THE IMPACT OF PALM OIL PRICES, BIODIESEL DEMAND AND INDUSTRIAL DEVELOPMENT ON THE FOOD PRICES IN MALAYSIA

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By

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ABSTRACT

THE IMPACT OF PALM OIL PRICES, BIODIESEL DEMAND AND INDUSTRIAL DEVELOPMENT ON THE FOOD PRICES IN MALAYSIA

Thurai Murugan Nathan

The palm oil industry plays a critical role in Malaysia's food and fuel production, significantly contributing to the country's economy. However, the industry's impact on food prices is complex and multifaceted. This is mainly due to the diversification of palm oil to cooking oil and biodiesel production. Despite the growing relevance of biodiesel in Malaysia, the structural relationship between palm oil prices, biodiesel demand, industrial development, and food prices remains insufficiently examined. This study investigates the intricate relationship between biofuel demand, palm oil prices, industrial growth, other control variables, and food prices in Malaysia, with the primary objective of assessing how these factors collectively influence food prices in the country. Employing a quantitative approach, the study utilizes ARDL and Toda-Yamamoto methods to identify short- and long-term relationships, and causality among these variables. The asymmetric linear ARDL model is used to investigate the asymmetric effect. Furthermore, the study employs the impulse response function to understand how the system reacts to variable changes and the forecast error variance decomposition to gauge the strength of shocks in the overall model. Data from January 2013 to May 2022 is used for analysis. The major findings of this research reveal that crude oil prices, palm oil prices, biodiesel demand, and industrial growth positively impact the food price in Malaysia, and the exchange rate has a negative impact, as expected. These findings align with existing literature and theories, underlining the significance of a well-balanced approach to managing palm oil prices, biodiesel demand, industrial growth, and food prices in Malaysia. The study highlights the necessity for integrated policies harmonising these crucial sectors, urging policymakers to evaluate potential trade-offs and synergies among different policy objectives. The key emphasis is prioritizing sustainability and food affordability in Malaysia's economy, alternative energy sector, and agricultural landscape.

Keywords: Biodiesel, Palm oil, Industrial Growth, Malaysia, ARDL, Bioenergy

Subject Area(s): TD169-171.8 Environmental protection

TD172-193.5 Environmental pollution

TD194-195 Environmental effects of industries and plants

S589.75-589.76 Agriculture and the environment

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LIST OF ABBREVIATIONS

Abbreviations	Terms of Abbreviations
4IR	National Fourth Industrial Revolution Policy
ACF	Autocorrelation Function
ADB	Asian Development Bank
ADF	Augmented Dickey-Fuller
AIC	Akaike Information Criterion
APM	Automatic Pricing Mechanism
ARDL	Auto Regressive Distributive Lag
ARIMA	Autoregressive Integrated Moving Average
ASEAN	Association of Southeast Asian Nations
B5	Blended mandate 5 per cent
B7	Blended mandate 7 per cent
B20	Blended mandate 20 per cent
B30	Blended mandate 30 per cent
B40	The bottom 40 per cent of low-income earners
B-100	100 per cent of Biodiesel
BBL	Barrel Oil
BTU	British thermal unit
CIA	Central Intelligence Agency
CIS	Commonwealth of Independent States
CO2	Carbon Dioxide
CPO	Crude Palm Oil
CPOPC	Council of Palm Oil Producing Countries
CPI	Consumer Price Index
CUSUM	Cumulative Sum
DOSM	Department of Statistics Malaysia
DF-GLS	Dickey-Fuller Generalized Least Squares
ECM	Error Correction Model
EU	European Union
EC_t	Error Correction Terms
EIA	US Energy Information Administration
FAO	Food and Agricultural Organization of the United Nations
FDI	Foreign Direct Investment
FEVD	forecast error variance decomposition
GARCH	Generalized Autoregressive Conditional Heteroskedasticity
GAPs	Good agricultural practices
GDP	Gross Domestic Product
GHG	Green gas
HQC	Hannan-Quinn criterion
ICCT	International Council on Clean Transportation
ICT	Information and Communication Technology
IEA	International Energy Agency
IUCN	International Union for Conservation of Nature
IMF	International Monetary Funds
IMP	Industrial Master Plan
IPI	Industrial production index

LIST OF ABBREVIATIONS (Continued)

Abbreviations	Terms of Abbreviations
IRF	Impulse Response Functions
KPSS	Kwiatkowski–Phillips–Schmidt–Shin
FAMA	Malaysia National Food Security Policy
MC	Marginal Cost
MPIT2030	Malaysian Palm Oil Industry Transformation Plan
MOF	Ministry of Finance
MPOB	Malaysian Palm Oil Board
MPOC	Malaysian Palm Oil Cooperation
MSPO	Malaysian Sustainable Palm Oil
MR	Marginal Revenue
MIDA	Malaysian Investment Development Authority
MITI	Ministry of International Trade and Industry
MT	Metric Tonnes
MyCC	Malaysian Competition Commission
MYR	Malaysian Ringgit
NAP 3	National Agriculture Policy 3
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary Least Square
OPEC	Organization of the Petroleum Exporting Countries
PP	Phillips-Perron
R & D	Research and Development
RFS	Renewable Fuel Standard
RWM	Random Walk Model
SBC	Schwarz Bayesian criterion
SIC	Schwarz Information Criterion
SMEs	Small and Medium Enterprises
SSR	Self-self-sufficiency ratio
SUR	Terawatt-hours
TWh	Seemingly Unrelated Regression
UK	United Kingdom
US	United States
USD	United States Dollar
USDA	United States Department of Agricultural
WHO	World Health Organization
WWF	Worldwide Fund for Nature
VAR	Vector autoregression
VECM	Vector Error Correction Models
VEETC	Volumetric Ethanol Excise Tax Credit
VIF	Variance Inflation Factor

CHAPTER ONE

INTRODUCTION

1.0 Introduction

One of the intriguing issues globally is the global crude oil price volatility. The crude oil price volatility directly impacts most of the country's economic growth, especially the oil-importing countries. Large numbers of past literature have proven this fact theoretically and empirically (for instance, Uri & Boyd, 1996; Pierru, 2007; Sadorsky, 2009; Nazlioglu & Soytas, 2011; Ibrahim, 2015; Wong & Shamsudin, 2017; Cheng, Shi, Yu & Zhang, 2019; Dash & Maitra, 2021; Tanaka et al., 2024). Two main issues are essentially debating on crude oil globally.

The first issue is the crude oil price fluctuation affecting the general price level of goods and services. Eltony and Al-Awadi (2001) summarised that the income from oil production is increasing in the country but consequently, it increases the country's price level and wages. It has been empirically proven by the study such as Nazlioglu and Soytas (2011) and Ji and Fan (2012). Besides, Sadorsky (2009) argued that a growing economy would increase the demand for their energy. Due to higher demand worldwide, the international market's crude oil price is getting higher, affecting the oil-importing countries. This is mainly due to the oil-importing countries having to allocate more and more yearly budgets to import oil into their country. Thus, the increasing crude oil price will directly reflect that particular country's general price level and services.

Consequently, this will affect the final consumers of that particular country. In detail, the general price level of goods and services is affected due to the usage of oil in transportation, power generation, residual used, and industrial production. Cheng et al. (2019) argued that more industrialised economies depend heavily on oil. Thus, using oil as an input in these sectors leads to the final price of goods and services becoming expensive.

The second issue is the negative impact of crude oil on the environment. Various studies are discovering this issue in the literature (Dutta, Bouri, & Noor, 2018; Wang, Bai, & Xie, 2019; Wang et al., 2021; Karkowska & Urjasz., 2024). Sodorsky (2009) argued that releasing carbon dioxide (CO_2) from crude oil into the atmosphere leads to global warming. The author added that this issue could lead to the catastrophic consequences of rising sea levels, altered rainfall volumes, and increased storm' intensity. Furthermore, Pierru (2007) added that the conventional petroleum fuels used in producing, transporting, and refining oil lead to greenhouse and pollutant emissions. To support those statements, The World Health Organization (WHO) highlighted that more than half of the world's population breathes unsafe air, with people in developing countries suspiciously exposed to air pollution (WHO, 2017). In addition, the WHO global air quality guidelines report published in 2021 stated that 4.2 million people die every year due to exposure to ambient air pollution globally. The report further stressed that almost 99 per cent of the global population, especially low and middle-income countries, breathe unsafe air, which exceeds the safe air limits set by WHO (WHO, 2021).

Due to the significant negative impact of crude oil on the general price and environment, as well as the growing demand for crude oil globally[1], organisations such as the U.S Energy Information Administration (EIA) are forced to adopt renewable energy such as solar power, bio-fuels (bio-ethanol, bio-gas and bio-diesel), biomass and hydropower to fulfil the future energy demand by balanced the future economic and environmental needs. This is because using renewable energies, especially biofuel in the transportation and manufacturing sector, can reduce greenhouse gas emissions by decreasing fossil fuel usage. Accordingly, various steps and policies, such as a blended mandate in the transportation and industrial sectors, have been implemented worldwide to reduce the dependency on crude oil[2].

