and the H_0 is rejected. Therefore, the Fixed Effects Model (FEM) is preferred.

Table 4.7: Panel Correlated Random Effects – Hausman Test Output for Panel Crude Oil Price Model of ASEAN-5 Countries

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Period random	14.506106	5	**0.0127**

Source: EViews output

In conclusion, the Fixed Effects Model (FEM) is the best and preferred model for the ASEAN-5 countries' crude oil price model. After comparing the significance of each variable of the estimation output for each fixed effect model with the determinants such as the Durbin-Watson statistic close to 2 is preferable; and the sum squared residuals like Akaike information criterion (AIC), Schwarz information criterion (SIC), Root Mean Square Error (RMSE), Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE) and U-Theil Criterion are lowest is preferable. As a result, the period fixed model is the most preferable. Therefore, the **period fixed effect panel model** equation for crude oil price model is shown in Equation (4.1):

$$lnCOP_{it} = 10.7848 + 2.5475 lnEXR_{it} + 0.1424 lnINF_{it} - 0.0072 lnITR_{it}$$

t = [5.1374***] [2.8766***] [-0.1338]

$$+ 0.7576 lnGDP_{it} - 0.1791 lnPCO_{it} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.1)$$

[2.3407**] [-0.6979***]

$R^2 = 0.7962$ Adjusted $R^2 = 0.7953$

Note:
* represents significant at $\alpha = 0.10$ significance level.
** represents significant at $\alpha = 0.05$ significance level.
*** represents significant at $\alpha = 0.01$ significance level.

Based on the period fixed effects model estimation results for crude oil price in ASEAN-5 countries, the explanatory variables accounted for 79.62% of the variation in crude oil price of ASEAN-5 countries model from 2007 to 2021. The estimation results show that the explanatory variable namely the GDP per capita (lnGDP) was the significant explanatory variable with statistically significance at 0.05 level in the crude oil price model; while exchange rate (lnEXR), inflation rate (lnINF), and production of crude oil (lnPCO) were the significant explanatory variables with statistically significance at 0.01 level in the crude oil price model. Therefore, a 1 unit increase in the GDP per capita, on average has the positive relationship effect of increasing crude oil price by 0.7576 units with statistically significance at 0.05 level. Then, a 1 unit increase in the exchange rate, on average has the positive relationship effect of increasing crude oil price by 2.5475 unit with statistically significance at 0.01 level. Next, a 1 unit increase in the inflation rate, on average has the positive relationship effect of increasing crude oil price by

0.1424 unit with statistically significance at 0.01 level. Lastly, a 1 unit increase in the production of crude oil, on average has the negative relationship effect of reducing crude oil price by 0.1791 unit with statistically significance at 0.01 level.

4.1.4 Residual Diagnosis

There are three (3) tests to be conducted for residual diagnosis which are normality test, multicollinearity test and heteroscedasticity test.

4.1.4.1 Normality

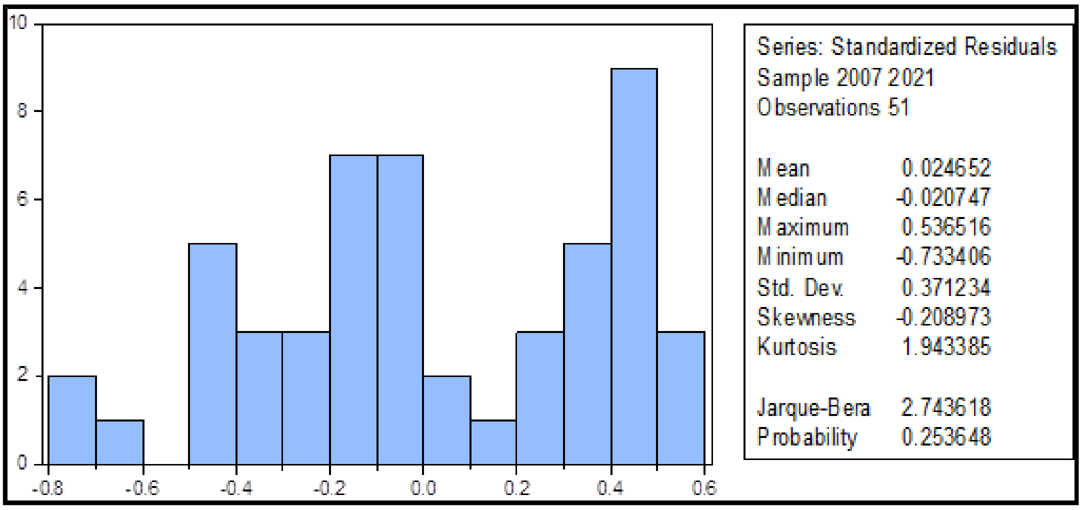
Normality test was performed for the residuals of fixed effects model for the crude oil price model of ASEAN-5 countries. Following are the hypotheses:

H_0: Residuals are not normally distributed.

H_A: Residuals are normally distributed.

Figure 4.1 presents the normality test results for crude oil price model ASEAN-5 countries. The results indicated that the p-value is 0.2536 which is more than α-value of 0.05 and H_0 was rejected. Therefore, residuals are normally distributed.

Figure 4.1: Normality Test for Residuals for Panel Crude Oil Price Model of ASEAN-5 Countries



Source: EViews output

4.1.4.2 Multicollinearity

Next, multicollinearity test was performed. The hypotheses for multicollinearity are:
H_0: The time series do not have multicollinearity.
H_A: The time series have multicollinearity.

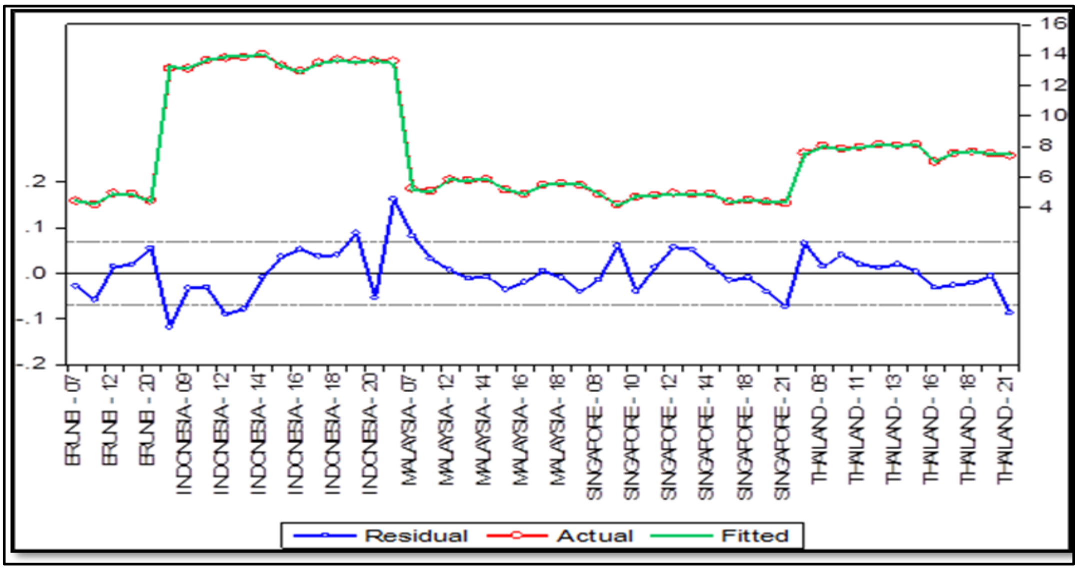
The decision rule for multicollinearity test is if value of VIF is greater than 5, reject H_0 and the time series have high multicollinearity. By using R-squared value is 0.7962, the computed VIF is $\frac{1}{(1-0.7962)}$ = 4.9068 which is less than 5. Therefore, do not reject the H_0 and the time series do not have multicollinearity problem.

4.1.4.3 Heteroscedasticity

Thirdly, Figure 4.2 is residual graph that used to determine whether is any heteroscadesaticty problem in crude oil price panel model of ASEAN-5 countries. The hypotheses of the heteroscedasticity test are:
H_0: Residuals are not heteroscedasticity.
H_A: Residuals are heteroscedasticity.

The residuals are considered homoscedasticityif the variance of the error term is constant and its mean and variance remain constant over time.. The residual graph in Figure 4.2 shown the residual line in blue is located within zero. Therefore, the variance of the error term is constant. and its mean and variance are constant over time. Thus, do not reject H_0 and this indicates that the residuals are not heteroscedasticity.

Figure 4.2: Residuals graph for Panel Crude Oil Price Model of ASEAN-5 Countries



Source: Eviews Output

4.1.5 Model Evaluation

Figure 4.3 shows the model evaluation output of period fixed effects panel model for ASEAN-5 countries. The RMSE value is 0.0503 and MAE value is 0.0390. For MAPE, the value obtained is 0.5493. Other than that, the U-Theil statistics value shows a 0.0029. While Figure 4.4 shows the out of period random fixed effect panel model for ASEAN-5 countries. The RMSE value is 0.0614 and MAE value is 0.0484. For MAPE, the value obtained is 0.6675 and the value of U-Theil statistics is 0.0036. Based on the results, period fixed effect model has the lowest value on RMSE, MAE, MAPE, and U-Theil statistics compared to period random fixed effect model. Besides, the U-Theil statistics for period fixed model is closer to 0. Thus, the results indicate that the period fixed model's predicting performance is satisfactory and preferred.

Figure 4.3: Model Evaluation Output of Period Fixed Effects Panel Model for ASEAN-5 countries

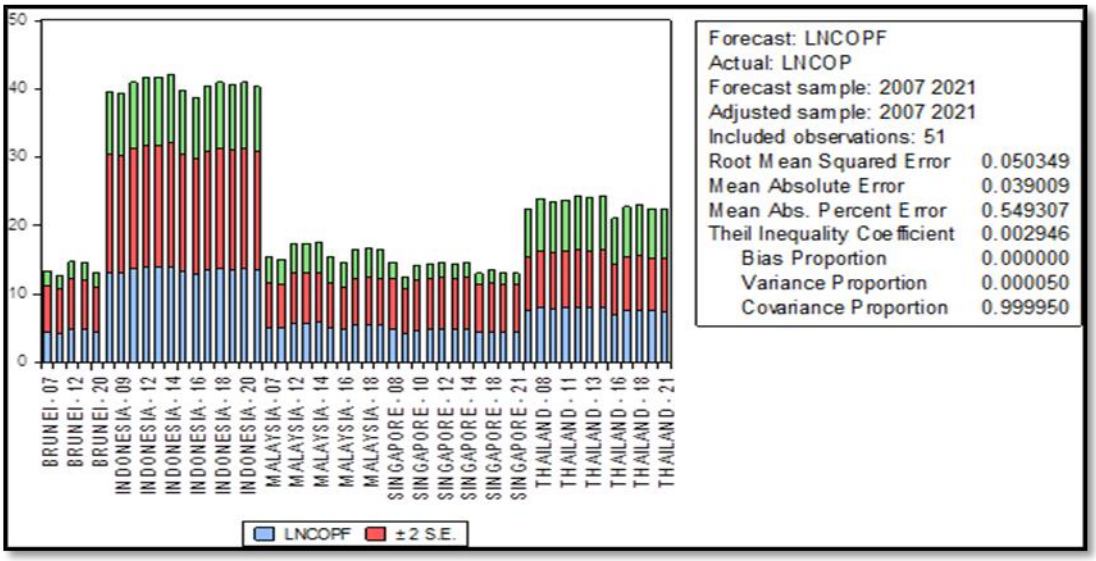
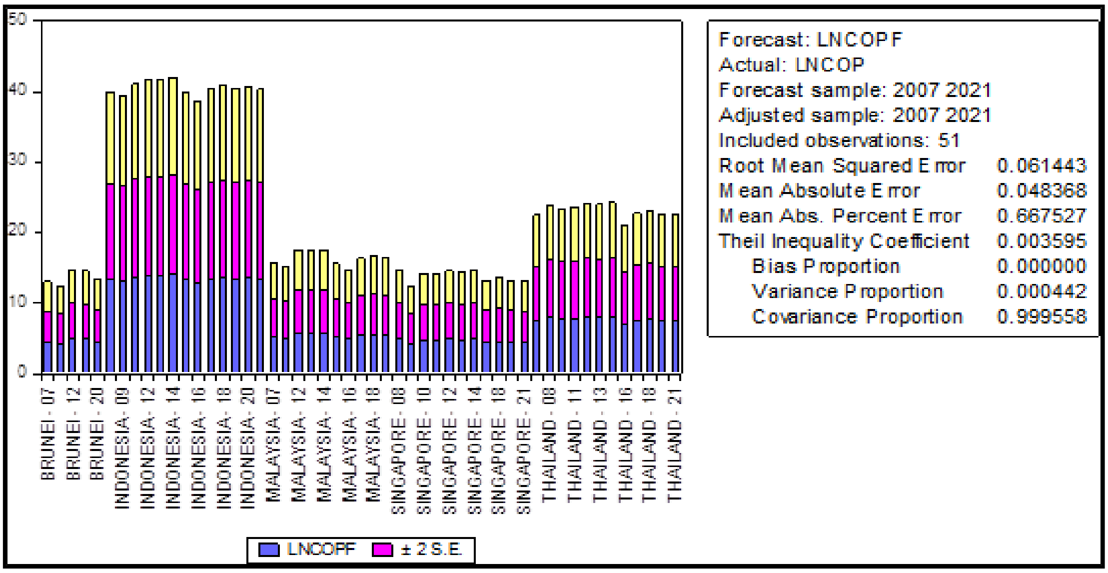


Figure 4.4: Model Evaluation Output of Period Random Fixed Effects Panel Model for ASEAN-5 countries



Source: Eviews Output

4.1.6 Ex-Post Forecast on Crude Oil Price

Table 4.8 shows the ex-post forecast for five years for crude oil price model of ASEAN-5 countries using ln data from 2007 to 2021. Based on the forecast, the crude oil price of Brunei is forecasted to have decreasing trend, but the actual crude oil price is slightly increase. For Indonesia, the crude oil price is forecasted to have increasing trend and the actual crude oil price also shows merely increase which indicate the similar trend with forecasted data. For Malaysia, the crude oil price is forecasted to increase, and the actual crude oil price also indicates the same trend with as forecasted. For Singapore, the crude oil price is forecasted to have decreasing trend and the actual crude oil price shown there is slightly decrease which means it followed the trend as forecasted. For Thailand, the actual crude oil price is followed the decreasing trend as forecasted.