For instance, Kristoufek et al. (2012) and Koizumi (2015) added that global interest in climate and environmental issues leads to the current demand for renewable energy. Accordingly, renewable energy consumption has proliferated in the past ten years, and renewable energy consumption is growing much faster than the real gross domestic product (GDP) growth in G7 countries

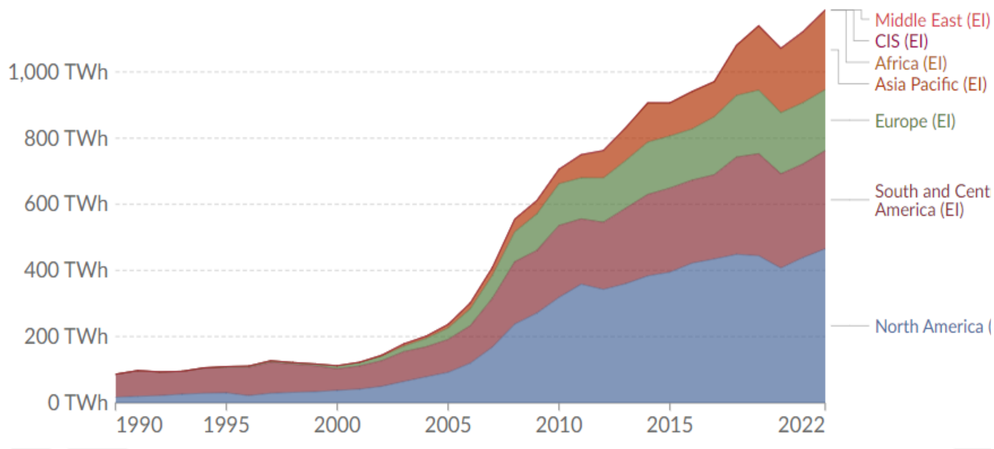
[1] According to Sharma and Singh (2017), the demand for the crude oil is increasing by 1.8 percent per annum, globally. Furthermore, Ahmad and Zhang (2020) forecasted that the world energy requirement is expected to increase to 739 quadrillion British thermal unit (BTU) by year 2040.

[2] Blended mandate requirement is referring to the usage of petrol/diesel with a certain amount of biofuel which is produced using the agriculture crops. Thus, the blended requirement will reduce the pure petrol/diesel usage in the transportation and industrial since a portion of biofuel will be combined into the fuel. For instance, B20 referring the blended of 20% of biofuel to 80% of petrol/diesel.

(Sodorsky, 2009)[3]. In addition, the Commission (2016) indicates that the European Union (EU) targeted about 20 per cent of renewable energy share in energy consumption by 2020 and proposed increasing it to 27 per cent by 2030. This suggests that renewable energy usage is growing worldwide by slowly substituting global dependency on crude oil. This can be seen in Figure 1.1, where regions' biofuel production shows an increasing trend from 1990 to 2022.

Based on Figure 1.1, it is notable that biofuel production improved dramatically from the year 2000 onwards globally. Thus, the US (North, South and Central America) covered more than 50 per cent of the biofuel production globally in 2020 compared to the rest of the regions. Hence, followed by Europe and the Asia Pacific. Interestingly, biofuel production in Asia has notably increased production from 2010 onwards. No significant production exists in regions such as the Middle East, the Commonwealth of Independent States (CIS) and Africa. Interestingly, the growth pace of biofuel production in the Asia Pacific was slow before 2005. However, the growth pace increases dramatically after 2010, and the production rate currently equals the European region[4].

[3] G7 countries are the seven major advanced economies in the world. G7 countries consist of Canada, France, Germany, Italy, Japan, the United Kingdom (UK) and the United States (US).
[4] According to the United Nations, Asia Pacific consists of East Asia, Oceania, the Russian Far East, South Asia, and Southeast Asia which includes about 48 countries and Malaysia is one of them.



Source: Energy Institute Statistical Review of World Energy (2023).
Notes: Biofuel production is measured in terawatt-hours (TWh) per year and includes both bioethanol and biofuel.

Figure 1.1: Biofuel Production by Region from 1990 to 2022

With the global trend in increasing the usage of renewable energies, ongoing research on renewable energy mainly concentrates on biofuel/biodiesel. This is due to biofuel production is frequently linked with the food price hike and food security (refer to the study of Kristoufek et al., 2012; Koizumi, 2015; Persson, 2015; Priyati & Typers, 2016; Shrestha, Staab, & Duffield, 2019; Bilgili, Kocak, Kuskaya & Bulut, 2020; Brinkman et al., 2020; Sun et al., 2023; Alnour et al., 2023). Based on the literature, the overall structure of the relationship between the energy-biofuel-food price is founded by the supply and demand framework (Serra & Zilberman, 2013; Koizumi, 2015; Al-Maadid et al., 2016; Tanaka et al., 2023).

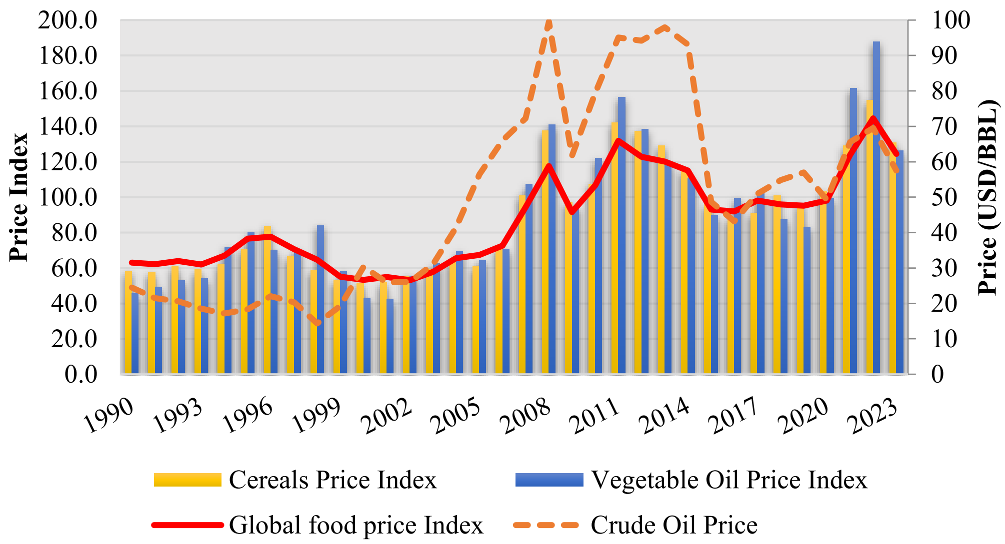
The clue to connect biofuel production to food price is mainly due to the usage of crops as the feedstock for biofuel production and the substitution effect on the crude oil in the production inputs. Consequently, the additional demand for the crops due to biofuel production could create price pressure depending on the availability and stock. To support the above statement, the study of Nazlioglu and Soytas (2011) and Ji and Fan (2012) claimed that agricultural commodities such as wheat, corn, soybeans, and sugarcane have a close relationship with the energy market since it is demanded and used in the production of alternative energy sources, i.e., biofuels (including bio-ethanol and biofuel) which is become a substitution for gasoline and diesel usage[5]. Butt et al. (2021) indicated that commodities such as palm oil and rubber are affected by the oil price through the input price, which will channel the competition in agriculture output markets or biofuels.

This can be viewed in Figure 1.2, whereby the agricultural commodity prices are parallel to the global food price index. The figure uses two types of agriculture price indexes, i.e., the cereal and vegetable price index. The cereal price index consists of the grouped prices of cereals such as corn, wheat, rice, oats, etc. Meanwhile, vegetable oil represents agricultural commodities such as soybean, sunflower, corn, palm, etc. Accordingly, based on Figure 1.2, the global food price index's movement highly reflects the movement of the cereal and vegetable price index. At the same time, the pricing trend of crude oil also shows similar fluctuation based on the annual data from 1990 to 2023.

Notably, the global food crisis of 2008 increased agriculture commodity prices, as seen in the figure. Interestingly, oil prices and the global food index show a similar trend for 2008. The recent food price hike due to the COVID-19

[5] However, other renewable energies such as solar power and hydro power are produced based on the available natural resources. Due to this recent, most of the studies are focus on the biofuel since this renewable energy having potential impact on the economy and sustainability.

pandemic shows that agriculture commodity prices are increasing. Thus, this relationship has been developed as a *bioenergy model* by Ciaian and Kanc (2011) to show the impact of biofuel production on the food sector interconnected by crude oil. Furthermore, a recent study by Chong et al. (2021) indicates that food crops and water are the resources used in biofuel production, and since food is a basic human need, this will influence biofuel sustainability.



Sources: Food and Agriculture Organization of United Nations (FOA, 2024); WorldBank, 2021.

Figure 1.2: The Price of Agriculture Commodities, Food and Crude oil from the Year 1990 to 2023

Interestingly, due to the growing demand for renewable energy, the global production of biofuels shows an increasing trend, whereby the International Energy Agency (IEA) indicates that worldwide biofuel production increased by 10 billion litres in 2018 (IEA, 2019). The report further illustrated that biofuel outputs are expected to expand 24 per cent from 2019 to 2024. Thus, this could contribute to the additional demands for agricultural commodities such as corn, sugarcane and palm oil, mainly used in biofuel production, which will be directed to the food versus fuel debate (Negash & Swinnen, 2013; Chong et al., 2021). The additional demands due to the market expansion in biofuel production in the agricultural commodities market are expected to influence the commodity's price, as argued by Subramaniam et al. (2019) and Bilgili et al. (2020). This argument is further supported by Kretschmer, Bowyer, and Buckwell's (2012) study by summarising a few studies that forecast the effect of agricultural prices in 2020 due to biofuel production globally in Table 1.1.