Table 4.8: Ex-post Forecast for Five Years for Panel Crude Oil Price Model of ASEAN-5 Countries

Country/Year	Actual	Ex-post Forecast
Brunei		
2007	4.4105	4.4394
2009	4.1784	4.2367
2012	4.9202	4.9060
2013	4.8607	4.8417
2020	4.4221	4.3679
Indonesia		
2007	13.0928	13.2113
2009	13.1017	13.1347
2012	13.7900	13.8800
2013	13.8333	13.9119
2020	13.5953	13.6495
Malaysia		
2007	5.2351	5.1529
2009	5.0525	5.0211
2012	5.8087	5.8017
2013	5.7667	5.7778
2020	5.4506	5.4912
Singapore		
2007	4.8661	4.8805
2009	4.1784	4.1184
2012	4.9202	4.8632
2013	4.8607	4.8096
2020	4.2632	4.3372
Thailand		
2007	7.5629	7.4976
2009	8.0102	7.9959
2012	8.1254	8.1136
2013	8.0590	8.0393
2020	7.3828	7.4702

Source: Author’s own calculation

4.2 Results of ARIMA Model Analysis

4.2.1 Descriptive Analysis of ARIMA Model

Table 4.9 illustrates the results of descriptive analysis for ARIMA crude oil price model for ASEAN-5 countries respectively. For Brunei's crude oil price, the mean value is 87.4374. The median value is 83.6600, maximum value for crude oil price is 161.6100, and the minimum value is 29.9700. The standard deviation is 25.9615.

Next, for Indonesia's crude oil price, the mean falls on 815612.3000 and the median falls on 802321.8000. The maximum value is 1164625.0000 and the minimum value is 613916.3000. The standard deviation recorded is 96844.2700.

Thirdly, for Malaysia's crude oil price, the mean is 268.7693 with the median of 251.3000, the maximum value and minimum value is 514.1100 and 91.6400; while the standard deviation is 82.9421.

For Singapore's crude oil price, the mean falls on 87.4371and the median falls on 83.6600. The maximum value is 161.6100 and the minimum value is 29.9700. The standard deviation recorded is 25.9550.

Lastly, for the Thailand's crude oil price, the mean is 2093.2790 with the median of 1965.2900, the maximum value and minimum value is 4082.9700 and 686.4100; while the standard deviation is 687.4220.

Table 4.9: Descriptive Analysis Results for ARIMA Model of ASEAN-5 Countries

	COP BRUNEI	COP INDONESIA	COP MALAYSIA	COP SINGAPORE	COP THAILAND
Mean	87.4374	815612.3000	268.7693	87.4371	2093.2790
Median	83.6600	802321.8000	251.3000	83.6600	1965.2900
Maximum	161.6100	1164625.0000	514.1100	161.6100	4082.9700
Minimum	29.9700	613916.3000	91.6400	29.9700	686.4100
Std. Dev.	25.9615	96844.2700	82.9421	25.9550	687.4220
Observations	69	69	69	69	69

Source: EViews Output

4.2.2 Preliminary Analysis of ARIMA Model

Preliminary analysis will include unit root test and correlogram on ARIMA crude oil price model of ASEAN-5 countries' data. The ARIMA model unit root test is going to be conducted to test on stationarity of each variable by using ADF and PP test. The correlogram will be performed to determine the format of ARIMA model.

4.2.2.1 Unit Root Test of ARIMA Model

The ARIMA crude oil price model unit root tests for the ASEAN-5 nations employed the Augmented Dickey-Duller test (ADF) and Phillips-Perron test (PP) tests. Table 4.10 shows the unit root test results of ASEAN-5 countries for both tests. The outputs revealed that all the data were not stationary at level I (0), but stationary at first differencing, I (1) and second differencing, I (2) with statistically significant at 0.01 level for both tests. Therefore, the null hypotheses are rejected for all ASEAN-5 countries at first difference. Thus, the ARIMA model will be estimated for first difference data, and the "d" in ARIMA (p,d,q) format will be equal to 1.

Table 4.10: Unit Root Test Results for ARIMA Model ASEAN-5 Countries

	ADF			PP		
	I (0)	**I (1)**	**I (2)**	**I (0)**	**I (1)**	**I (2)**
COP Brunei	-1.6667	**-5.7938*****	-8.7704***	-1.3	**-5.8106*****	-23.6369***
COP Indonesia	-2.5462	**-6.2177*****	-10.0123***	-2.1853	**-6.0866*****	-23.2130***
COP Malaysia	-1.5249	**-5.9648*****	-8.6732***	-1.0912	**-5.6938*****	-24.4311***
COP Singapore	-1.6664	**-5.8017*****	-8.7843***	-1.2993	**-5.8121*****	-23.6336***
COP Thailand	-1.2797	**-6.0795*****	-8.6798***	-0.8852	**-5.8761*****	-25.4612***

Source: Eviews Output

Note:
* represents the stationary at $\alpha = 0.10$ significance level.
** represents the stationary at $\alpha = 0.05$ significance level.
*** represents the stationary at $\alpha = 0.01$ significance level.

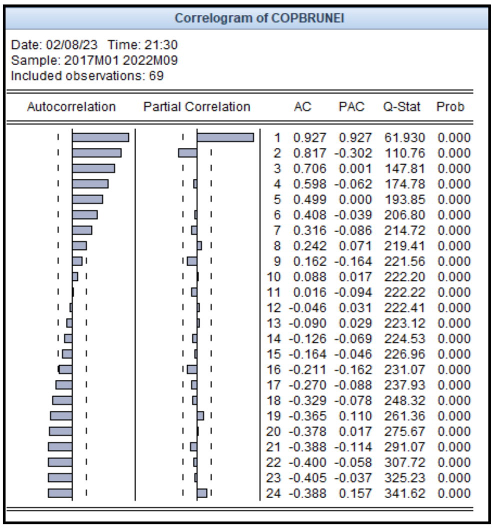
4.2.2.2 Correlogram

Figure 4.5 shows the correlogram of Brunei's crude oil price. The correlogram indicates only the first value from PAC showed the highest so the AR term (p) equals to 1 and since we take 1 for (p), and we also take MA term (q) equals to 1. Combining with the results of unit root test in Section 4.2.2.1, the COPBRUNEI model is ARIMA (1,1,1) model as a result.

Next, Figure 4.6 to Figure 4.9 show the correlograms for crude oil price of Indonesia, Malaysia, Singapore, and Thailand. All of the correlograms indicate the similar result with correlogram of Brunei's crude oil price, which AR term (p) equals to 1 as only the first value for PAC is showed the highest value and MA term (q) also equals to 1. Since the unit root test results showed all the ASEAN-5 crude oil price stationary at first differences, hence the ARIMA model for all ASEAN-5 crude oil price model is ARIMA (1,1,1).

Figure 4.5 to Figure 4.9: Correlograms of Crude Oil Price of ASEAN-5 Countries

Figure 4.5: COP of Brunei

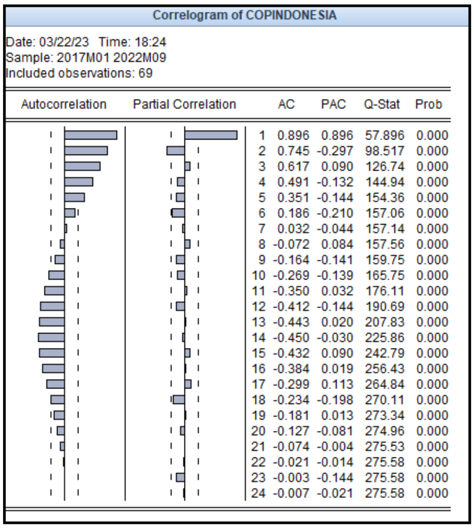


Correlogram of COPBRUNEI

Date: 02/08/23 Time: 21:30
Sample: 2017M01 2022M09
Included observations: 69

Lag	AC	PAC	Q-Stat	Prob
1	0.927	0.927	61.930	0.000
2	0.817	-0.302	110.76	0.000
3	0.706	0.001	147.81	0.000
4	0.598	-0.062	174.78	0.000
5	0.499	0.000	193.85	0.000
6	0.408	-0.039	206.80	0.000
7	0.316	-0.086	214.72	0.000
8	0.242	0.071	219.41	0.000
9	0.162	-0.164	221.56	0.000
10	0.088	0.017	222.20	0.000
11	0.016	-0.094	222.22	0.000
12	-0.046	0.031	222.41	0.000
13	-0.090	0.029	223.12	0.000
14	-0.126	-0.069	224.53	0.000
15	-0.164	-0.046	226.96	0.000
16	-0.211	-0.162	231.07	0.000
17	-0.270	-0.088	237.93	0.000
18	-0.329	-0.078	248.32	0.000
19	-0.365	0.110	261.36	0.000
20	-0.378	0.017	275.67	0.000
21	-0.388	-0.114	291.07	0.000
22	-0.400	-0.058	307.72	0.000
23	-0.405	-0.037	325.23	0.000
24	-0.388	0.157	341.62	0.000

Figure 4.6: COP of Indonesia

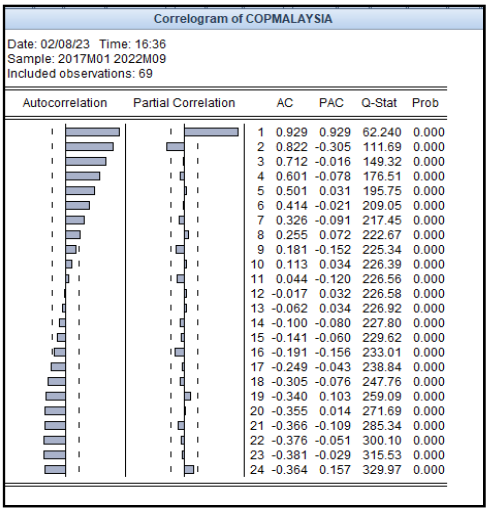


Correlogram of COPINDONESIA

Date: 03/22/23 Time: 18:24
Sample: 2017M01 2022M09
Included observations: 69

Lag	AC	PAC	Q-Stat	Prob
1	0.896	0.896	57.896	0.000
2	0.745	-0.297	98.517	0.000
3	0.617	0.090	126.74	0.000
4	0.491	-0.132	144.94	0.000
5	0.351	-0.144	154.36	0.000
6	0.186	-0.210	157.06	0.000
7	0.032	-0.044	157.14	0.000
8	-0.072	0.084	157.56	0.000
9	-0.164	-0.141	159.75	0.000
10	-0.269	-0.139	165.75	0.000
11	-0.350	0.032	176.11	0.000
12	-0.412	-0.144	190.69	0.000
13	-0.443	0.020	207.83	0.000
14	-0.450	-0.030	225.86	0.000
15	-0.432	0.090	242.79	0.000
16	-0.384	0.019	256.43	0.000
17	-0.299	0.113	264.84	0.000
18	-0.234	-0.198	270.11	0.000
19	-0.181	0.013	273.34	0.000
20	-0.127	-0.081	274.96	0.000
21	-0.074	-0.004	275.53	0.000
22	-0.021	-0.014	275.58	0.000
23	-0.003	-0.144	275.58	0.000
24	-0.007	-0.021	275.58	0.000

Figure 4.7: COP of Malaysia

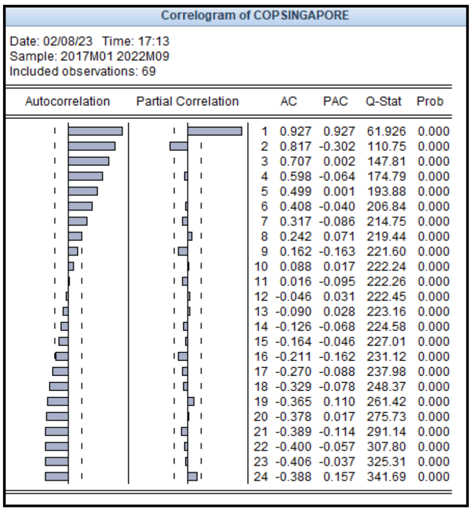


Correlogram of COPMALAYSIA

Date: 02/08/23 Time: 16:36
Sample: 2017M01 2022M09
Included observations: 69

Lag	AC	PAC	Q-Stat	Prob
1	0.929	0.929	62.240	0.000
2	0.822	-0.305	111.69	0.000
3	0.712	-0.016	149.32	0.000
4	0.601	-0.078	176.51	0.000
5	0.501	0.031	195.75	0.000
6	0.414	-0.021	209.05	0.000
7	0.326	-0.091	217.45	0.000
8	0.255	0.072	222.67	0.000
9	0.181	-0.152	225.34	0.000
10	0.113	0.034	226.39	0.000
11	0.044	-0.120	226.56	0.000
12	-0.017	0.032	226.58	0.000
13	-0.062	0.034	226.92	0.000
14	-0.100	-0.080	227.80	0.000
15	-0.141	-0.060	229.62	0.000
16	-0.191	-0.156	233.01	0.000
17	-0.249	-0.043	238.84	0.000
18	-0.305	-0.076	247.76	0.000
19	-0.340	0.103	259.09	0.000
20	-0.355	0.014	271.69	0.000
21	-0.366	-0.109	285.34	0.000
22	-0.376	-0.051	300.10	0.000
23	-0.381	-0.029	315.53	0.000
24	-0.364	0.157	329.97	0.000