Table 1.1 shows the summarized table of various studies conducted to study the effect of biofuel policy. The studies have been categorised into two groups, i.e., studies that focus on the impact of European Union biofuel policy and studies that analyse the impact of global/ multi-regional biofuel mandates. The top five highly impacted agriculture commodities are listed in the table. Understandably, biofuel policy is projected to affect all the agriculture commodity prices. The impact is higher on the agricultural commodities used to produce the biofuel. For instance, vegetable oil, cereals, wheat and sugar. Unfortunately, those commodities are highly correlated with food prices (refer to Figure 1.2), strengthening the influence of biofuel production on food prices.

Based on Table 1.1, vegetable oils are forecasted to have a high impact on price due to the biofuel productions in biofuel policy and the blended mandates in both the European Union region and the multi-region level. Thus, it is expected to increase about 36 per cent and 35 per cent by 2020, respectively, followed by cereals, sugarcane, wheat, and others[6]. The lowest impact is on the wheat price, which is projected to be 13 per cent in the European Union, and oilseeds at the global level, i.e., about 7 per cent, followed by wheat. Thus, the forecasted price effect of this commodity could be due to the spillover effect due to the other agriculture commodities' price effects.

Table 1.1: Summary of Studies (in percentage) Forecasting Agricultural Commodity Price Effect in the Year 2020

Feedstock (Group)	Range of Price Effect Commentary
Studies that focus on the effects of the European Union biofuel policy	
Oilseeds	8 – 20%
Vegetable oils	1 – 36%
Cereals/Maize	1 – 22%
Wheat	1 – 13%
Sugar (cane/beet)	1 – 21%
Studies that analyse the impacts of global/multi-regional biofuel mandates	
Oilseeds	2 – 7%
Vegetable oils	35%
Cereals/maize	1 – 35%
Wheat	1 – 8%
Sugar (cane/beet)	~10%

Source: Kretschmer, Bowyer and Buckwell (2012).

Remarkably, the food price responds positively to the agricultural commodities price changes. According to Tadesse et al. (2013), the international market prices of agricultural commodities increased more than doubled during the 2007-08 food crises. This statement further strengthens Arshad and Hameed (2009) by identifying that the food price increase due to the demand for agricultural commodities is chasing the supply. Furthermore, those authors indicate that higher energy price increases production costs in nature. The

[6] Vegetable oils are the oil extracted from plants such as palm oil, coconut oil, corn oil and others. Basically, vegetable oils are used in food production, cooking and as supplements. Palm oil is the largest cooking oil produced globally. Its production among is 75.88 million tonnes in 2020, followed by soybean which is 58.62 million tonnes (FAO, 2022).

debates on the food-biofuel-energy in literature well justify this. Thus, how significant biofuel's impact on the agricultural price hike is an exciting issue to be explored.

Interestingly, Chong et al. (2021) argued that the effect of biofuel production on the food supply chain is still unclear. Hence, Piesse and Thirtle (2009) added that appropriate action is needed since the agricultural sector can provide sufficient food and energy in the future. These are exciting structures to be explored since this is directly related to the future sustainability of livelihood, the environment, and the economy. Accordingly, the scope of the study will be narrowed down to Malaysia, and the issue of food prices, economic growth, palm oil and biofuel will be further discussed.

1.1 Background of the Study

The discussion will concentrate on a country basis to explore the nature of relationships. Malaysia will be a sample country to investigate the structural relationship between the agricultural commodity market, industrial outputs, biodiesel, and food prices[7]. Malaysia is a developing country (upper-middle-income economy) and one of the 13 countries where the recorded average growth of more than 7 per cent per year for more than 25 years (World Bank,

[7] Biofuels encompass a variety of biological source fuels, including bio-ethanol, bio-gas, and biodiesel. The production of biofuels varies depending on the available resources in a given country. Specifically, in Malaysia, biodiesel derived from palm oil serves as the primary bioenergy source for industries and transportation. Throughout the text, both terms, 'biofuel' and 'biodiesel,' will be consistently employed as needed in the discussions to maintain precision and clarity.

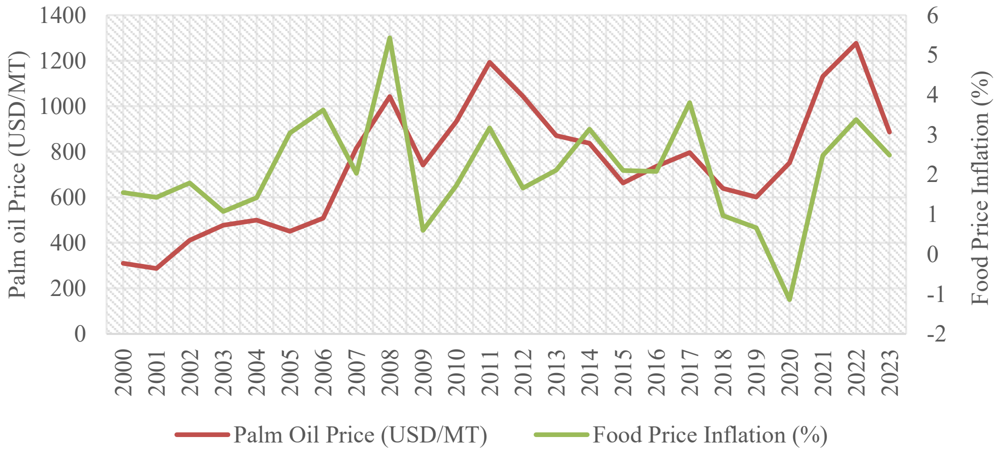
2019)[b]. With Malaysia's industrial growth and growing population, the food price increases trend by year. Interestingly, food price inflation is a hot topic debated in Malaysia, especially after the COVID-19 pandemic. According to the Department of Statistics Malaysia (DOSM, 2022), the food price, consisting of food and non-alcoholic beverages, recorded an average rate of 3.2 per cent in 2021 compared to only 1.2 per cent in 2020. This is a worrying situation whereby the food price hike may raise the price of basic and necessary products, burdening low-income families.

Figure 1.3 shows Malaysia's food price inflation from 2000 to 2020. Based on Figure 1.3, The average food inflation from 2000 to 2020 is recorded at 2.294 in Malaysia, whereby the highest is recorded in 2008, i.e., 5.43, and the lowest is in 2019. The food price hike in 2008 was due to the global financial crisis. Overall, it is observable that the food price in Malaysia has highly fluctuated over the years. Business Today (2022) reported that increasing food prices will affect the living cost among Malaysians. Due to this, the government introduced some initiatives to control food prices, such as MYR 31 billion allocated as subsidies for petrol, diesel, cooking oil and flour in Budget 2022. Interestingly, the government focused on stabilising the cooking oil price in 2022, whereby MYR 400 million was allocated for the price control mechanism programme until March 2022. This stressed the importance of the cost of cooking oil (vegetable oil) other than the petrol/diesel price in controlling the price of food (Business Today, 2022).

Further, narrow down the discussion on the crops produced domestically. The palm oil industry is known as the key to national economic expansion. Malaysia is the second leading exporter of palm oil globally, whereas Indonesia is the most extensive palm oil planting and export country in the region. Malaysia and Indonesia account for approximately 85-90 per cent of world palm oil production (Voora et al., 2019). According to the Malaysian Palm Oil Cooperation (MPOC, 2017), Malaysia produces 12 per cent of the world's oil and fat and 27 per cent of the total world exporter of oil and fat. In 2016, palm oil was Malaysia's top five export earner after electrical and electronics products, chemicals, petroleum products, and natural gas (Trading Economics, 2017). It has recorded about 5.1 per cent of the total export revenue of Malaysia.

In addition, based on the global perception, the International Union for Conservation of Nature (IUCN, 2018) indicates that about half of the world's population depends on palm oil as part of their food. The organisation added that palm oil is the dominant used oil in food in Asia and Africa. Besides, Tullis (2019) further strengthens the statement by indicating that India, China, and Indonesia account for about 40 per cent of palm oil consumed worldwide for cooking. Those arguments clearly show that palm oil plays a vital role in food in the local and international markets. So, it is rationalised why the government should subsidise cooking oil to control food inflation in Malaysia.

Accordingly, Figure 1.3 shows the integration between palm oil prices and food price inflation in Malaysia from 2000 to 2023. Based on the figure, palm oil price offers high co-movement with Malaysia’s food price, especially from the year 2006 onwards, whereby before the years, there was a lack of coordination between the food price and the palm oil price. Based on the correlation statistics, the correlation between the palm oil price and food between 2000 and 2006 was about 23.34 per cent. However, the correlation improved from 2006 to 2023 by 56.45 per cent. This phenomenon questioned why the integration between palm oil and food inflation doubled after 2006.



Source: FAO (2024) and WorldBank (2024).

Figure 1.3: Malaysia's Price of Palm Oil and Food Price Inflation from 2000 to 2023.

Interestingly, on the other hand, Malaysia's biofuel policy was introduced in 2006, and the country started its biodiesel production from 2008 onwards. So, the increasing correlation between palm oil and food prices leads to the assumption that biodiesel production could be a reason for the growing integration between palm oil and food prices in Malaysia. Thus, this aligns with the cost-of-production theory of value, whereby the food price is determined by the crops used as feedstocks in food production (Gordon, 1959). Besides, the pricing theory indicates that the cost of the product and services is determined by the supply and demand of the market where the equilibrium is achieved (Weyl, 2019).

According to the European Union Delegation to Malaysia (2012) report, roughly three-quarters of palm oil goes into foodstuffs production. The balance goes into industrial products such as chemicals, animal feed, and fuels. In addition, Dutta et al. (2021) indicated that about 75 per cent of the global palm oil production is used in food production plants. Furthermore, the Chief Executive Officer of Malaysia Palm Oil Council, Datuk Dr Kalyana Sundram, highlighted that the forecasted high price of palm oil in 2021 might be suitable for this industry but not for the food industry as its translation to increase the cost of production (Neo, 2021)[8]. Besides, the argument is supported by the study of Mosarof et al. (2015), which indicated that higher palm oil prices might impact the residents who regularly use palm oil in food.