Figure 4.8: COP of Singapore

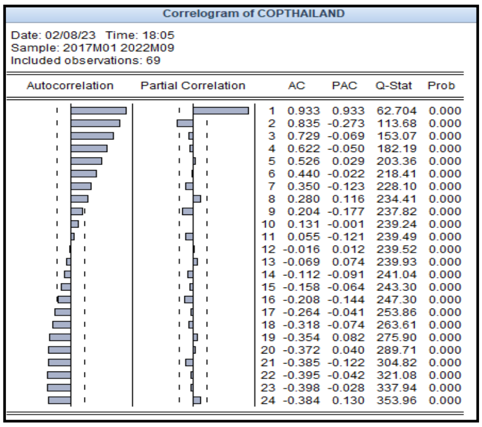


Correlogram of COPSINGAPORE

Date: 02/08/23 Time: 17:13
Sample: 2017M01 2022M09
Included observations: 69

Lag	AC	PAC	Q-Stat	Prob
1	0.927	0.927	61.926	0.000
2	0.817	-0.302	110.75	0.000
3	0.707	0.002	147.81	0.000
4	0.598	-0.064	174.79	0.000
5	0.499	0.001	193.88	0.000
6	0.408	-0.040	206.84	0.000
7	0.317	-0.086	214.75	0.000
8	0.242	0.071	219.44	0.000
9	0.162	-0.163	221.60	0.000
10	0.088	0.017	222.24	0.000
11	0.016	-0.095	222.26	0.000
12	-0.046	0.031	222.45	0.000
13	-0.090	0.028	223.16	0.000
14	-0.126	-0.068	224.58	0.000
15	-0.164	-0.046	227.01	0.000
16	-0.211	-0.162	231.12	0.000
17	-0.270	-0.088	237.98	0.000
18	-0.329	-0.078	248.37	0.000
19	-0.365	0.110	261.42	0.000
20	-0.378	0.017	275.73	0.000
21	-0.389	-0.114	291.14	0.000
22	-0.400	-0.057	307.80	0.000
23	-0.406	-0.037	325.31	0.000
24	-0.388	0.157	341.69	0.000

Figure 4.9: COP of Thailand



Correlogram of COPTHAILAND

Date: 02/08/23 Time: 18:05
Sample: 2017M01 2022M09
Included observations: 69

Lag	AC	PAC	Q-Stat	Prob
1	0.933	0.933	62.704	0.000
2	0.835	-0.273	113.68	0.000
3	0.729	-0.069	153.07	0.000
4	0.622	-0.050	182.19	0.000
5	0.526	0.029	203.36	0.000
6	0.440	-0.022	218.41	0.000
7	0.350	-0.123	228.10	0.000
8	0.280	0.116	234.41	0.000
9	0.204	-0.177	237.82	0.000
10	0.131	-0.001	239.24	0.000
11	0.055	-0.121	239.49	0.000
12	-0.016	0.012	239.52	0.000
13	-0.069	0.074	239.93	0.000
14	-0.112	-0.091	241.04	0.000
15	-0.158	-0.064	243.30	0.000
16	-0.208	-0.144	247.30	0.000
17	-0.264	-0.041	253.86	0.000
18	-0.318	-0.074	263.61	0.000
19	-0.354	0.082	275.90	0.000
20	-0.372	0.040	289.71	0.000
21	-0.385	-0.122	304.82	0.000
22	-0.395	-0.042	321.08	0.000
23	-0.398	-0.028	337.94	0.000
24	-0.384	0.130	353.96	0.000

Source: EViews Output

4.2.3 ARIMA Model Research Estimation Method

4.2.3.1 ARIMA Model Estimation for Crude Oil Price of Brunei

Equation 4.2 shows the estimation output of Brunei's crude oil price model (COPBRUNEI). In the equation of ARIMA model of COPBRUNEI, the parameters of AR and MA explain about 60.47 percent of the variation in the Brunei's crude oil price model. The coefficient value of the term $\phi_1 \Delta COPBrunei_{t-1}$ (ϕ_1 represents the AR parameter of order 1) is 0.6073 and the coefficient value of the term of $\theta_1 1\ \varepsilon_{\downarrow}(t-1)$ ($\theta_1 1$ represents the MA parameter of order 1) is 0.4157. ε_t denotes the data series' error term at period t with a coefficient value of 0.6963. Since the value of AR and MA parameter is near to 1, hence the model is valid.

$$\Delta COPBrunei_t = 0.9195 + 0.6073\Delta COPBrunei_{t-1} + 0.4157\varepsilon_{t-1} + 0.6963\varepsilon_t$$

t = [8.9612***] [6.1321***] ……..(4.2)

$R^2 = 0.6047$ Adjusted $R^2 = 0.5921$

Harvey Heteroscedasticity Test:

F-statistic: 2.2742 Prob. F(5,60): 0.1113

Note:

* represents significant at α = 0.10 significance level.

** represents significant at α = 0.05 significance level.

*** represents significant at α = 0.01 significance level.

4.2.3.2 ARIMA Model Estimation for Crude Oil Price of Indonesia

Equation 4.3 shows the estimation output of Indonesia's crude oil price model (COPINDONESIA). In the equation of ARIMA model of COPINDONESIA, the parameters of AR and MA explain about 60.36 percent of the variation in the Indonesia's crude oil price model. The coefficient value of the term $\phi_2 \Delta COPIndonesia_{t-1}$ (ϕ_2 represents the AR parameter of order 1) is 0.5857 and the coefficient value of the term of $\theta_{\downarrow}2\ \varepsilon_{\downarrow}(t-1)$ ($\theta_{\downarrow}2$ represents the MA parameter of order 1) is 0.4080. ε_t denotes the data series' error term at period t with a coefficient value of 3376.4370. Since the value of AR and MA parameter is near to 1, hence the model is valid.

$$\Delta COPIndonesia_t = 1514.1500 + 0.5857\Delta COPIndonesia_{t-1} + 0.4080\varepsilon_{t-1}$$

t = [8.7915***] [6.1756***]

$$+3376.4370\varepsilon_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(4.3)$$

$R^2 = 0.6036$ Adjusted $R^2 = 0.5911$

Harvey Heteroscedasticity Test:

F-statistic: 0.0150 Prob. F(2,63): 0.9852

4.2.3.3 ARIMA Model Estimation for Crude Oil Price of Malaysia

Equations 4.4 shows the estimation output of Malaysia's crude oil price model (COPMALAYSIA). In the equation of ARIMA model of COPMALAYSIA, the parameters of AR and MA explain about 59.46 percent of the variation in the Malaysia's crude oil price model. The coefficient value of the term $\phi_3\Delta COPMalaysia_{t-1}$ (ϕ_3 represents the AR parameter of order 1) is 0.6082 and the coefficient value of the term of $\theta_{\downarrow}3\ \varepsilon_{\downarrow}(t-1)$ ($\theta_{\downarrow}3$ represents the MA parameter of order 1) is 0.4148. ε_t denote the data series' error term at period t with a coefficient value of 2.1381. Since the value of AR and MA parameter is near to 1, hence the model is valid.

$$\Delta COPMalaysia_t = 3.0185 + 0.6082\Delta COPMalaysia_{t-1} + 0.4148\varepsilon_{t-1}$$

t = [8.7755***] [5.9933***]

$$+2.1381\varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots....(4.4)$$

$R^2 = 0.5946$ Adjusted $R^2 = 0.5817$

Harvey Heteroscedasticity Test:

F-statistic: 1.4555 Prob. F(2,63): 0.2410

4.2.3.4 ARIMA Model Estimation for Crude Oil Price of Singapore

Equation 4.5 shows the estimation output of Singapore's crude oil price model (COPSINGAPORE). In the equation of ARIMA model of COPSINGAPORE, the parameters of AR and MA explain about 60.50 percent of the variation in the Singapore's crude oil price model. The coefficient value of the term $\phi_4 \Delta COPSingapore_{t-1}$ (ϕ_4 represents the AR parameter of order 1) is 0.6071 and the coefficient value of the term of $\theta_{\downarrow}4\ \varepsilon_{\downarrow}(t-1)$ ($\theta_{\downarrow}4$ represents the MA parameter of order 1) is 0.4157. ε_t denotes the data series' error term at period t with a coefficient value of 0.6959. Since the value of AR and MA parameter is near to 1, hence the model is valid.

$$\Delta COPSingapore_t = 0.9192 + 0.6071 \Delta COPSingapore_{t-1} + 0.4157 \varepsilon_{t-1}$$

t = [8.9646***] [6.1384***]

$$+ 0.6959 \varepsilon_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.5)$$

$R^2 = 0.6050$ Adjusted $R^2 = 0.5925$

Harvey Heteroscedasticity Test:

F-statistic: 2.1190 Prob. F(2,63): 0.1286

4.2.3.5 ARIMA Model Estimation for Crude Oil Price of Thailand

Equation 4.6 shows the estimation output of Thailand's crude oil price model (COPTHAILAND). In the equation of ARIMA model of COPTHAILAND, the parameters of AR and MA explain about 59.74 percent of the variation in the Thailand's crude oil price model. The coefficient value of the term $\phi_5 \Delta COPThailand_{t-1}$ (ϕ_5 represents the AR parameter of order 1) is 0.6160 and the coefficient value of the term of $\theta_{\downarrow}5\ \varepsilon_{\downarrow}(t-1)$ ($\theta_{\downarrow}5$ represents the MA parameter of order 1) is 0.4130. ε_t denotes the data series' error term at period t with a coefficient value of 16.5898. Since the value of AR and MA parameter is near to 1, hence the model is valid.

$$\Delta COPThailand_t = 25.4458 + 0.6160\Delta COPThailand_{t-1} + 0.4130\varepsilon_{t-1}$$

t = [8.9542***] [5.9839***]

$$+16.5898\varepsilon_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4.6)$$

$R^2 = 0.5974$ Adjusted $R^2 = 0.5846$

Harvey Heteroscedasticity Test:

F-statistic: 0.6677 Prob. F(2,63): 0.5165

4.2.4 ARIMA Model Residual Diagnosis

4.2.4.1 Heteroscedasticity

The hypotheses of the heteroscedasticity test are:

H_0: Residuals are not heteroscedasticity.

H_A: Residuals are heteroscedasticity.

Table 4.11 illustrates the outputs of Harvey heteroscedasticity test for ARIMA model of ASEAN-5 countries. The results show all the p-values for all the ASEAN-5 countries in Harvey heteroscedasticity test are more than > α 0.05. Therefore, do not reject the null hypotheses, and the residuals are not heteroscedasticity.

Table 4.11: Harvey Heteroscedasticity Test for ARIMA Model of ASEAN-5 Countries

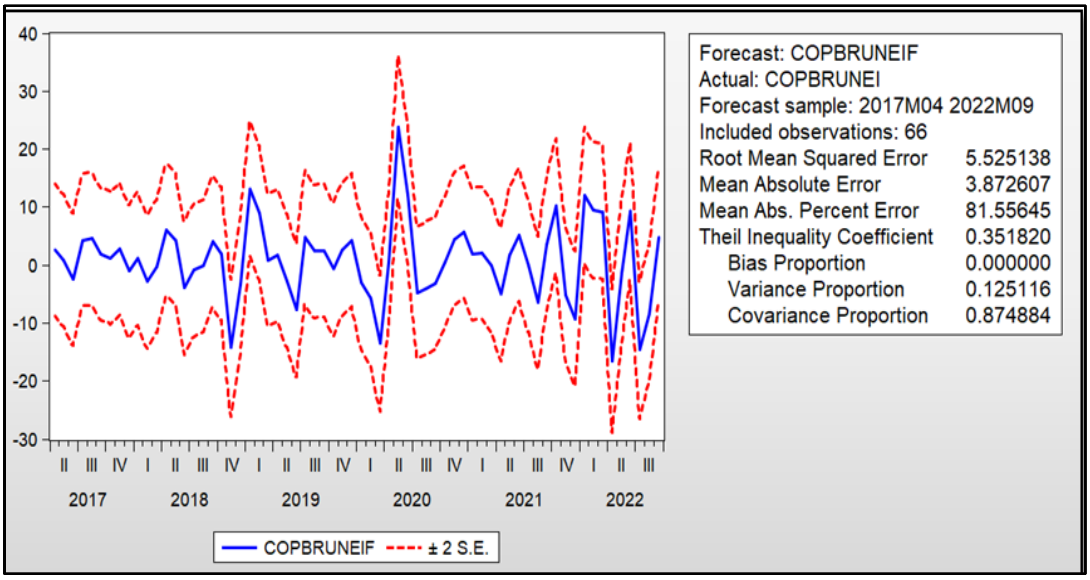
Diagnostic Tests	Results	Hypotheses	Decision
Heteroscedasticity	Brunei: p-value = 0.1113 Indonesia: p-value = 0.9852 Malaysia: p-value = 0.4555 Singapore: p-value = 0.1286 Thailand: p-value = 0.5165	H_0: Residuals are not heteroscedasticity. H_A: Residuals are heteroscedasticity.	**ALL** p-values >α 0.05 **Do not reject H_0,** residuals are not heteroscedasticity.

Source: EViews Output

4.2.5 ARIMA Model Evaluation

Figure 4.10 shows the model evaluation output of ARIMA COP model for Brunei. The RMSE value is 5.5251 and MAE value is 3.8726. For MAPE, the value obtained is 81.5565. Other than that, the U-Theil value shows a 0.3518, which is being close to 0, thus the estimated model's forecasting performance is satisfactory.

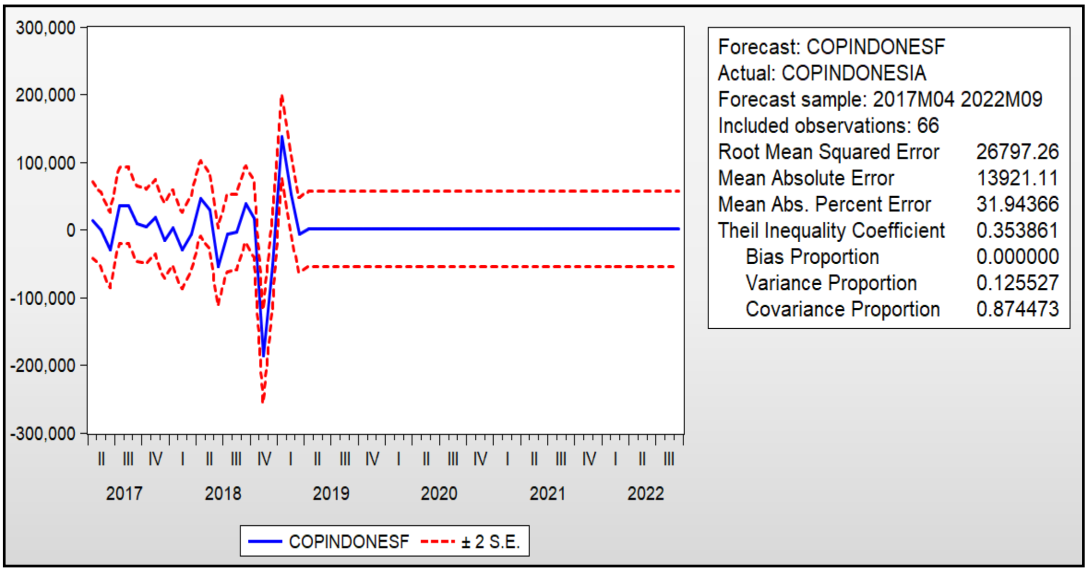
Figure 4.10: Model Evaluation Output of ARIMA COP Model for Brunei



Source: EViews Output

Figure 4.11 shows the model evaluation output of ARIMA COP model for Indonesia. The RMSE value is 26797.2600 and MAE value is 13921.1100. For MAPE, the value obtained is 31.9437. Other than that, the U-Theil value shows a 0.3539, which is being close to 0, therefore suggesting that the estimated model's forecasting performance is satisfactory.

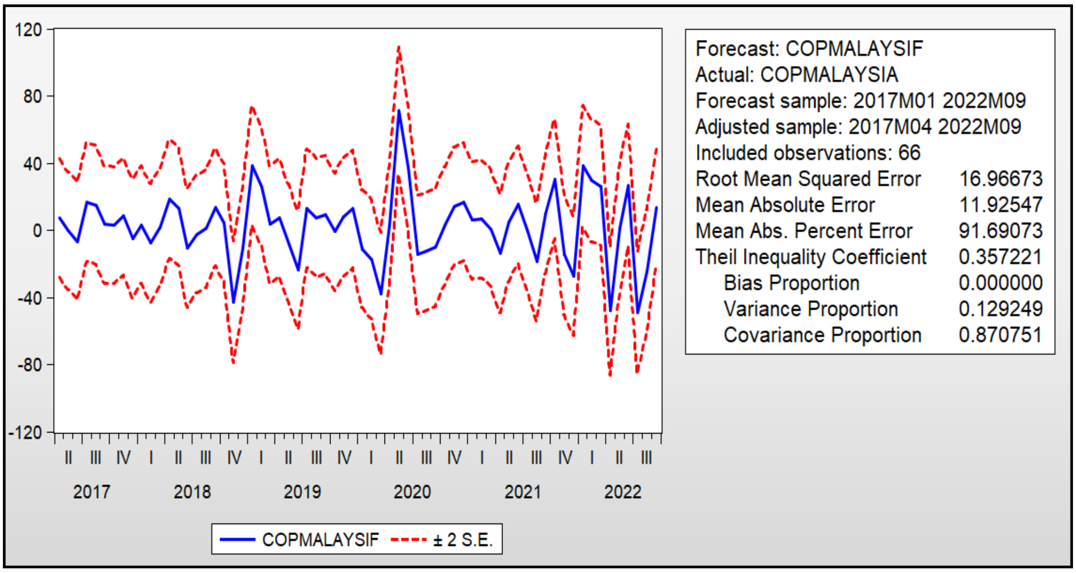
Figure 4.11: Model Evaluation Output of ARIMA COP Model for Indonesia



Source: EViews Output

Figure 4.12 shows the model evaluation output of ARIMA COP model for Malaysia. The RMSE value is 16.9667 and MAE value is 11.9255. For MAPE, the value obtained is 91.6907. Other than that, the U-Theil value shows a 0.3572, which is being close to 0, thus suggesting that the estimated model's forecasting performance is satisfactory.

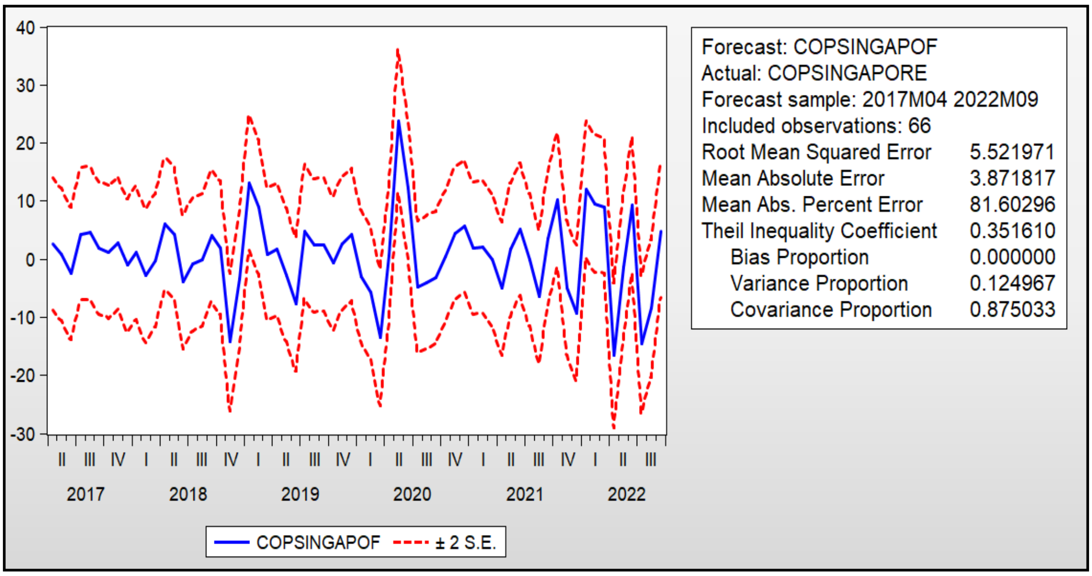
Figure 4.12: Model Evaluation Output of ARIMA COP Model for Malaysia



Source: EViews Output

Figure 4.13 shows the model evaluation output of ARIMA COP model for Singapore. The RMSE value is 5.5220 and MAE value is 3.8718. For MAPE, the value obtained is 81.6030. Other than that, the U-Theil value shows a 0.3516, which is being close to 0, therefore the estimated model's forecasting performance is satisfactory.

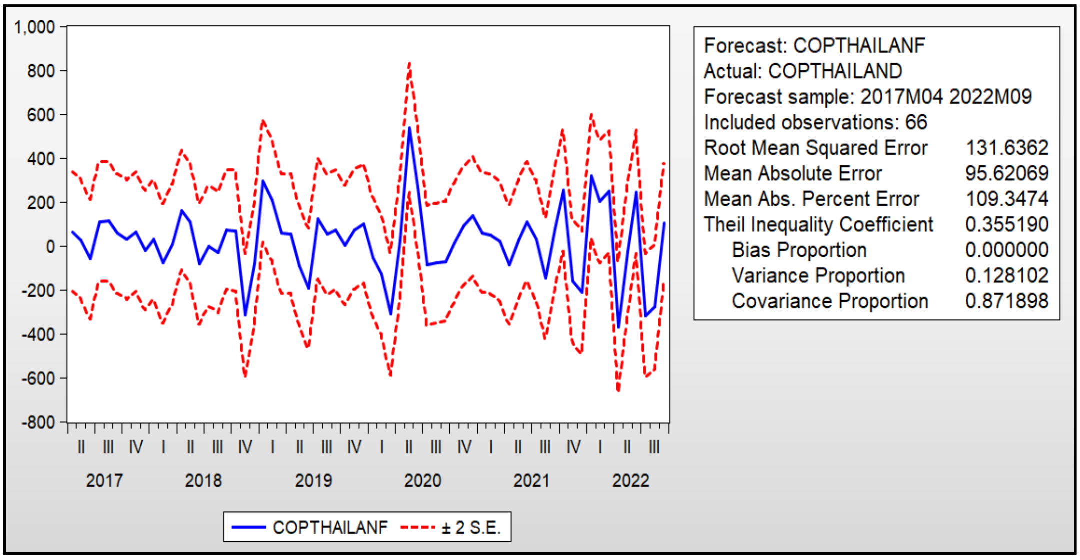
Figure 4.13: Model Evaluation Output of ARIMA COP Model for Singapore



Source:Eviews Output

Figure 4.14 shows the model evaluation output of ARIMA COP model for Thailand. The RMSE value is 131.6362 and MAE value is 95.6207. For MAPE, the value obtained is 109.3474. Other than that, the U-Theil value shows a 0.3552, this is being close to 0. Thus, the estimated model's forecasting performance is satisfactory.

Figure 4.14: Model Evaluation Output of ARIMA COP Model for Thailand



Source:Eviews Output

4.3 Discussions of Major Findings

4.3.1 Panel Model Analysis

4.3.1.1 Panel Model Analysis Hypothesis Testing

Table 4.12 below will provide the summary of the hypotheses testing results of the panel model in this research study.

Table 4.12: Hypotheses Testing for Panel Crude Oil Price Model of ASEAN-5 Countries

	Hypotheses	Decision	Supported/Rejected
H_{A1}:	There are significant relationships among exchange rate, inflation rate, interest rate, GDP per capita, production of crude oil, and crude oil price of ASEAN-5 countries.		

H_{A11}:	There is a significant relationship between exchange rate and crude oil price.	Sig-p-value < α 0.01	**Supported** by Adam et al. (2018)
H_{A12}:	There is a significant relationship between inflation rate and crude oil price.	Sig-p-value < α 0.01	**Supported** by Castillo et al. (2020)
H_{A13}:	There is a significant relationship between interest rate and crude oil price.	Sig-p-value > α 0.10	**Rejected** by Shangle & Solaymani (2020)
H_{A14}:	There is a significant relationship between GDP per capita and crude oil price.	Sig-p-value < α 0.05	**Supported** by Sha (2022)
H_{A15}:	There is a significant relationship between production of crude oil and crude oil price.	Sig-p-value < α 0.01	**Supported** by Chatziantoniou et al. (2021)

H_{A11}: There is a significant relationship between exchange rate and crude oil price. H_{A11} is supported. Based on the study of Adam et al. (2018) who investigated on the relationship between the exchange rate between the Indonesian rupiah (IDR) and the euro (EUR) and crude oil price by employing VAR model and Granger Causality and utilized dataset from January 2000 to September 2017. From the findings of Adam et al. (2018), there is a positive relationship exists between exchange rate and crude oil price.

H_{A12}: There is a significant relationship between inflation rate and crude oil price. Then, H_{A12} is supported. Regarding to the research of Castillo et al. (2020), the study used VAR model and utilised monthly data from 1973 to 2019. The results of Castillo et al. (2020) shows that there is a positive relationship between inflation rate and crude oil price.

H_{A13}: There is a significant relationship between interest rate and crude oil price. Next, H_{A13} is rejected. According to Shangle and Solaymani (2020), the study examined the link between interest rate in monetary policy and crude oil price in Malaysia by using CGE model from 2014 to 2018. The study of Shangle and

Solaymani (2020) indicates that no relationship founded between interest rate and crude oil price.

H_{A14}: There is a significant relationship between GDP per capita and crude oil price. Furthermore, H_{A14} is supported. This H_{A14} is supported by Sha (2022) where the study examined the relationships among global economic performance, crude oil prices, and total natural resources by adopting adopted time series approaches to analyze the data from period 1960 to 2020 and Granger Causality test. The result of the study shows that there is positive relationship exists between GDP per capita and crude oil price.

H_{A15}: There is a significant relationship between production of crude oil and crude oil price.
Lastly, H_{A15} is supported. Regarding to the study of Chatziantoniou et al. (2021), the study the influence of crude oil production on crude oil price by using TVP-VAR model 1990 to 2015. The results of Chatziantoniou et al. (2021) found out that crude oil production negatively influence crude oil price instability.

4.3.1.1 Panel Model Analysis Discussion

Based on the empirical results on crude oil price panel model for ASEAN-5 countries, there is significant positive relationships among exchange rate, inflation rate, GDP per capita with crude oil price, significant negative relationship between production of crude oil with crude oil price and there is no significant relationship between interest rate and crude oil price.