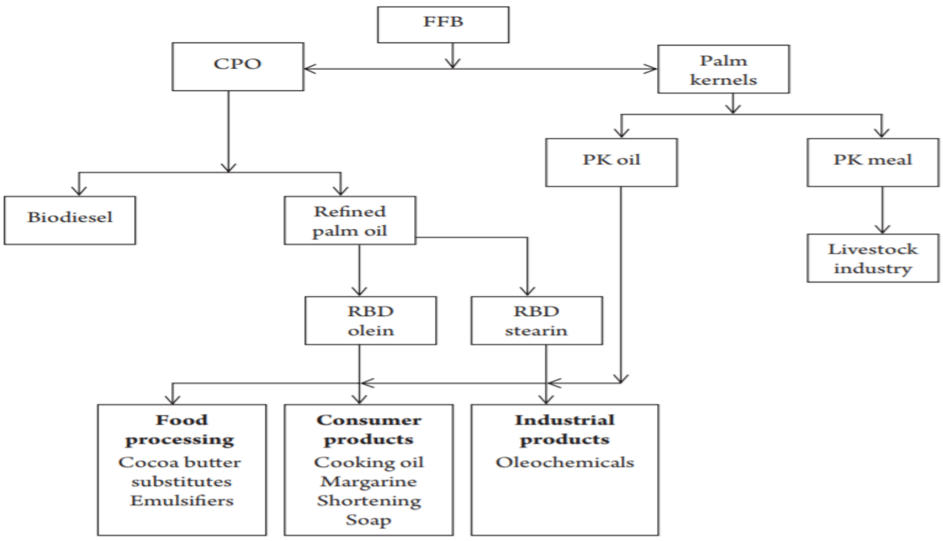
Due to the production of biodiesel, the palm oil industry faces the challenge of diversifying palm oil production into two components, i.e., food production and alternative oil production. Arshad and Hammeed (2008) claimed that about 100 million tonnes of cereals were distracted from human consumption to fulfil the fuel thirst of vehicles in developed economies. Accordingly, Plantation Industries and Commodities Minister Datuk Dr Mohd. Khairuddin Aman Razali said the Blended mandate 20 per cent (B20) biofuel

[8] Refined palm oil and refined palm stearin are also available and are suitable for various food-uses. The four main traditional uses of palm oil in food products are for cooking/frying oil, shortenings, and margarine and confectionary fats. Palm oil is popularly used in both solid fat products as well as in the liquid cooking oil sector especially in industrial frying applications (Malaysian Palm Oil Board, MPOB, 2021).

program would require about 1.06 million tonnes of palm oil to serve the local consumption of biodiesel (The Malaysian Reserve, 2020). Nevertheless, this could directly impact food prices in the future since the demand for palm oil will be diversified into food production and alternative energy production in Malaysia, as Ibrahim (2015) argued. This could create price pressure on palm oil and be reflected in the final products due to the higher cost of production.

Accordingly, Figure 1.4 shows how the food market of Malaysia will be impacted due to the palm oil downstream processing. The figure shows the palm oil value chain activities, indicating how the palm oil channels to food processing, industrial products, and chemical production. Figure 1.4 shows that fresh fruit bunches are divided into Crude palm oil (CPO) and palm kernel oil. According to Byerlee et al. (2016), about 75 per cent of the CPO is used for food and others for biodiesel, palm oil-based products such as soaps, and finally, to produce chemicals for industrial use such as polyols, polyurethanes, and polyacrylates. Accordingly, the additional demand for biodiesel production due to the growing demand could pressure the CPO route based on the availability of crude palm oil. Based on the law of supply and demand, this phenomenon could indirectly influence the price of food products transmitted from increased vegetable oil. Thus, this is an exciting area to explore.

Interestingly, the Food and Agriculture Organization of the United Nations (2022) published a recent report indicating that one of the reasons for the global food price increase in January 2022 is vegetable oil, mainly dominated by palm oil. The report further stressed that the vegetable price index recently jumped to 4.2 per cent due to supply-side constraints. Furthermore, the additional demand created by biodiesel could impact the global market's vegetable oil supply and demand. This may influence food prices. Therefore, identifying the influence of biodiesel demand and palm oil prices on food prices is essential to understand the role of the palm oil industry on the food price in Malaysia. Besides, the potentially significant relationship between palm oil prices and food price fluctuation can enhance the existing role of palm oil towards economic growth and develop a new chapter in the socio-economic in Malaysia. Thus, the discussion will be narrowed to palm oil outputs and biodiesel production/ demand based on palm oil feedstocks and the role of industrial growth in Malaysia's food price hike.



Source: Adopted from Byerlee et al. (2016).

Figure 1.4: Palm Oil Value Chain Activities (Refining Process)

1.1.1 The Interrelation of Palm Oil Industry and Bio-diesel Production/ Demand to the Food Price in Malaysia

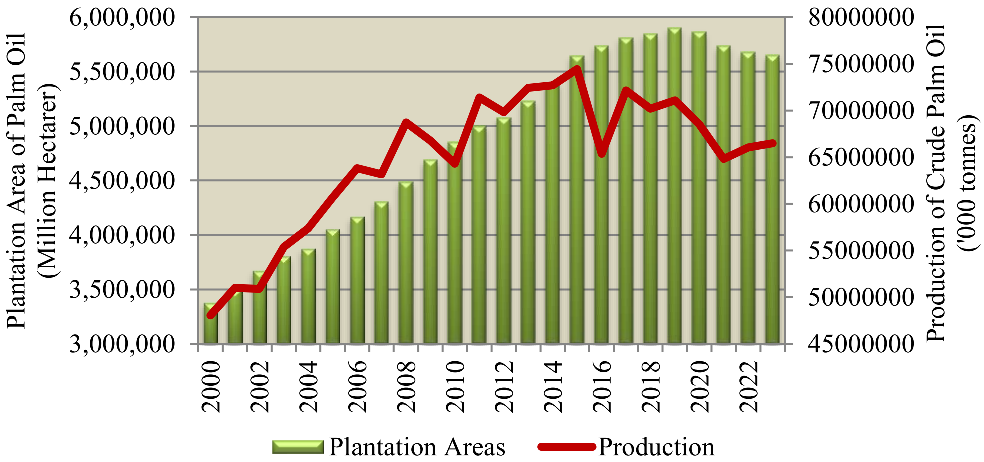
The palm oil industry has become significant and active in Malaysia recently. The palm oil plantation in Malaysia has already crossed 100 years; subsequently, the sector is a successful contributor of oils and fats in the world, giving this country an advantage. According to Teoh (2002), the British government introduced the oil palm plantation in 1871 as ornamental plants for landscaping in Malaysia[9]. Rubber and tea were the primary commodities driving the agricultural sector during that period. Palm oil was introduced as a commercial plantation in the *Rantau Panjang* (Selangor) in 1911 to replace the coffee plantation, which was unsuccessful. Teoh (2002) added that workers from India were brought to work in the palm oil plantation area.

Accordingly, after independence in 1957, the palm oil sector developed rapidly. The palm oil sector started to grow due to the various schemes and assistance from the government. In early 1960, the Malaysian government began diversifying the economy to other alternative crops since rubber and tin prices were unstable in the world market. In this situation, the government promoted palm oil plantations to reduce the dependency on rubber and tin. Hence, the palm oil plantation effectively increased from only 400 hectares in the 1920s to 3.4 million hectares in 2000. This amount reached 5.9 million hectares in 2020 (MPOB, 2021). Due to the active expansion of cultivation areas in East Malaysia

[9] Teoh, Cheng Hai is an advisor of Plantation Agriculture, Worldwide Fund for Nature (WWF) Malaysia.

(Sabah and Sarawak), oil palm has become the biggest plantation crop in Malaysia. Hence, Sabah and Sarawak covered about 1.543 million hectares and 1.585 million hectares, respectively, in 2020 (MPOB, 2021).

The production and the plantation area of palm oil are shown in Figure 1.5. According to Awalludin et al. (2015), palm oil plantations have increased dramatically in Malaysia. This can be seen in Figure 1.5, whereby the plantation areas of Palm oil in Malaysia show an increasing trend from 2000 to 2023. The growth rate of palm oil plantations is about 74.73 per cent from 2000 to 2023[10]. Furthermore, due to the increasing plantation, crude palm oil production also shows a growing trend. Based on Figure 1.5, even though palm oil production fluctuates in the growth rate, overall, it offers an increasing trend by year from the year 2000 to 2020 and a slight drop from the year 2020 onwards.