Firstly, H_{A11} is supported and there is a significant positive relationship between exchange rate and crude oil price in ASEAN-5 countries. This positive relationship can be explained by several reasons. Since crude oil is traded in dollars, this is one of the key reasons; this implies that a fluctuation in the exchange rate of the dollar in relation to other currencies might have an effect on the price of oil. For instance, if the value of the US dollar rises relative to that of other currencies, it will be more costly for other nations to acquire crude oil because they would have to convert a greater quantity of their own currency into US dollars to maintain the same purchasing power. As a result, the price of crude oil will rise to compensate for the amount of local currency that must be converted into US dollars in order to purchase crude oil. On the other hand, if the value of the US dollar falls relative to other currencies, it will cost other nations less money to buy crude oil, which would result in a decrease in the price of crude oil.

According to Adam et al. (2018), changing in currency exchange rates may also have an effect on the costs of producing and transporting crude oil, which is another reason why currency exchange rates can have a positive effect on the price of crude oil. In this context, if a nation's currency rises, it may lead to an increase in the cost of production and transportation, which can lead to an increase in the price of crude oil. Hence, this positive relationship between exchange rate and crude oil price is supported by Adam et al. (2018) as the result of their study also shows the there is a positive relationship between exchange rate and crude oil price.

Secondly, there is significant positive relationship between inflation rate and crude oil price in ASEAN-5 countries and H_{A12} is supported. The positive relationship that found out in this research study is in line with the study's result of Castillo et al. (2020). This is due to the fact that governments and central banks commonly react to inflation by enacting measures that might boost economic development, such as raising government expenditure or lowering interest rates. These measures might result in a rise in industrial activities such as manufacturing, transportation, and building, all of which demand significant quantities of energy. Furthermore, crude oil is an important component of a wide variety of goods and businesses, such as the manufacture of plastics and fertilizers, as well as fuels for vehicles.

As a result of inflation, the cost of the inputs used in production goes up, which in turn drives up the overall cost of manufacturing and shipping these goods. For instance, the cost of producing crude oil will go up as a result of inflation-driven increases in the cost of inputs such as labour and materials, which would ultimately lead to an increase in price. This might result in higher costs for the final goods, which in turn could lead to a rise in demand for crude oil as firms and consumers strive to maintain their current levels of production and consumption. As a result, there will be a rise in the price of crude oil whenever there is a greater demand for it. Therefore, there is positive relationship between inflation and crude oil price.

Thirdly, H_{A13} is rejected and there is no significant relationship between interest rate and crude oil price. The result is in line with the study of Shangle and Solaymani (2020). The influence of interest rates on crude oil prices in the ASEAN area may be mitigated by consumers' expectation of higher expenses overall. If the rate of inflation is greater than the interest rate, the interest rate will be negative; this could motivate investors to invest in commodities that can protect them against inflation, such as commodities like crude oil. If the inflation rate is higher than the interest rate, the interest rate will be negative. If investors are more worried about inflation than they are about interest rates, then it is possible that interest rates will not have a substantial influence on the price of crude oil. There is a possibility that demand for crude oil is rather inelastic. This indicates that fluctuations in price could not have a substantial impact on the amount of crude oil that is required. According to Shangle & Solaymani (2020), this is because crude oil is a vital input in many industries and transportation, and there may not be suitable alternatives available to replace it. Therefore, even if interest rates increase, the demand for crude oil may remain high, and the price may not change significantly.

Fourthly, H_{A14} is supported and there is significant positive relationship between GDP per capita and crude oil price and this is consistent with the results of Sha (2022). According to the study of Sha (2022), an rise in a country's GDP per capita indicates that there was also an increase in the investments and activity of the manufacturing sectors in that country. When there is a greater level of investment and industrial development, there is a corresponding increase in the need for significant quantities of energy to power manufacturing, transportation, and the construction of infrastructure. As a result of the fact that crude oil is the principal source of energy for these activities, a rise in GDP per capita might lead to a demand of crude oil increase. The price of crude oil will go up in response to an increase in the amount of demand for it. As a result of this, it can be concluded that there is a positive relationship between the GDP per capita and the price of crude oil.

Lastly, H_{A15} is supported and there is significant negative relationship between production of crude oil and crude oil price. This is supported by the study of Chatziantoniou et al. (2021) that also indicates negative relationship between crude oil production and crude oil price. According to Chatziantoniou et al. (2021), when production of crude oil exceeds demand, the oil market can become oversupplied, and this can lead to a decrease in crude oil prices. This is due to the fact that an excessive supply results in an excess of inventory, which might result in a decrease in the price of crude oil. This may result in an increase in supplies as well as storage space, both of which may exert downward pressure on the price of crude oil. It is possible that manufacturers may need to decrease their pricing in order to stay competitive as they work to sell off their surplus inventory. As a result, this provided a rationale for the large negative relationship that exists between the production of crude oil and the price of crude oil.

4.3.2 ARIMA Model Analysis

4.3.2.1 ARIMA Model Analysis Hypothesis Testing

Table 4.13 below will provide the summary of the hypotheses testing results of the ARIMA model in this research study.

Table 4.13: Hypotheses Testing for ARIMA Crude Oil Price Model of Each ASEAN-5 Countries

	Hypotheses	Decision	Supported/Rejected
Brunei			
H_{A2}:	There is a relationship between AR parameter (lagged value of COP of Brunei) and COP of Brunei.	Sig-p-value < α 0.01	**Supported** by Selvi et al. (2018)
H_{A3}:	There is a relationship between MA parameter (lagged value of error term of Brunei) and COP of Brunei.	Sig-p-value < α 0.01	**Supported** by Mensah (2015)

Indonesia			
H_{A4}:	There is a relationship between AR parameter (lagged value of COP of Indonesia) and COP of Indonesia.	Sig-p-value < α 0.01	**Supported** by Sukono, Suryamah, and Novinta S (2020)
H_{A5}:	There is a relationship between MA parameter (lagged value of error term of Indonesia) and COP of Indonesia.	Sig-p-value < α 0.01	**Supported** by Gunarto, Azhar, Tresiana, Supriyanto, and Ahadiat (2020)
Malaysia			
H_{A6}:	There is a relationship between AR parameter (lagged value of COP of Malaysia) and COP of Malaysia.	Sig-p-value < α 0.01	**Supported** by Shah and Kiruthiga (2020)
H_{A7}:	There is a relationship between MA parameter (lagged value of error term of Malaysia) and COP of Malaysia.	Sig-p-value < α 0.01	**Supported** by Nyangarika and Tang, (2018)
Singapore			
H_{A8}:	There is a relationship between AR parameter (lagged value of COP of Singapore) and COP of Singapore.	Sig-p-value < α 0.01	**Supported** by Merabet, Zeghdoudi, Yahia, and Saba, (2021)
H_{A9}:	There is a relationship between MA parameter (lagged value of error term of Singapore) and COP of Singapore.	Sig-p-value < α 0.01	**Supported** by Ariyanti and Yusnitasar (2023)
Thailand			
H_{A10}:	There is a relationship between AR parameter (lagged value of COP of Thailand) and COP of Thailand.	Sig-p-value < α 0.01	**Supported** by Alrweili and Fawzy (2022)
H_{A11}:	There is a relationship between MA parameter (lagged value of error term of Thailand) and COP of Thailand.	Sig-p-value < α 0.01	**Supported** by Aamir and Shabri (2016)

H_{A2}: There is a relationship between AR parameter (lagged value of COP of Brunei) and COP of Brunei.

Firstly, H_{A2} is supported. Regarding to the research of Selvi et al. (2018) which adopting ARIMA model to forecast crude oil price. The model specification of the study employed by Selvi et al. (2018) is ARIMA (2,1,1) model. Therefore, H_{A2} is supported.

H_{A3}: There is a relationship between MA parameter (lagged value of error term of Brunei) and COP of Brunei.

Next, H_{A3} is supported by Mensah (2015) who conducted ARIMA model to forecast Brent crude oil price. According to the study of Mensah (2015), the model specification of the study employed ARIMA (1,1,1) model. Thus, H_{A3} is supported.

H_{A4}: There is a relationship between AR parameter (lagged value of COP of Indonesia) and COP of Indonesia.

Moreover, H_{A4} is supported. This is supported by Sukono et al. (2020) whose studied on "Application of ARIMA-GARCH Model for Prediction of Indonesian Crude Oil Prices" from January 2005 to November 2012. The study employed ARIMA (1,2,1) model in forecasting Indonesian crude oil price. Therefore, H_{A4} is supported.

H_{A5}: There is a relationship between MA parameter (lagged value of error term of Indonesia) and COP of Indonesia.

Meanwhile, H_{A5} is supported. Based on the study of Gunarto et al. (2020), the authors adopted ARIMA (1,2,1) model specification to estimate global crude oil price from 2009 to 2018. Therefore, H_{A5} is supported.

H_{A6}: There is a relationship between AR parameter (lagged value of COP of Malaysia) and COP of Malaysia.

Furthermore, H_{A6} is supported by Shah and Kiruthiga (2020). The authors investigated at the crude oil price's time series and employed an ARIMA model to forecast future prices by using data from July 1987 to March 2020.As a result, specification for this study is ARIMA (0,1,4). Therefore, H_{A6} is supported.

H_{A7}: There is a relationship between MA parameter (lagged value of error term of Malaysia) and COP of Malaysia.

Additionally, H_{A7} is supported. Regarding to Nyangarika and Tang (2018), their study used data from January 1991 to December 2016 to forecast Brent crude oil price by employing ARIMA (1,1,1) specification. Thus, H_{A7} is supported.

H_{A8}: There is a relationship between AR parameter (lagged value of COP of Singapore) and COP of Singapore.

H_{A8} is supported by Merabet et al. (2021) whose studied on crude oil price volatility by using ARIMA-GARCH model. The study used daily crude oil price from 1 January 2019 to 31 December 2019 by employing ARIMA (3,1,1) model specification. Therefore, H_{A8} is supported.

H_{A9}: There is a relationship between MA parameter (lagged value of error term of Singapore) and COP of Singapore.

Additionally, H_{A9} is supported by Ariyanti and Yusnitasar (2023). Regarding to their study, the authors studied on forecasting crude oil price by adopting ARIMA and Seasonal Effect of Autoregressive Integrated Moving Average (SARIMA). The study utilized data from January 2020 to January 2023 by employing ARIMA (0,1,0) model specification. Thus, H_{A9} is supported.

H_{A10}: There is a relationship between AR parameter (lagged value of COP of Thailand) and COP of Thailand.

Meanwhile, H_{A10} is supported. This hypotheses is supported by Alrweili and Fawzy, (2022) whose employed ARIMA model and the Artificial Neural Networks (ANN) hybrid model to forecast crude oil price. The authors used monthly data from July 2001 to May 2021 and employed ARIMA (1,1,0) specification in their model. Therefore, H_{A10} is supported.

H_{A11}: There is a relationship between MA parameter (lagged value of error term of Thailand) and COP of Thailand.

Lastly, H_{A11} is supported. Regarding to the study of Aamir and Shabri (2016), the authors developed ARIMA model to forecast crude oil price in Pakistan. H_{A11} is supported by Aamir and Shabri (2016) as the model specification of their study is ARIMA (3,1,1).

4.4 Conclusion

In Chapter 4, we accomplished the data testing and analysis to make sure the model is reliable and gives the appropriate and correct results. Based on the panel model empirical results, there is significant positive relationship among exchange rate, inflation rate, GDP per capita with crude oil price; and there is significant negative relationship between production of crude oil and crude oil price. Regarding on the results of five (5) ARIMA models, all the crude oil price models for ASEAN-5 countries is significant and valid. The following Chapter 5 will present further discussion, including a summary of statistical analysis, findings, implications, limits, recommendations, and conclusions.

CHAPTER 5: DISCUSSION, CONCLUSION AND IMPLICATIONS

5.0 Introduction

The previous chapter revealed the estimation outputs and findings of a research study on the "Forecasting Model on Crude Oil Price Instability in ASEAN-5 Countries". Chapter 5 will begin with an introduction of this chapter. It will then summarize the statistical analyses from Chapter 4. The implications of the research will be presented, including how it can be applied in theory and practice to policymakers, society, businesses, and individuals. The chapter will also point out the research study's limitations, provide recommendations for further investigation, and conclude with a summary of the entire research study.

5.1 Summary of Statistical Analysis

First and foremost, this research study examined the factors that influence the instability of crude oil price and forecast the crude oil price in ASEAN-5 countries (Brunei, Indonesia, Malaysia, Singapore, and Thailand) by employing panel model analysis and ARIMA model analysis. The independent variables selected to study the relationships with crude oil price are: (1) exchange rate, (2) inflation rate, (3) interest rate, (4) GDP per capita, and (5) production of crude oil. The output results generated by EViews show that the unit root tests for both panel and ARIMA model have been successfully passed when first difference is applied.

For panel model analysis, period fixed effect model is selected as the best model for ASEAN-5 after performing Redundant Fixed Effects Test, Lagrange Multiplier Test, and Hausman Test. Based on the estimation outputs from EViews, GDP per capita is statistically significant at 0.05 level, while exchange rate, inflation rate, and production of crude oil are statistically significant at significant at 0.01 level. Also, the model is normally distributed and there is no multicollinearity and heteroscedasticity problem occurred. From the panel model evaluation, period fixed effect is again showing the best model compared to period random effect model as the RMSE, MAE, MAPE and U-Theil statistics for period fixed effect model is the lowest. Regarding to the ex-post forecast, it shows that the actual crude oil price followed the forecasted crude oil price.

For ARIMA model analysis, the correlograms of all ASEAN-5 countries show that the partial correlation function (PACF) indicates its peak value at lag 1, whereas the autocorrelation function (ACF) shows its peak value at lag 1 as well. Therefore, the model specification for five (5) ARIMA crude oil price model for ASEAN-5 countries is ARIMA (1,1,1). Based on the Harvey heteroscedasticity test, there is no heteroscedasticity for all ARIMA models. Hence, the ARIMA models for each ASEAN-5 country are valid.

5.2 Implications of Study

This research study investigates the relationships among exchange rate, inflation rate, interest rate, GDP per capita, production of crude oil and crude oil price by using panel model analysis. It also analyses the forecast time series of crude oil price instability using ARIMA model analysis. The study proposes several implications and provides a more comprehensive understanding for policymakers, practitioners and investors regarding the factors that contribute to crude oil price instability in commodity economics. The study's outcomes can be divided into two categories in theoretically and empirically.

5.2.1 Theoretical Contribution

Firstly, this research study has substantiated the significance of production of crude oil variable in line with the theory of supply of commodities price (Whelan et al., 2001). The results of this research showed that production of crude oil is highly significant and important in affecting crude oil price in ASEAN-5 countries.

According to theory of supply of commodities price, the supply of commodity has a negative relationship with commodity price. This means that when the supply of crude oil increase or crude oil surplus, this will cause the crude oil price to reduce. Vice versa, if the crude oil production decrease, the price of crude oil will increase. Hence, this suggests that crude oil producers should be cautious in producing the quantity of crude oil avoid oversupply problem in crude oil market. The crude oil producers will be highly affected in their revenue by unstable crude oil price when the production of crude oil is facing surplus or shortage. Next, the outcomes of this research study also indicated that exchange rate is highly significant to crude oil price. This significant finding can be explained by the theory of one price changes and the effect of exchange rate on crude oil price in ASEAN-5 countries (Blomberg & Harris, 1995).

The crude oil price such as WTI, Brent, and Dubai/Oman is basically traded in one currency which is US dollar. When the local currency in ASEAN-5 countries appreciate or depreciate against US dollar, and the crude oil price will be affected simultaneously. Therefore, the difference between two currencies will induce a change in crude oil price based on theory of one price. Hence, the importers of crude oil should pay attention to this relationship between exchange rate and crude oil price. The fluctuations in exchange rate will incur more costs for the importers and causing to the crude oil price becomes high.

5.2.2 Practical Contribution

This research study proved that macroeconomic variables such as exchange rate, inflation rate, GDP per capita, and production of crude oil significantly affect crude oil price instability. For exchange rate, this research study found a positive relationship with crude oil price which is in line with the results of Sun et al. (2022). Furthermore, the production of crude oil has also been found to be a significant factor in determining crude oil prices, which indicates similar results to the study of Lu et al. (2021). This implies that the practitioners and oil traders, such as crude oil producers, exporters, and importers, should pay attention to the fluctuations in the exchange rate when trading in the oil market. If the changes in exchange rates against the US dollar are relatively volatile, crude oil prices may follow these fluctuations and become unstable. As a result, crude oil price instability will create more costs for oil traders, as they need to pay more to obtain US dollars. A weaker currency can improve oil export profits for oil exporters while raising import prices for oil importers. Similarly, an oversupply in crude oil production will decrease crude oil prices and negatively impact practitioners such as crude oil producers or exporters' revenue, but it will benefit importers.

Additionally, the significance of the inflation rate and GDP per capita in this research study are in line with the study of Maheu et al. (2020) and Olofin and Salisu (2017). The results highlight the necessity for policymakers to properly and efficiently formulate policies to control inflation and boost economic growth. Policymakers can adjust money supply to control inflation. For instance, tighter monetary policy may result in a stronger currency, which would lower the price of importing crude oil and lower crude oil prices. Moreover, this study brings implications to policymakers to brainstorm how to maintain crude oil price stability and boost economic growth simultaneously. It is difficult to trade-off between high economic growth and low crude oil price. For instance, policymakers can increase spending to subsidize petrol prices to keep the country's crude oil prices stable.

Lastly, the ex-post forecast will provide investors useful information about the oil market and assist them in making wise investment choices. Crude oil price forecasts can assist investors in timing their purchases on the oil market. For example, investors may refer to the forecast and choose to buy the crude oil related stocks or to maximise their potential profit in the future. Nevertheless, unanticipated events like pandemics and war can affect oil prices, making it important for investors to keep in mind that multiple types of information should be considered when making investment decisions.

5.3 Limitations of Study

Throughout this research study, there are some limitations that constraint the researchers to obtain more accurate outcomes.

Firstly, the limitation of data availability limited this research study to getting equal data for variables and countries, such as the crude oil price in Indonesia. Therefore, the researcher had to refer to the data from previous years to proceed with the research. Other than that, the time constraints also restricted this research study to further exploring other ASEAN countries due to the given time to complete this research study being only two (2) semesters. Another reason is that this research study combined the panel and ARIMA models and was a time-consuming process. Lastly, there are limited previous studies on this combined panel-ARIMA model specifically targeting every ASEAN-5 country individually. Thus, it is difficult to compare the outcomes of this research study with previous studies.

5.4 Recommendations for Future Research

A few limitations have been specifically mentioned and highlighted in the previous section. However, the shortcomings may provide opportunities and suggestions for future researchers looking to further their research in this area. Therefore, this section aims to provide valuable recommendations for addressing the research study's limitations.

Firstly, government should regularly check and plan the policies of crude oil price fluctuations. The government play an important role in controlling the crude oil price by implementing various types of policies. The government should always pay attention to the causes and impacts of crude oil price fluctuations and come out with the policies accordingly. For example, the government may provide subsidised fuel prices to ease the burden on both consumers and businesses. Furthermore, the government may grant tax incentives to renewable energy sources such as solar, hydropower, wind, and others in order to reduce the cost of renewable energy. This will help to decrease the demand of crude oil and maintain the crude oil price stability.

Besides, researchers in the future are urged to include or propose more variables from various dimensions to have broader understanding about the factors affecting crude oil prices. For example, the researchers can consist of socioeconomic, environmental, etc. Other than that, the researchers also can include more countries sample such as more ASEAN countries, G-7 countries, G-20 countries, European countries, etc. in the research. Also, future researchers should include ARIMA forecasting methods in the research such as combining ARIMA model with panel model. This will provide a more comprehensive view of the countries' crude oil price instability. Hence, this will help the policymakers get more precise directions to formulate policies effectively.

5.5 Conclusion

Overall, this research study studied the factors that influence crude oil price in ASEAN-5 countries by examining the relationships among exchange rate, inflation rate, interest rate, GDP per capita, production of crude oil and crude oil price. The findings of this research study found out that all the variables except for interest rate are having significant relationship with crude oil price. Based on the ex-post forecast, Brunei, Indonesia, and Malaysia had increasing trend in crude oil price within the estimated periods, while Singapore and Thailand had decreasing trend in crude oil price within the estimated periods. From the ARIMA analysis, the crude oil prices in all ASEAN-5 countries are proved to be fluctuated over the estimated periods.

This research study would like to provide some implications to the stakeholders. From the theoretical implications, this research study contributes to practitioners and oil traders such as oil producers, exporters, and importers by providing them to understand the significance of exchange rate and production of crude oil can affect the crude oil price instability. This will directly affect their revenue and business growth. In terms of practical implications, this research study will provide policymakers on have clearer direction to formulate policy in stabilising crude oil price in the country. Besides this study also provides investors to make better investment decisions that related to crude oil financial assets based on the trend in forecasted crude oil price. Finally, the researcher encourages government and future researchers to consider the limitations and recommendations provided by this study for further research and implementation. Lastly, the researcher comes to the conclusions that the study objectives have been met, and the project will be completed with the conclusion.

REFERENCES

Aamir, M., & Shabri, A. (2016). Modelling and forecasting monthly crude oil price of Pakistan: A comparative study of ARIMA, GARCH and ARIMA Kalman model. *AIP Conference Proceedings*, *1750*(June 2016). https://doi.org/10.1063/1.4954620

Abdelsalam, M. A. M. (2020). Oil price fluctuations and economic growth: the case of MENA countries. *Review of Economics and Political Science*. https://doi.org/10.1108/reps-12-2019-0162

Adam, P., Rosnawintang, Saidi, L. O., Tondi, L., & Sani, L. O. A. (2018). The causal relationship between crude oil price, exchange rate and rice price. *International Journal of Energy Economics and Policy*, *8*(1), 90–94.

Adeosun, O. A., Tabash, M. I., & Anagreh, S. (2022). Oil price and economic performance: Additional evidence from advanced economies. *Resources Policy*, *77*(October 2021). https://doi.org/10.1016/j.resourpol.2022.102666

Ahmad, I., Iqbal, S., Khan, S., Han, H., Vega-Muñoz, A., & Ariza-Montes, A. (2022). Macroeconomic effects of crude oil shocks: Evidence from South Asian countries. *Frontiers in Psychology*, *13*(August). https://doi.org/10.3389/fpsyg.2022.967643

Akram, Q. F. (2009). Commodity prices, interest rates and the dollar. *Energy Economics*, *31*(6), 838–851. https://doi.org/10.1016/j.eneco.2009.05.016

Alberta Energy. (2015). *Let's talk royalties : not all oil is equal: explaining price differences*. 3. Retrieved from https://open.alberta.ca/dataset/5e6f425a-e1c7-441a-9aa0-64890e4ecade/resource/b7080f88-f748-45f0-8294-81d32a7a834c/download/13-Explaining-oil-price-differentials-formatted.pdf

Alrweili, H., & Fawzy, H. (2022). Forecasting Crude Oil Prices Using an ARIMA-ANN Hybrid Model. *Journal of Statistics Applications and Probability*, *11*(3), 845–855. https://doi.org/10.18576/jsap/110308

Amarfio, E. M., Marfo, S. A., & Gyagr, M. (2017). *Determining the Key Factors Affecting Global Pricing of Crude Oil Using Trend Analysis and Numerical Modelling* *. (1), 82–90.

Apergis, N., Ewing, B. T., & Payne, J. E. (2016). A time series analysis of oil production, rig count and crude oil price: Evidence from six U.S. oil producing regions. *Energy*, *97*, 339–349. https://doi.org/10.1016/j.energy.2015.12.028

Ariyanti, V. P., & Yusnitasar, T. (2023). Comparison of ARIMA and SARIMA for Forecasting Crude Oil Prices. *Jurnal Resti*, *7*(2), 405–413. https://doi.org/http://dx.doi.org/10.29207/resti.v7i2.4895

ASEAN Centre for Energy. (2017). *The 5th ASEAN Energy Outlook*. Retrieved from https://asean.org/wp-content/uploads/2021/08/5th-ASEAN-Energy-Outlook-AEO5.pdf

ASEAN Centre for Energy. (2018). How ASEAN Should Respond to Oil Price Hike. Retrieved from https://aseanenergy.org/how-asean-should-respond-to-oil-price-hike/

ASEAN Stats. (2021). *ASEAN Statistical Yearbook 2021* (Vol. 18). Retrieved from https://www.aseanstats.org/wp-content/uploads/2021/12/ASYB_2021_All_Final.pdf

Basher, S. A., Haug, A. A., & Sadorsky, P. (2012). Oil prices, exchange rates and emerging stock markets. *Energy Economics*, *34*(1), 227–240. https://doi.org/10.1016/j.eneco.2011.10.005

Baumeister, C., & Peersman, G. (2013). Time-varying effects of oil supply shocks on the US economy. *American Economic Journal: Macroeconomics*, *5*(4), 1–28. https://doi.org/10.1257/mac.5.4.1

Becken, S. (2011). Oil, the global economy and tourism. *Tourism Review*, *66*(3), 65–72. https://doi.org/10.1108/16605371111175339

Beckmann, J., Czudaj, R. L., & Arora, V. (2020). The relationship between oil prices and exchange rates: Revisiting theory and evidence. *Energy Economics*, *88*, 104772. https://doi.org/10.1016/j.eneco.2020.104772

Bekkeheien, M., Håland, Ø., Klovening, R., & Stokholm, R. (1999). Energy Demand Patterns Towards 2050. *Technological Forecasting and Social Change*, *18*(4), 95–120. https://doi.org/10.1016/0040-1625(80)90092-X

Bloch, H., Dockery, A. M., & Sapsford, D. (2006). Commodity Prices and the Dynamics of Inflation in Commodity-Exporting Nations: Evidence from Australia and Canada. *Economic Record*, *82*, 97–109.