Source: MPOC (2024); Central Bank of Malaysia, Monthly Statistical Bulletin September 2024

Figure 1.5: Plantation and Production of Palm Oil in Malaysia from 2000 to 2023

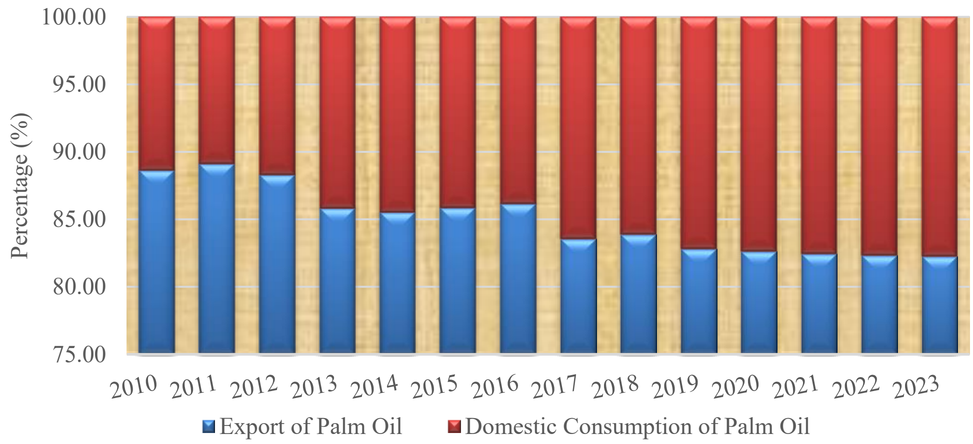
[10] There is a slight drop in the plantation and production of palm oil in Malaysia for year 2020 to 2023. The decrease rate is about 0.594 and 3.61 percent for the plantation and production rate, respectively. This drop is expected due to the Covid-19 pandemic impact on the palm oil industry and other issues such as labour shortages.

The weather plays a vital role in the production of palm oil. For instance, the drop in production in the years 2010 and 2016 is mainly due to the El-Nino climate condition (The Business Times, 2016; Zulqarnain et al., 2020). Palm oil production dropped about 10 per cent in 2016 due to this El-Nino climate. At the same time, the output in 2010 decreased due to the replanting process in the years 2009 and 2010. Interestingly, both of these drops increase the price of palm oil, and the food price inflation is also rising. This can be viewed in Figure 1.3, whereby the price of palm oil boomed in 2011 and 2017 after El El-Nino, and the food inflation of Malaysia is responding well to these jumps. This fluctuation directed the understanding to the possibility of an asymmetric effect between palm oil prices to food prices in Malaysia. As theory of *Nonlinear Supply and Demand Dynamics* acknowledges that factors influencing supply and demand, such as weather patterns and consumer preferences, may have non-linear relationships with price. For example, extreme weather events might cause a sharp drop in supply, leading to a disproportionately large price increase compared to the gradual price decrease experienced with a moderate surplus. This is an interesting viewpoint.

The growing palm oil production should increase Malaysia's palm oil exports. Interestingly, the export growth rate of palm oil shows a slowly decreasing trend in Malaysia by year, especially from 2010 onwards, even though the quantity of palm oil exports shows an increasing trend (MPOC, 2021). The growth of palm oil exports from 2010 to 2016 is -3.71 per cent (Economics and Industry Development Division, 2017). Besides, based on the data supplied by MPOC (2021), the palm oil export growth rate from 2000 to

2010 was 62.12 per cent. However, the growth rate from 2011 to 2020 was only -1.77 per cent. This phenomenon led to the palm oil drop from the second-highest export earner in 2011 to the top three in 2021 in Malaysia (Ministry of International Trade and Industry, MITI, 2021).

Consequently, the drop in the palm oil export growth rate is further explored. Thus, Figure 1.6 shows the proportion of exports and domestic palm oil consumption from the total production from 2010 to 2023. The figure clearly illustrates that the proportion of palm oil exports is reducing, and domestic consumption has increased over the years. In 2010, the total palm oil export was about 88.61 per cent of the entire production, and the balance of 11.39 per cent was for domestic use. However, the export values in 2023 reduced to 82.26 per cent, and domestic consumption increased to 17.74 per cent. The growth rate of quantity used for domestic usage is about 52.24 per cent from 2010 to 2023. This incident indicates that by year, more palm oil production portions are used domestically for food, palm oil-based products, and biodiesel production in Malaysia. The figure clearly shows that the importance of palm oil to the local market keeps increasing by the year.



Source: USDA (2024)

Figure 1.6: The Export and the Domestic Consumption of Palm Oil in Percentage from 2010 to 2023.

The data supplied by the United States Department of Agriculture (USDA, Foreign Agricultural Services, 2021) further supports the statement. The organisation indicates that the feedstock used for biodiesel production in Malaysia increased dramatically from 119,000 metric tonnes in 2010 to 1,362,000 metric tonnes in 2019. Palm oil usage as feedstock for biodiesel production increased by about 1044.58 per cent in just nine years (refer to Figure 1.7). Accordingly, this creates an assumption that the government is more focused on producing biodiesel than palm oil export income. To support this assumption, the minister of the primary industry of Malaysia indicates that the government is committed to increasing the blend of biodiesel with diesel petroleum in the domestic market for a cleaner environment. In line with that, the Government has allocated RM35 million to undertake the engineering design involving 35 depots to implement Malaysia's B20 and B30 agenda (Global Oil and Fat Online, 2020). Thus, it shows that biodiesel production and usage will increase with transportation and industrial use.

Hence, the growing demand for biodiesel production is a new element in the palm oil market. For now, about 16 biodiesel refineries are operating in producing biodiesel in Malaysia (Yusoff et al., 2021). This is considered an expansion of the palm oil industry, suitable for the country's economic condition and contributing to the farmers' income. Due to the global warming issue, the awareness of using more sustainable fuels compared to fossil fuels is rising internationally. Accordingly, Malaysia introduced the *National Biofuel Policy* on March 21, 2006. The objective of the National Biofuel Policy is "*to use an environmentally friendly and sustainable energy source to reduce dependency on fossil fuels and stabilise and boost palm oil prices*" (USDA, Foreign Agricultural Service, 2016). The development of the biofuel industry in Malaysia aims to reduce the greenhouse gas (GHG) emission rate by 45 per cent of GDP by 2030.

In Malaysia, biodiesel is mainly produced using palm oil. Thus, based on the law of demand and supply, the increase in biodiesel usage is expected to boost the price of its feedstock, as stated in the objective of the National Biofuel Policy of Malaysia. In this case, growing demand due to the higher blended requirement in transportation and industrial domestically and internationally for biodiesel is expected to increase the palm oil price. Besides, under the National Biofuel Policy, biodiesel production and supply mainly focus on transportation, industry, and exportation. According to the annual report of the USDA Foreign Agricultural Service, the parliament of Malaysia passed the *Biofuel Industry Act* in 2007. This act allowed the Ministry of Plantation Industries and Commodities to implement a biodiesel blend in the industrial sector. However, the National

Biofuel Policy excludes ethanol as a source of alternative fuels. This is because ethanol is not used as a source of energy, other industrial chemicals, and beverages due to a lack of advanced technology, requires high capital investment, and it is hard to find a constant feedstock supply. These challenges lead to no significant ethanol production in Malaysia using biomass (USDA, Foreign Agricultural Service, 2016).

Based on the Biofuel Industry Act, the biodiesel blend mandate of five per cent (B5) consists of five per cent of total diesel used in the industrial sector starting June 1, 2011[11]. The five per cent of biodiesel indicates that five per cent is represented by biodiesel from the total diesel usage, and 95 per cent is pure diesel. So, the blend of five per cent biodiesel can reduce the use of pure diesel in production to a certain level. Thus, it could achieve the objective of the National Biofuel Policy, which mainly focuses on reducing the dependency on fossil fuels in the long run. Accordingly, biodiesel is primarily used in the industrial sector as a source of material to heat boilers and generate electricity. Furthermore, Malaysia's crude palm oil quantity blended increased to B7 (usage of seven per cent biodiesel) in 2015.

In addition, the B10 blended mandate was supposed to be implemented in mid-2016 for the transportation sector in Malaysia but has been delayed to the end of the year. This is because the industry shareholders and the vehicle suppliers argued that a higher amount of biodiesel blended into the diesel could

[11] Biodiesel blend mandate started in Central region (Negeri Sembilan and Selangor) first on 1st June 2011, followed by Southern region (Malacca and Johor) on 22nd June 2012. Then, Northern region (Perak, Penang, Kedah and Perlis) on 1st October 2013 and finally, in East Coast states of Pahang and Kelantan in February 2014.

reduce the performance of the current engine. Furthermore, the suppliers added that the current engines must be modified to ensure the vehicle can adapt to the B10 blended mandate, which will consume some time. This is the main reason for the delay in adopting B10 in 2016. According to the USDA Foreign Agricultural Service (2016), full implementation of B10 in the transportation sector (road and sea) and B7 in the industrial sector will increase biodiesel consumption to 770.7 million litres in 2017.