Blomberg, S. B., & Harris, E. S. (1995). The Commodity-Consumer Price Connection: Fact or Fable? *Economic Policy Review*, *1*(3), 21–38. Retrieved from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1028825

Brahmasrene, T., Huang, J. C., & Sissoko, Y. (2014). Crude oil prices and exchange rates: Causality, variance decomposition and impulse response. *Energy Economics*, *44*, 407–412. https://doi.org/10.1016/j.eneco.2014.05.011

Caldara, D., Cavallo, M., & Iacoviello, M. (2019). Oil price elasticities and oil price fluctuations. *Journal of Monetary Economics*, *103*, 1–20. https://doi.org/10.1016/j.jmoneco.2018.08.004

Castillo, P., Montoro, C., & Tuesta, V. (2020). Inflation, oil price volatility and monetary policy. *Journal of Macroeconomics*, *66*(July 2019), 103259. https://doi.org/10.1016/j.jmacro.2020.103259

Chai, T., & Draxler, R. R. (2014). Root mean square error (RMSE) or mean absolute error (MAE)? -Arguments against avoiding RMSE in the literature. *Geoscientific Model Development*, *7*(3), 1247–1250. https://doi.org/10.5194/gmd-7-1247-2014

Chance, D., & Brooks, R. (2015). *An Introduction to Derivatives and Risk Management* (10th ed). Ohio: Cengage Learning. https://doi.org/10.3905/jpm.1999.319702

Chatziantoniou, I., Filippidis, M., Filis, G., & Gabauer, D. (2021). A closer look into the global determinants of oil price volatility. *Energy Economics*, *95*(105092). https://doi.org/10.1016/j.eneco.2020.105092

CNA. (2023). Malaysia government signals targeted fuel subsidies that might exclude the rich. Retrieved from https://www.channelnewsasia.com/asia/malaysia-ahmad-maslan-fuel-subsidies-targeted-rich-t20-3314286

Difeto, M., van Eyden, R., Gupta, R., & Wohar, M. E. (2019). *Oil Price Volatility and Economic Growth: Evidence from Advanced OECD Countries using over One Century of Data*. (233–234), 612–621. https://doi.org/https://doi.org/10.1016/j. apenergy.2018.10.049.

Downes, P. (2007). ASEAN Fiscal and Monetary Policy Responses to Rising Oil Prices Author : *Final Report*, (06).

Dunn, S., & Holloway, J. (2012). The Pricing of Crude Oil. *Reserve Bank of Australia Bulletin*, *3*(3), 65–74. https://doi.org/10.1016/0301-4215(75)90003-8

Ekananda, M. (2022). Role of macroeconomic determinants on the natural resource commodity prices: Indonesia futures volatility. *Resources Policy*, *78*(December 2021). https://doi.org/10.1016/j.resourpol.2022.102815

EMA Singapore. (2022). *Energy 2050 Committee Report - Charting the Energy Transition to 2050*.

Faisol, W., Indriastuti, S., & Trihartono, A. (2020). Indonesia and OPEC: Why does Indonesia maintain its distance? *IOP Conference Series: Earth and Environmental Science*, *485*(1). https://doi.org/10.1088/1755-1315/485/1/012010

Federal Statistical Office. (2022). *National accounts*. Retrieved from https://www.destatis.de/EN/Themes/Economy/National-Accounts-Domestic-Product/Publications/Downloads-National-Accounts-Domestic-Product/at-a-glance-pdf-0310200.pdf?__blob=publicationFile

Fong, Y. C., Khin, A. A., & Lim, C. S. (2020). Determinants of Natural Rubber Price Instability for Four Major Producing Countries. *Pertanika Journal of Social Sciences and Humanities*, *28*(2), 1179–1197.

Fox, J. (2022). Moving Away from Oil: How Can Brunei Diversify its Economy? Retrieved from ASEAN Briefing website: https://www.aseanbriefing.com/news/moving-away-from-oil-how-can-brunei-diversify-its-economy/

Fratzscher, M., Schneider, D., & Robays, I. Van. (2014). Oil Prices , Exchange Rates and Asset Prices. *Econstor*, (1689). Retrieved from http://hdl.handle.net/10419/154122%0A

Fu, M. C., & Suhaila, J. (2022). Forecasting Malaysia Bulk Latex Prices Using Autoregressive Integrated Moving Average (ARIMA) and Exponential Smoothing. *Malaysian Journal of Fundamental and Applied Sciences*, *18*(1), 70–81. https://doi.org/10.11113/MJFAS.V18N1.2404

Gharib, C., Mefteh-wali, S., Serret, V., & Ben, S. (2020). Impact of COVID-19 pandemic on crude oil prices: Evidence from Econophysics approach. *Elsevier: Resources Policy*, (January). https://doi.org/https://doi.org/10.1016%2Fj.resourpol.2021.102392

Gujarati, D. N., & Porter, D. C. (2009). Basic Econometrics. In *Mc Graw Hill*.

Gunarto, T., Azhar, R., Tresiana, N., Supriyanto, & Ahadiat, A. (2020). Accurate estimated model of volatility crude oil price. *International Journal of Energy Economics and Policy*, *10*(5), 228–233. https://doi.org/10.32479/ijeep.9513

Guo, H., & Kliesen, K. L. (2005). Oil Price Volatility and U.S. Macroeconomic Activity. *Review-Federal Reserve Bank of Saint Louis*, *87*(6), 669.

Hack, M., & Nicholls, S. (2021). Low Interest Rates and Bank Profitability-The International Experience So Far. *Bulletin*, (June), 77–85. Retrieved from https://www.rba.gov.au/publications/bulletin/2021/jun/low-interest-rates-and-bank-profitability-the-international-experience-so-far.html

Hamilton, A. (2018). Understanding Exchange Rates and Why They Are Important. *Reserve Bank of Australia Bulletin*, (December 2018), 1–18. Retrieved from https://www.rba.gov.au/publications/bulletin/2018/dec/pdf/understanding-exchange-rates-and-why-they-are-important.pdf

Hamilton, J. D. (1983). Oil and the macroeconomy since world war II. *Journal of Political Economy*, *91*(2), 228–248. https://doi.org/10.1086/261140

Hamilton, J. D. (1996). This is what happened to the oil price macroeconomy relationship. *Journal of Monetary Economics*, *38*(2), 215–220. https://doi.org/https://doi-org.libezp2.utar.edu.my/10.1016/S0304-3932(96)01282-2

Hamilton, J. D. (2009). Causes and consequences of the oil shock of 2007-08. *National Bureau of Economic Research*.

Hamilton, J. D. (2013). Historical oil shocks. *National Bureau of Economic Research*, 239– 265. https://doi.org/10.1117/12.414008

Hlongwane, N. W. (2022). The relationship between oil prices and exchange rates in South Africa. *Munich Personal RePEc Archive*. Retrieved from https://mpra.ub.uni-muenchen.de/113209/

Horn, M. (2004). OPEC's optimal crude oil price. *Energy Policy*, *32*(2), 269–280. https://doi.org/10.1016/S0301-4215(02)00289-6

Huang, B. N., Lee, C. C., Chang, Y. F., & Lee, C. C. (2021). Dynamic linkage between oil prices and exchange rates: new global evidence. *Empirical Economics*, *61*(2), 719–742. https://doi.org/10.1007/s00181-020-01874-8

IMF. (2019). *Brunei Darussalam: 2019 Article IV Consultation—Press Release and Staff Report*. Retrieved from https://www.elibrary.imf.org/view/journals/002/2019/310/article-A001-en.xml

IMF. (2021). *Brunei Darussalam: 2021 Article IV Consultation-Press Release; Staff Report; and Statement by the Executive Director for Brunei Darussalam*.

Inagaki, H., & Matsuura, H. (2018). How a rise in crude oil prices may affect Asian countries. *Mizuho Research Institute*, 11. Retrieved from https://www.mizuhori.co.jp/publication/research/pdf/eo/MEA180913.pdf

Index Mundi. (2022). Crude Oil (petroleum) Monthly Price - US Dollars per Barrel. Retrieved from https://www.indexmundi.com/commodities/?commodity=crude-oil&months=60

International Monetary Fund. (2021). *Brunei Darussalam Staff Report for the 2021 Article IV Consultation*. *21*(214), 1–54.

International Trade Administration. (2022). Brunei - Country Commercial Guide. Retrieved from https://www.trade.gov/country-commercial-guides/brunei-market-overview

International Trade Administration. (2023). Energy Resource Guide: Singapore - Oil & Gas. Retrieved from https://www.trade.gov/energy-resource-guide-singapore-oil-and-gas

InvestASEAN. (2023). Single Market and Production Base. Retrieved from https://investasean.asean.org/asean-economic-community/view/670/newsid/758/single-market-and-production-base.html

IRENA. (2017). Renewable Energy Outlook: Thailand. In *International Renewable Energy Agency*. Retrieved from https://www.irena.org/-/media/files/irena/agency/publication/2017/nov/irena_outlook_thailand_2017.pdf

Jalal, R., & Gopinathan, R. (2022). Time-varying and asymmetric impact of exchange rate on oil prices in India: Evidence from a multiple threshold nonlinear ARDL model. *Finance Research Letters*, *50*(July). https://doi.org/10.1016/j.frl.2022.103297

Jarrett, U., Mohaddes, K., & Mohtadi, H. (2019). Oil price volatility, financial institutions and economic growth. *Energy Policy, 126*(November 2018), 131–144. https://doi.org/10.1016/j.enpol.2018.10.068

Joyce, T. S. Y. (2017). Country Reports: Brunei Darussalam. *Economic Research Institute for ASEAN and East Asia*, *3*(iv), 87–104. Retrieved from https://www.eria.org/3.5.ASEAN_50_Vol_3_Country_Reports_Brunei.pdf

Khin, A. A., Bin, R. L. L., Keong, O. C., Yie, F. W., & Liang, N. J. (2019). Critical factors of the natural rubber price instability in the world market. *Humanities and Social Sciences Reviews*, *7*(1), 199–208. https://doi.org/10.18510/hssr.2019.7124

Khin, A. A., Chiun, F. Y., Chun, C. K., Qian, L. Y., & Yee, W. M. (2017). *Vector Error Correction Models for Major Agricultural and Mining Commodities ' Prices and Crude Oil Price Changes in the World*. *1*(3), 121–130.

Kilian, L. (2017). How the Tight Oil Boom Has Changed Oil and Gasoline Markets. *SSRN Electronic Journal*, (6380). https://doi.org/10.2139/ssrn.2941444

Kilian, L., & Hicks, B. (2013). Did unexpectedly strong economic growth cause the oil price shock of 2003-2008? *Journal of Forecasting*, *32*(5), 385–394. https://doi.org/10.1002/for.2243

Kilian, L., & Zhou, X. (2022). Oil prices, exchange rates and interest rates. *Journal of International Money and Finance*, *126*, 1–16. https://doi.org/10.1016/j.jimonfin.2022.102679

Kimura, S., & Morikawa, T. (2018). Potential of Oil Stockpiling at Oil Terminals in Southeast Asia. *Economic Research Institute for ASEAN and East Asia*. Retrieved from https://www.eria.org/publications/potential-of-oil-stockpiling-at-oil-terminals-in-southeast-asia/

Kimura, S., & Phoumin, H. (2016). Energy Outlook and Energy Saving Potential in East Asia. *Economic Research Institute for ASEAN and East Asia*. Retrieved from https://www.eria.org/RPR_FY2015_No.5.pdf

Kocoglu, M., Kyophilavong, P., Awan, A., & Lim, S. Y. (2022). Time-varying causality between oil price and exchange rate in five ASEAN economies. *Economic Change and Restructuring*. https://doi.org/10.1007/s10644-022-09457-6

Leduc, S., & Sill, K. (2004). A quantitative analysis of oil-price shocks, systematic monetary policy, and economic downturns. *Journal of Monetary Economics*, *51*(4), 781–808. https://doi.org/10.1016/j.jmoneco.2003.09.004

Lee, C. Y., & Huh, S. Y. (2017). Forecasting long-term crude oil prices using a bayesian model with informative priors. *Sustainability (Switzerland)*, *9*(2), 1–15. https://doi.org/10.3390/su9020190

Lescaroux, F., & Mignon, V. (2008). On the influence of oil prices on economic activity and other macroeconomic and financial variables. *OPEC Energy Review*, *32*(4), 343–380. https://doi.org/10.1111/j.1753-0237.2009.00157.x

Lu, Q., Sun, S., Duan, H., & Wang, S. (2021). Analysis and forecasting of crude oil price based on the variable selection-LSTM integrated model. *Energy Informatics*, *4*(Suppl 2).

https://doi.org/10.1186/s42162-021-00166-4

Lyu, H., & Chang, Y. (2017). Research on International Crude Oil Price Forecasting Model. *International Journal of New Developments in Engineering and Society*, *1*(3), 2014–2017.

Maheu, J. M., Song, Y., & Yang, Q. (2020). Oil price shocks and economic growth: The volatility link. *International Journal of Forecasting*, *36*(2), 570–587. https://doi.org/10.1016/j.ijforecast.2019.07.008

Mahidin, M. U. (2021). Analysis of Annual Consumer Price Index 2020. Retrieved from Department of Statistics Malaysia website: https://www.dosm.gov.my/v1/index.php?r=column/cthemeByCat&cat=490&bul_id=ZWE0MEZ4MzNZS2xlcm4zdGNWbEJtZz09&menu_id=bThzTHQxN1ZqMVF6a2I4RkZoNDFkQT09

McCarthy, R. V., McCarthy, M. M., & Ceccucci, W. (2021). *Applying Predictive Analytics Finding Value in Data*. Springer. https://doi.org/10.1007/978-3-030-83070-0_3

Medina, A. F. (2022). Singapore's Incentives and Schemes to Attract Industry 4.0 Investments, Bolster Innovation Capacity. Retrieved from ASEAN Briefing website: https://www.aseanbriefing.com/news/singapore-incentives-to-attract-industry-4-investors-expand-innovation-capacity/

Mensah, E. K. (2015). Box-Jenkins modelling and forecasting of Brent crude oil price. *MPRA*, (67748). Retrieved from https://mpra.ub.uni-muenchen.de/67748/

Merabet, F., Zeghdoudi, H., Yahia, R. H., & Saba, I. (2021). Modelling of Oil Price Volatility Using ARIAMA-GARCH Model. *Advances in Mathematics: Scientific Journal*, *10*(5), 2361–2380. https://doi.org/10.37418/amsj.10.5.6

Millia, H., Adam, P., Saenong, Z., Balaka, M. Y., Pasrun, Y. P., Saidi, L. O., & Rumbia, W. A. (2020). The influence of crude oil prices volatility, the internet and exchange rate on the number of foreign tourist arrivals in Indonesia. *International Journal of Energy Economics and Policy*, *10*(6), 280–287. https://doi.org/10.32479/ijeep.10083

Ministry of Finance Malaysia. (2022). Total subsidies in 2022 nearly RM80 bln, highest in history – Tengku Zafrul. Retrieved from https://www.mof.gov.my/portal/en/news/press-citations/total-subsidies-in-2022-nearly-rm80-bln-highest-in-history-tengku-zafrul

Mofema, V. M., & Mah, G. (2021). An empirical analysis of volatility in

South African oil prices. *Journal of Energey in Southern Africa*, *32*(3), 67–75. https://doi.org/http://dx.doi.org/10.17159/2413-3051/2021/v32i3a8852

Moffett, M. H., Stonehill, A. I., & Eiteman, D. K. (2021). *Fundamentals of Multinational Finance* (6th editio). Boston: Pearson Prentice Hall.