Table 1.2: Planned and Actual Roll-Out of Blended Requirements

Blend	Transportation Sector*		Manufacturing Sector**	
	Planned Roll-Out	**Actual Roll-Out**	**Planned Roll-Out**	**Actual Roll-Out**
B5	2008	2011 (Central Region) 2012 (Southern Region) 2013 (Northern Region) 2014 (Nationwide)	None	None
B7	January 1, 2015	2016 (Nationwide)	Early 2019	July 2019
B10	Early 2019	February 2019	No Plans	No Plans
B20	2020	2020 (Langkawi & Labuan) 2021 (Sarawak)	No Plans	No Plans
B30	2025		No Plans	No Plans

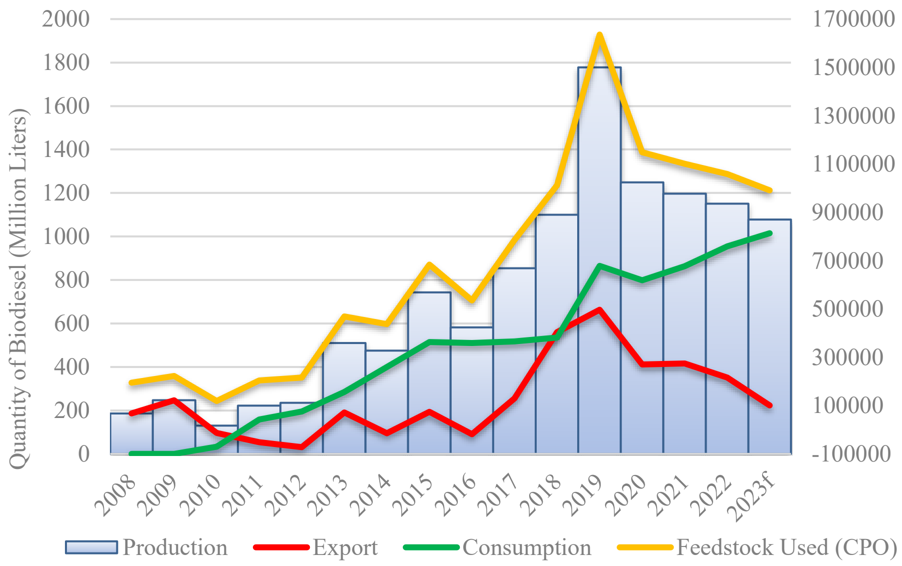
Source: USDA Foreign Agricultural Service, Biofuel Annual Report, 2023.
Notes: * Cars, trucks, vans, pickups, and small fishing vessels.
** Diesel boilers

Furthermore, as a long-term plan, the 11th Malaysia Plan (2016-2020) included having B15 on-road transportation by 2020. Table 1.2 shows the roll-out of the blended requirement in Malaysia for the transportation and manufacturing sector. Accordingly, Aziz (2021) indicates that the B20 blended mandate programme for transportation will be implemented in phases in Malaysia. The programme was launched on Feb 20, 2020. it started in Langkawi and Labuan and will be introduced to other regions in Malaysia. Besides, according to the Ministry of Plantation Industries and Commodities (MPIC), Malaysia is looking forward to implementing the B30 biofuel programmes by 2030 or earlier based on sufficient technical data availability. This shows that biodiesel usage and demand in the economic sectors are increasing yearly. Notably, the pace of improving blended mandate in transportation is faster than the industrial usage in Malaysia. In the vehicle, up to B20 is already implemented until 2021. However, only up to seven per cent blended mandate has been introduced for the industrial sector. Thus, this could be due to the investment in the limited industrial technology in Malaysia, whereby advanced technological machinery is needed to cope with the high blended requirements.

Besides, the growing blended mandate requirement in transportation and industrial growth could increase Malaysia's biodiesel demand. Figure 1.7 shows biodiesel production, export, and domestic consumption from 2008 to 2023f, whereby production and domestic consumption show an increasing trend in Malaysia. The biodiesel production in Malaysia recorded about 570 per cent of the growth rate from 2008 to 2020 and dropping trend after 2020. Furthermore, Figure 1.6 shows that in Malaysia's beginning phase of biodiesel production, almost all the outputs were exported to other countries until 2009. After 2010, the domestic consumption of biodiesel has increased until now. The biodiesel consumption is 1015 million litres in 2023 compared to no consumption in 2009.

Consequently, the export level remains significantly unchanged from 2008 to 2016. However, from 2016 to 2019, there has been some dramatic improvement in biodiesel exports. This could be due to consistent improvement in biodiesel production from 2016 to 2019, as shown in Figure 1.7. Nevertheless, there has been a consistent drop in the export of biodiesel till now. Notable, biodiesel production is influenced by palm oil production. Due to unfavourable weather conditions, these components have a trend whereby palm oil production dropped in 2010 and 2016 and after the year 2020. Similarly, biodiesel production decreased as well for those two particular years. Thus, it clearly shows that the palm oil supply plays an essential role in biodiesel production in Malaysia.

In addition, the feedstock used (crude palm oil) in biodiesel production also increases yearly. Based on Figure 1.7, the feedstock used in biodiesel production increased by about 416.67 per cent from 2008 to 2020. These statistics indicate that crude palm oil usage in biodiesel production increased four times in 12 years. This figure supported the previous arguments that domestic palm oil consumption is rising, and the export level is dropping significantly (refer to Figure 1.6). Accordingly, increasing palm oil crops in biodiesel production will increase the demand for palm oil crops. Consequently, this is expected to increase the price of palm oil in the coming years, whereby Applanaidu et al. (2011) identified that an increase in the biodiesel demand could increase the domestic price of palm oil by about 13 per cent. Furthermore, Nurul et al. 2022) indicate that biodiesel development based on palm oil could create issues with high feedstock prices and food competition. Overall, this phenomenon is expected to impact food prices through increasing vegetable oil prices in Malaysia.

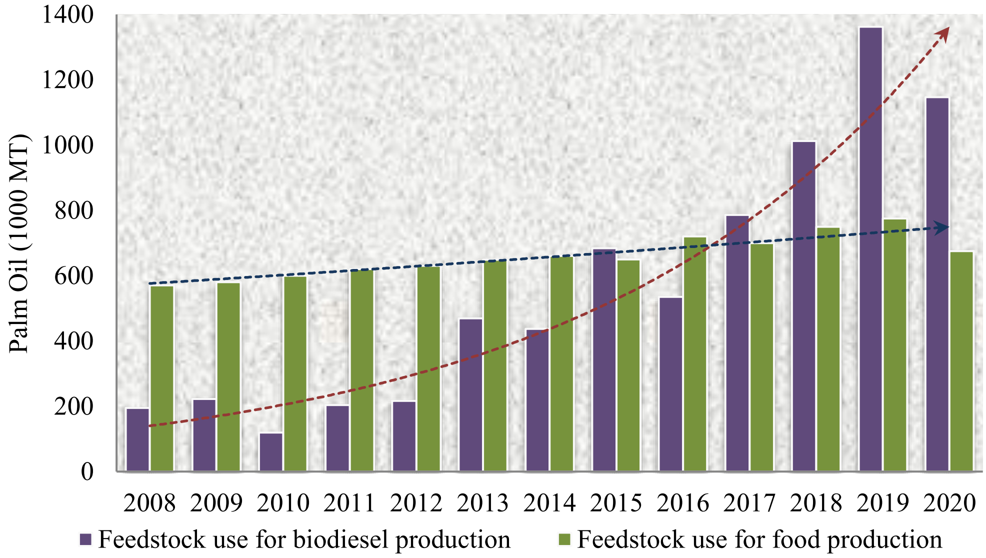


Source: USDA Foreign Agricultural Service, 2021
Note: (f) represents the expected value. CPO means crude palm oil.

Figure 1.7: The Production, Export, and Consumption of Biodiesel and the Feedstock Used in Producing Biodiesel in Malaysia from 2008 to 2023f.

Moreover, Figure 1.8 shows the direct competition of palm oil feedstock usage in biodiesel and food production. This figure shows the proportion of palm oil used in biodiesel and food production from 2008 to 2020. Based on Figure 1.8, the domestic consumption of palm oil was highly used in food production from 2008 to 2016. The palm oil usage in biodiesel production was less than the feedstock used for food production for the particular period. This could be due to the development of the biodiesel industry in Malaysia being in the initial stage. The blended mandate requirement was about 7 per cent only in transportation and industrial usage at that time. However, from 2016 onwards, feedstock usage for biodiesel production increased and surpassed the feedstock amount used for food production supported by favourable market conditions.

Interestingly, the feedstock used in food production shows a steadily increasing trend, whereas the feedstock used for biodiesel production shows an intense trend. This has been highlighted using the trend line in Figure 1.8. Thus, this figure shows the significant development of the biodiesel industry, competing for the feedstock of food production. Hence, it confirms the biofuel-food debates in the literature.

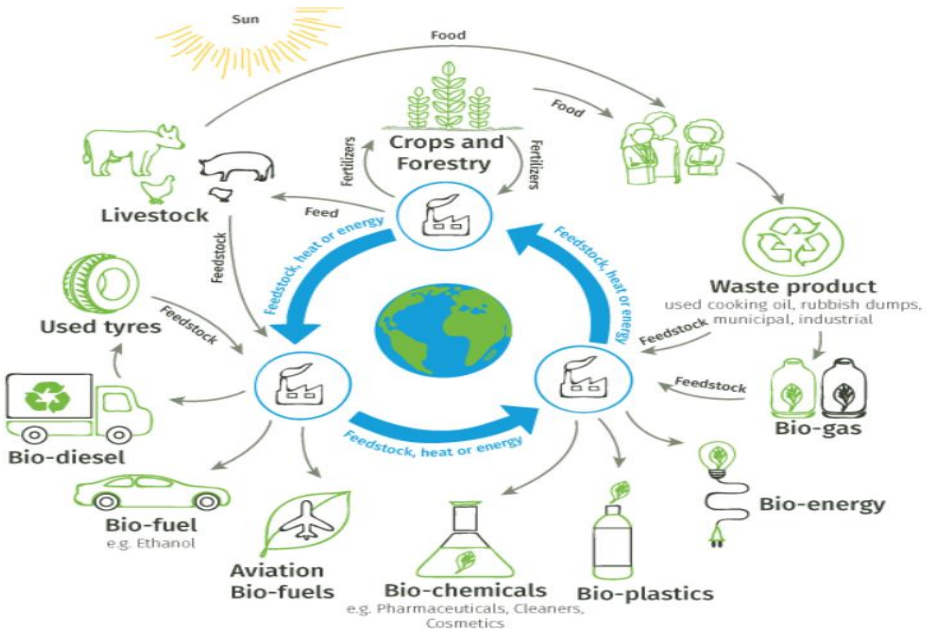


Source: Malaysia: Oilseeds and Products Annual, USDA (2021)

Figure 1.8: The Total Domestic Consumption of Palm Oil in Food and Biodiesel Production in Malaysia from 2008 to 2020

1.1.2 The Integration of Industrial Growth and Food Prices in Malaysia

Industrial growth is vital in integrating oil, commodity, and renewable energy. This can be reflected in Figure 1.9, which shows how the industry is connected to oil, agriculture commodities, and food at every value chain level. For instance, value-added activities are involved in every stage of production. Thus, industrial growth is vital in value-added activities regardless of renewable energy, agriculture, food production, or livestock. Besides, Malaysia's blended mandate effect is expected to increase the integration between biodiesel, commodity markets, and industrial growth. This is another exciting area that could create new insight into Malaysia's literature on renewable energy. Thus, the attention to the industrial-food relationship is fresh, and a proper understanding of these elements is necessary.