Muthalib, A. A., Adam, P., Rostin, Saenong, Z., & Suriadi, L. O. (2018). The influence of fuel prices and unemployment rate towards the poverty level in Indonesia. *International Journal of Energy Economics and Policy*, *8*(3), 37–42. Retrieved from https://www.econjournals.com/index.php/ijeep/article/view/6233

Nyangarika, A. M., Mikhaylov, A. Y., & Tang, B. J. (2018). Correlation of oil prices and gross domestic product in oil producing countries. *International Journal of Energy Economics and Policy*, *8*(5), 42–48.

Nyangarika, A. M., & Tang, B. (2018). Oil price factors: Forecasting on the base of modified auto-regressive integrated moving average model. *International Journal of Energy Economics and Policy*, *9*(1), 149–159. https://doi.org/10.32479/ijeep.6812

OECD. (2022). Interest Rate. Retrieved from https://stats.oecd.org/glossary/detail.asp?ID=1392

Olofin, S., & Salisu, A. (2017). Modelling oil price-inflation nexus : The role of asymmetries and structural breaks. *Center for Econometric and Allied Research (CEAR)*, 1–42.

Oner, C. (2017). Inflation: Prices on the rise. *International Monetary Fund Finance & Development*, 10–13. Retrieved from https://www.imf.org/external/pubs/ft/fandd/basics/inflat.htm%0Ahttp://www.imf.org/external/pubs/ft/fandd/basics/inflat.htm

OPEC. (2021). The Declaration of Cooperation of OPEC and non-OPEC oil-producing countries reaches five years. Retrieved from https://www.opec.org/opec_web/en/press_room/6748.htm

Philips, A. S., Akinseye, A. B., & Oduyemi, G. O. (2022). Do exchange rate and inflation rate matter in the cyclicality of oil price and stock returns? *Resources Policy*, *78*(June), 102882. https://doi.org/10.1016/j.resourpol.2022.102882

Pindyck, R., & Rubinfeld, D. (2018). *Mircroeconomics Ninth Edition*. Pearson.

Pippenger, J. (2016). Commodity Arbitrage and the Law of One Price: Setting the Record Straight. *Theoretical Economics Letters*, *06*(05), 1017–1033. https://doi.org/10.4236/tel.2016.65101

Prasad, A., Narayan, P. K., & Narayan, J. (2007). Exploring the oil price and real GDP nexus for a small island economy, the Fiji Islands. *Energy Policy*, *35*(12), 6506–6513. https://doi.org/10.1016/j.enpol.2007.07.032

Rafiq, S., Salim, R., & Bloch, H. (2009). Impact of crude oil price volatility on economic activities: An empirical investigation in the Thai economy. *Resources Policy*, *34*(3), 121–132. https://doi.org/10.1016/j.resourpol.2008.09.001

Raghavan, M. (2015). The Macroeconomic Effects of Oil Price Shocks on ASEAN-5 Economies. *Tasmanian School of Business and Economics. Discussion Paper Series No.2015-10*.

Rapiah, R. (2018). Why Oil Prices Rose And Crashed In 2018. Retrieved from Oil Price.com website: https://oilprice.com/Energy/Oil-Prices/Why-Oil-Prices-Rose-And-Crashed-In-2018.html

Ratti, R. A., & Vespignani, J. L. (2014). OPEC and non-OPEC oil production and the global economy. *Energy Economics*, *50*, 364–378. https://doi.org/10.1016/j.eneco.2014.12.001

Razek, N. H. A., & Michieka, N. M. (2019). OPEC and non-OPEC production, global demand, and the financialization of oil. *Research in International Business and Finance*, *50*(March), 201–225. https://doi.org/10.1016/j.ribaf.2019.05.009

Saddiqui, S. A., Jawad, M., Naz, M., & Niazi, G. S. K. (2018). Exchange Rate, Fiscal Policy and International Oil Prices Impact on Oil Prices in Pakistan: a Volatility and Granger Causality Analysis. *Review of Innovation and Competitiveness*, *4*(1), 27–46. https://doi.org/10.32728/ric.2018.41/2

Selvi, J. J., Shree, R. K., & Krishnan, J. (2018). Forecasting Crude Oil Price Using ARIMA Models. *International Journal of Advance Research in Science and Engineering*, *7*(5), 334–343.

Sha, Z. (2022). Total natural resources, oil prices, and sustainable economic performance: Evidence from global data. *Resources Policy*, *79*(September). https://doi.org/10.1016/j.resourpol.2022.103046

Shah, P. A. J., & Kiruthiga, D. G. (2020). Crude Oil Price Forecasting Using ARIMA model. *International Research Journal of Engineering and Technology (IRJET)*, *7*(3), 1–11. Retrieved from https://www.academia.edu/download/66675654/IJASI_0101_02.

Shangle, A., & Solaymani, S. (2020). Responses of monetary policies to oil price changes in Malaysia. *Energy*, *200*.

https://doi.org/10.1016/j.energy.2020.117553

Sukono, S., Suryamah, E., & Novinta S, F. (2020). Application of ARIMA-GARCH Model for Prediction of Indonesian Crude Oil Prices. *Operations Research: International Conference Series*, *1*(1), 25–33. https://doi.org/10.47194/orics.v1i1.21

Sulaiman, N., Harun, M., & Yusuf, A. A. (2022). Impacts of Fuel Subsidy Rationalization on Sectoral Output and Employment in Malaysia. *Asian Development Review*, *39*(1), 315–348. https://doi.org/10.1142/S0116110522500081

Sun, C., Zhan, Y., Peng, Y., & Cai, W. (2022). Crude oil price and exchange rate: Evidence from the period before and after the launch of China's crude oil futures. *Energy Economics*, *105*(May 2021), 105707. https://doi.org/10.1016/j.eneco.2021.105707

Taghizadeh Hesary, F., & Yoshino, N. (2014). Monetary policies and oil price determination: an empirical analysis. *OPEC Energy Review*, *38*(1), 1–20. https://doi.org/10.1111/opec.12021

The Scoop. (2020). COVID-19 pandemic pushes up Brunei's inflation rate. Retrieved from https://thescoop.co/2020/07/08/covid-19-pandemic-pushes-up-bruneis-inflation-rate/

The Star. (2022). Indonesia inflation hits new 7-year high after fuel price hike. Retrieved from https://www.thestar.com.my/business/business-news/2022/10/03/indonesia-inflation-hits-new-7-year-high-after-fuel-price-hike

Togonidzea, S., & Kočenda, E. (2022). Macroeconomic responses of emerging market economies to oil price shocks: An analysis by region and resource profile. *Economic Systems Journal*, *46*(April), 449–458. https://doi.org/10.4324/9780429347917-65

Tverberg, G. E. (2012). Oil supply limits and the continuing financial crisis. *Energy*, *37*(1), 27–34. https://doi.org/10.1016/j.energy.2011.05.049

U.S. Department of Agriculture. (2022). Agricultural Exchange Rate Data Set. Retrieved from https://www.ers.usda.gov/data-products/agricultural-exchange-rate-data-set/

U.S. Energy Information Administration. (2014). Benchmarks play an important role in pricing crude oil. Retrieved from https://www.eia.gov/todayinenergy/detail.php?id=18571

U.S. Energy Information Administration. (2015). Indonesia rejoining OPEC despite being a net importer of petroleum. Retrieved from https://www.eia.gov/todayinenergy/detail.php?id=23352

U.S. Energy Information Administration. (2017). Thailand Analysis. Retrieved from https://www.eia.gov/international/analysis/country/THA

U.S. Energy Information Administration. (2021). Singapore Overview. Retrieved from https://www.eia.gov/international/analysis/country/SGP

U.S. Energy Information Administration. (2022a). Oil and petroleum products explained. Oil prices and outlook. Retrieved from https://www.eia.gov/energyexplained/oil-and-petroleum-products/prices-and-outlook.php

U.S. Energy Information Administration. (2022b). Oil and petroleum products explained. Retrieved from https://www.eia.gov/energyexplained/oil-and-petroleum-products/

U.S. Energy Information Administration. (2022c). Petroleum. Retrieved from https://www.eia.gov/international/data/world%0A

U.S. Energy Information Administration. (2022d). What drives crude oil prices: Supply OPEC. Retrieved from https://www.eia.gov/finance/markets/crudeoil/supply-opec.php

U.S. Energy Information Administration. (2023). What drives crude oil prices: Spot Prices. Retrieved from https://www.eia.gov/finance/markets/crudeoil/spot_prices.php

Urom, C., Guesmi, K., Abid, I., & Dagher, L. (2021). Dynamic integration and transmission channels among interest rates and oil price shocks. *The Quarterly Review of Economics and Finance*.

Vaughan, A. (2018). What are the factors driving up the price of crude oil? Retrieved from The Guardian website: https://www.theguardian.com/business/2018/may/17/what-are-the-factors-driving-up-the-price-of-crude-oil

Vu, T. K., & Nakata, H. (2018). Oil price fluctuations and the small open economies of Southeast Asia: An analysis using vector autoregression with block exogeneity. *Journal of Asian Economics*, *54*, 1–21. https://doi.org/10.1016/j.asieco.2017.11.001

Wang, Y., & Wu, C. (2012). Forecasting energy market volatility using GARCH models: Can multivariate models beat univariate models? *Energy Economics*, *34*(6), 2167–2181. https://doi.org/10.1016/j.eneco.2012.03.010

Whelan, J., Forrester, J. W., & Msefer, K. (2001). Economic Supply &

Demand. *MIT System Dynamics in Education Project*, *520*, 46. Retrieved from http://ocw.mit.edu/courses/sloan-school-of-management/15-988-system-dynamics-self-study-fall-1998-spring-1999/readings/economics.pdf

World Bank. (2022a). GDP per capita. Retrieved from https://data.worldbank.org/indicator/NY.GDP.PCAP.KD

World Bank. (2022b). Inflation (annual %). Retrieved from https://data.worldbank.org/indicator/FP.CPI.TOTL.ZG

World Bank. (2022c). Interest Rate. Retrieved from https://data.worldbank.org/indicator/FR.INR.RINR

World Economic Forum. (2022). Explainer: What is OPEC? Retrieved from https://www.weforum.org/agenda/2022/11/oil-opec-energy-price/

Yan, L. (2012). Analysis of the International Oil Price Fluctuations and Its Influencing Factors. *American Journal of Industrial and Business Management*, *02*(02), 39–46. https://doi.org/10.4236/ajibm.2012.22006

Yang, Y. T., Yang, T. Y., Chen, S. H., & Tong, C. V. (2022). Exploring the non-linearity of West Texas Intermediate crude oil price from exchange rate of US dollar and West Texas Intermediate crude oil production. *Energy Strategy Reviews*, *41*(April). https://doi.org/10.1016/j.esr.2022.100854

Yeo, J., Chalmers, B., Hunter, S., & Tanjanco, B. (2017). The impact of oil prices on Asia. *Marsh & McLennan Companies*.

Yoshino, N., & Taghizadeh-Hesary, F. (2014). Monetary policy and oil price fluctuations following the subprime mortgage crisis. *International Journal of Monetary Economics and Finance*, *7*(3), 157–174. https://doi.org/10.1504/IJMEF.2014.066482

Yuniarti, D., Rosadi, D., & Abdurakhman. (2021). Inflation of Indonesia during the COVID-19 pandemic. *Journal of Physics: Conference Series*, *1821*(1). https://doi.org/10.1088/1742-6596/1821/1/012039

Zhang, Y., Hyder, M., Baloch, Z. A., Qian, C., & Berk Saydaliev, H. (2022). Nexus between oil price volatility and inflation: Mediating nexus from exchange rate. *Resources Policy*, *79*(August). https://doi.org/10.1016/j.resourpol.2022.102977

Zhang, Y. J., Fan, Y., Tsai, H. T., & Wei, Y. M. (2008). Spillover effect of US dollar exchange rate on oil prices. *Journal of Policy Modeling*, *30*(6), 973–991. https://doi.org/10.1016/j.jpolmod.2008.02.002

Zhao, J. (2022). Exploring the influence of the main factors on the crude oil price volatility: An analysis based on GARCH-MIDAS model with Lasso approach. *Resources Policy*, *79*(May). https://doi.org/10.1016/j.resourpol.2022.103031

Zulfikar, R. (2018). Estimation model and selection method of panel data regression: An overview of common effect, fixed effect, and random effect model. *JEMA: Jurnal Ilmiah Bidang Akuntansi*, 1–10. Retrieved from https://scholar.google.com/scholar?oi=bibs&cluster=193289084434328157&btnI=1&hl=en