Source: Adapted from https://www.aurecongroup.com/thinking/thinking-papers/circular-economy-economic-development.

Figure 1.9: Interlinked between Biodiesel, Industrial Growth, and Food

Accordingly, the integration between the agriculture sector and industrial growth started in the National Agriculture Policy 3 (NAP 3) (1998-2010), whereby one of the objectives of NAP 3 is to deepen linkages with other sectors. Under NAP 3, two approaches have been introduced, i.e., agroforestry and product-based approaches. Accordingly, the product-based strategy can increase the downstream activities and strengthen the internal and external linkages between the sectors. This includes the expanding intermediate and supporting industries under the agriculture sectors.

Besides, the Malaysian government continues to undertake adjustment measures to expedite the industry’s competitiveness to face new challenges at domestic and international levels. Accordingly, the National Agrofood and Commodity policies were launched from 2011 to 2020. Subsequently, National Agrofood Policy 2.0 was established from 2021 to 2030 in Malaysia. The National Agrofood Policy 2.0 (2021-2030) aims to ensure food security and increase the income of the target groups and the national economy overall. This is incorporated and guided by the 12th Malaysia Plan, which focuses on modernising the agriculture sector in Malaysia while maintaining the balance between the supply and demand of the national food supply. Based on the mid-term review reports of the 12th Malaysia Plan, due to the focus on agro-food, the contribution of the agro-food industries to the manufacturing value-added is recorded as 18.3 per cent in the year 2020 in Malaysia (DOSM, 2020; Economic Planning Unit, 2020). Interestingly, since the National Agrofood Policy 2.0 is projected for the long term, i.e., up to 2030, the contribution of agro-food on the industrial value-added is expected to increase by the year.

On the other hand, the National Fourth Industrial Revolution (4IR) policy incorporated the agriculture sector as one of the keys out of the ten sectors under 4IR. Interestingly, based on the 4IR, the government targeted the growth of the agricultural sector by 55 per cent. Accordingly, under the potential benefits of 4IR, few are covering the scope of this study. The first is efficiency and productivity gains; this benefit could be linked to the energy market. When highlighting the efficiency, more advanced technology, which is more fuel-user-friendly, could be enhanced. This is interconnected to the next benefit of 4IR, which focuses on improving environmental quality. The higher blended mandate can mainly do this in the production process. Lastly, the 4IR focuses on improving the quality of life by job creation in various sectors. Thus, this supported the asymmetric effect as well, since the *Threshold Theory* that there are critical "tipping points" in an economy's development beyond which small changes can trigger large shifts in growth patterns. For example, reaching a certain level of technological advancement or infrastructure development might unlock new possibilities for rapid industrial expansion, creating an asymmetry where further small improvements lead to disproportionately large growth increments.

This is an essential element to concentrate on since it may increase the demand for food in Malaysia. Hence, this is how industrial growth is linked to the food price in the current study. Interestingly, industrial growth in Malaysia increases the population’s income and living standards. However, it may increase the food demand and demand for biodiesel used in production.

1.2 Problem Statement

Malaysia has experienced significant economic and industrial progress, leading to an annual increase in income and a subsequent rise in food demand.

The Malaysian government has strategically focused on industrial growth, particularly in the context of IR4, to enhance the income and living standards of its citizens. However, the surge in food demand has contributed to a rise in food prices in Malaysia, exacerbated by the limited availability of food in a country known for being a net food importer. Statistical data indicates a consistent upward trend in food prices over the years, posing a concerning situation that could disproportionately affect low-income families (bottom 40%, B40 families) and small to medium enterprises (SMEs) engaged in micro-level businesses within the food industry. To address the challenges posed by escalating food prices, the Malaysian government has implemented various initiatives and programs aimed at controlling prices, such as setting ceiling prices and providing subsidies. However, the sustainability of these initiatives remains a significant question. The effectiveness and long-term viability of these measures are subjects of uncertainty. Failing to address the issue of rising food prices effectively could result in social unrest and adversely impact the overall economic condition of Malaysia.

Drawing from existing literature, the exploration of food prices in Malaysia reveals a limited emphasis on the bioenergy sector, prompting a need for increased attention in the current landscape. The palm oil industry, playing a pivotal role in both the food and bioenergy sectors, holds substantial significance in Malaysia. The convergence of palm oil, energy, and food prices is becoming more pronounced, influenced by the financialization of commodities[12]. The

[12] The concept of the financialization of commodities tells that the commodities are treated as another investable asset to overcome the heating and creating spillovers in the financial market (Cheng & Xiong, 2013; Ordu-Akkaya & Soytas, 2020).

palm oil industry contributes vegetable oil, a highly tradable commodity globally and a primary cooking and frying oil in Malaysia. However, the recent expansion of the palm oil downstream industry, particularly in the production of biodiesel using palm oil, is anticipated to raise domestic demand for palm oil. This expansion could potentially drive up the prices of palm oil feedstocks, presenting an additional challenge for the food markets in Malaysia. This strategy has raised concerns about food sustainability, with arguments suggesting that biodiesel production may have a negative impact on future food availability and supply. The contention lies in the diversion of a portion of crops from human consumption to meet the demands of the biodiesel industry.

Furthermore, the anticipation of an increase in biodiesel production in the upcoming years is attributed to the government's dedicated focus and policies aimed at boosting the use of renewable energy while simultaneously reducing reliance on fossil fuels. The biodiesel industry in Malaysia is experiencing robust growth, driven by both global and domestic demands for biodiesel. An intriguing aspect is the dual role of biodiesel production, serving as fuel for domestic use, including transportation and industrial consumption, while also contributing to export earnings. Notably, both domestic consumption and export levels of biodiesel display a consistent upward trend annually in Malaysia. Consequently, this surge is poised to escalate domestic biodiesel demand within Malaysia's transportation and manufacturing sectors in the coming years, marking a significant step toward economic and environmental sustainability. However, the critical question of food sustainability looms large in this scenario. The intricate relationships between biodiesel demand, palm oil prices, and food prices in Malaysia remain inadequately explored, leaving the impact of growing biodiesel demand on food prices unanswered. While several researchers such as Khatun et al. (2017), Ghani et al. (2019), Johari et al. (2015), and Abdullah (2015) have highlighted the potential link between biodiesel and food price competition, most of these studies are conceptual and do not provide empirical validation. This notable gap in understanding forms the focal point of this study, as it seeks to address and shed light on the complex dynamics at the intersection of biodiesel demand, palm oil prices, and food prices in Malaysia.

The escalating demand for biodiesel has intensified the competition for limited agricultural lands, creating a dynamic interplay between food, fuel, and feed for humans. This scenario unfolds as users and downstream activities burgeon. Intriguingly, data analysis reveals that the integration between palm oil and food price inflation has been more pronounced from the year 2006 onwards compared to the periods preceding 2006. Significantly, it aligns with the introduction of the biofuel policy in Malaysia during that year. This issue warrants a two-fold perspective, examining it from both the impact of commodity market prices on food prices and the influence of bioenergy demand on food prices. These relationships, crucial in understanding the intricate dynamics at play, are yet to be well-established in the Malaysian context. The launch of the biofuel policy in 2006 provides a crucial temporal marker for investigating the evolving relationships between palm oil, food prices, and the broader implications of bioenergy demand on the food market in Malaysia.

Additionally, considering the perspective of growth, long-term policies such as the National Agro-Food Policy 2.0 (2021-2030) and the Fourth Industrial Revolution (4IR) introduced by the Malaysian government offer a distinct viewpoint on food prices in the context of Malaysia's industrial growth. According to the National Agro-Food Policy 2.0, agricultural outputs made a significant contribution to industrial value-added in 2020. Conversely, the 4IR initiative prioritizes agriculture, energy, and transportation among its ten focus sectors to drive new socio-economic growth in Malaysia in the coming years. Furthermore, the 4IR strategy emphasizes technology innovation and environmental concerns, acknowledging the role of renewable energy, including biodiesels, in production. Notably, the significance of industrial growth in relation to food price hikes becomes a pivotal issue in this context. This idea introduces a fresh perspective to the field of food-bioenergy studies, as well as the extent of the role played by industrial growth in influencing food prices. This is often omitted from empirical models despite its conceptual linkage, as highlighted by Serra and Zilberman (2013), and Janda and Kristoufek (2019). The scopes and implications of this relationship have yet to be comprehensively discovered, presenting an essential area for further research and investigation.

Furthermore, the integration of bioenergy concepts into Malaysia's energy-food relationship is relatively new. This is evident as the substantial usage of biodiesel in Malaysia's economic sectors is still in its early stages compared to our neighbouring countries. Malaysia's biodiesel sector remains relatively small in scale, making it less practical to assess impacts from production volume alone. Instead, the growing structural demand for biodiesel, driven by transport growth, blending mandates, and infrastructure development, could offer a more realistic lens for evaluating its potential influence on food price inflation. Consequently, obtaining an accurate and comprehensive understanding of the newly formed relationship between palm oil prices, biodiesel demand, industrial growth, and food prices becomes fundamental for the development of effective and sustainable policies pertaining to the palm oil industry, industrial growth, and food prices in Malaysia.

A proper understanding of the intricate relationships among these four components is crucial, considering the significant roles that biodiesels and food play in the context of sustainable development. A win-win solution must be sought for future sustainability. It is interesting to note that there has been a limited focus on exploring these variables in Malaysia. This limitation has resulted in a constrained understanding of the structure of the relationship between palm oil prices, food prices, industrial growth, and biodiesel demand. Addressing this gap in research and expanding the exploration of these variables in the Malaysian context is essential for a more thorough comprehension of the dynamics at play.

1.3 Research Questions

Based on the above problem statement, significant questions to be answered that can create new insight into the relationship and enhance the understanding among the variables understudies are listed below. To understand the relationship between palm oil prices, industrial growth, and food prices in linear form, the first research question is developed as below:

i. How do palm oil prices and industrial growth affect food prices in Malaysia?

Next, since there is an understanding of possible asymmetric effects that may exist between palm oil prices and industrial growth towards food prices in Malaysia, the second research question is formed as below:

ii. Do changes in palm oil prices and industrial growth have asymmetric effects on food prices in Malaysia?

The third research question is developed to understand the relationship between the biodiesel demand on the food price in Malaysia using the extended linear model. Since the biodiesel demand is not mutually exclusive to the palm oil price, the usage of an extended linear model is rational in this context.

iii. What is the impact of biodiesel demand on food prices in Malaysia?

Lastly, viewing the dynamic effect of the variables in the system is important to provide insight into sustainable policy-making under the bioenergy model in Malaysia. To vision this, the fourth research question is formed, as below:

iv. How do dynamic fluctuations in palm oil prices, industrial growth, and biodiesel demand impact food prices in Malaysia?

1.4 Research Objectives

1.4.1 General Objective

Based on the issues and the research question highlighted previously, this study aims to identify the determinant of food price using the bioenergy model. The study will investigate the impact in two different perspectives, i.e., commodity market and biodiesel demand on food prices. Thus, the general aim of this study is to create a comprehensive understanding of palm oil prices and industrial growth in food prices. Subsequently, extending the investigation to understand the effect of biodiesel demand on Malaysia's food prices. Accordingly, the specific objectives are listed below.

1.4.2 Specific Objectives

i. To examine the short-run, long-run, and causality relationship between the palm oil price, industrial growth and food price in Malaysia;
ii. To examine the existence of an asymmetric effect between the palm oil price and industrial growth on food prices in Malaysia;

iii. To examine the short-run, long-run, and causality relationship between the biodiesel demand factors and food price in Malaysia using the extended linear model;

iv. To analyse the dynamic effects of palm oil prices, industrial growth, and biodiesel demand on the food price in Malaysia.

1.5 Significance of the Study

Recently, food prices have been a hot issue debuting by global organisations such as the World Bank and Malaysia. The discussions on food price volatility are very rich in literature. Most studies summarised that population growth (for instance, Subramaniam et al., 2019; Mueller et al., 2011), higher per capita income (Akter & Basher, 2014), changing diets in developing countries(Bai et al., 2021), weather-related production shock (Kokpo et al., 2022), trade policy shock (Alnour et al., 2023) and the rising production for biofuel (Tanaka et al., 2023) are the most common factors that lead to food price volatility.

In the Malaysian context, reviews emphasize the issue of biodiesel as a significant factor contributing to the increase in food prices, particularly from 2014 onwards. Interestingly, there is a lack of significant studies indicating that biodiesel production or demand played a role in food price hikes in Malaysia before 2014. This observation underscores the evolving nature of this issue in the study of food prices in Malaysia. The limited impact before 2014 could be attributed to the early stages of biodiesel production in the country. However, as the demand for biodiesel production grows and its notable influence on palm oil prices becomes apparent, this issue gains prominence in Malaysia. This observation highlights that studies on the relationship between biodiesels and food are relatively young and emerging in the Malaysian context.

The research landscape concerning bioenergy and food prices in Malaysia remains underexplored, with minimal studies dedicated to this intersection. Despite a thorough review, no significant study on the relationship between bioenergy and food prices in Malaysia has been identified. Most of the recent studies on the food price in Malaysia emphasise that biodiesel could be a factor in the food hike in Malaysia, but no empirical evidence has been provided[13]. This underscores a substantial empirical gap in understanding the dynamics between bioenergy, particularly biodiesel, and food prices in the Malaysian context. Accordingly, the implication of this work centred on identifying (1) the relationship between the palm oil price and industry growth towards the food price using both linear and asymmetric models and (2) the relationship between biodiesel demand on the food price in Malaysia using the extended model; and finally, (3) dynamic effect of palm oil price, biodiesel demand and industrial growth on food price in Malaysia. By addressing these objectives, the research endeavours to contribute valuable empirical insights, bridging the existing gap in the literature and fostering a deeper understanding of the relationships between bioenergy, specifically biodiesel, palm oil price and food prices in the Malaysian context.

[13] Refer to study of Ibrahim (2015), Johari et al., (2015), Khatun et al., (2017), and Ghani et al., (2019).

The palm oil industry has significantly influenced Malaysia's growth. Simultaneously, palm oil plays a crucial role in providing vegetable oil to the global population, particularly in developing countries. The literature extensively examines the impact of palm oil on economic growth and the oil market (Parveez et al., 2020; Nambiappan et al., 2018; Hussein, 2017). Likewise, there is substantial research on the effects of biodiesel production/demand on palm oil prices (Dutta, 2021; Applanaidu et al., 2014). However, the exploration of the palm oil-food relationship remains limited. Understanding the influence of palm oil prices on food prices is vital for the sustainable growth of both the food industry and the palm oil industry in Malaysia. This study aims to bridge this gap by investigating the relationship between palm oil prices and food prices in Malaysia, utilizing both linear and asymmetric linear models. Employing these models will enhance and deepen our understanding of the impact of palm oil prices on food prices in the Malaysian context.

On the other hand, biodiesel production in Malaysia has considerable untapped potential for growth. Currently, fuel production has not even reached half of the biodiesel industry's capacity. The limited studies linking biodiesel to socioeconomic factors such as food security, income inequality, and rural livelihoods may be one of the reasons for the slow progress of the biodiesel industry in Malaysia. Most of the study on biodiesel in Malaysia is centred on the challenges faced by the industry (for instance, Nurul et al., 2022; Syafiuddin et al., 2020; Johari et al., 2015) and palm oil-biodiesel relationship (Johari et al. 2015; Applanaidu et al., 2014).

The lack of research on the socioeconomic impacts of biodiesel production could be a significant roadblock to the industry's progress in Malaysia. Furthermore, the increasing integration between industrial value-added and agriculture sector growth could guide the investigation of socioeconomic aspects in this study. This represents a novel and research-worthy area in Malaysia. Thus, gaining a foundational understanding of the relationship between commodities, fuel, industrial development, and food prices is crucial. The empirical evidence generated from this study may contribute significantly, manifesting in various ways, such as:

(1) The finding of this study could help understand and support designing sustainable policies without harming economic parties such as producers, wholesalers, and consumers, especially in the palm oil industry of Malaysia, which can provide food and fuel for sustainable growth. This helps smallholders/ entrepreneurs understand how biofuel expansion influences input price volatility. Encourages participation in sustainability certification (e.g., MSPO) aligned with food and fuel sector goals.

(2) Effective government policies for the palm oil and food sectors heavily rely on understanding the dynamics between their prices. This includes policies on biodiesel production, export controls, subsidies, and agricultural development. A clear understanding of the price relationship allows policymakers to design interventions that address concerns about food security, environmental sustainability, and economic stability. Government and policymakers can utilise the understanding created by

this study to balance biodiesel blending mandates with food price control policies. This study will create insights into palm oil price volatility to support fiscal planning and subsidy strategies in Malaysia. Furthermore, the study supports energy–food coordination in Malaysia's Low Carbon Mobility Blueprint and NETR.

(3) Studying the basic relationship between bioenergy and food prices opens doors for further research and innovation. This can include exploring alternative cooking oils, promoting sustainable palm oil production methods, developing more efficient biodiesel technologies, and identifying market mechanisms to stabilize prices. Such research can contribute to finding sustainable solutions for both food and energy needs in Malaysia. This study can highlight the risks of input competition with the food market to the biodiesel producers. Thus, the study can extend to use demand projections to plan capacity investment and price setting.

(4) Malaysia is a major palm oil producer and exporter, contributing to the global market. Studying the bioenergy-food price relationship within Malaysia can provide valuable insights and models for other countries (especially Asian countries) facing similar challenges in balancing food security, biodiesel production, and Industrial growth. Understanding the effect of palm oil price fluctuation on the food price to promote sustainable agriculture practices such as certification programs (Roundtable on Sustainable Palm Oil, RSPO) and efficient resource use within the palm oil sector can enhance resilience to market volatility and contribute to long-term socio-economic stability. Furthermore, it can

empower stakeholders, enabling better decision-making and helping mitigate the impact of asymmetric information. This is very helpful for food manufacturers in Malaysia. This study will create insights into cost-push pressures to help in pricing strategy, procurement planning, and input diversification. This will encourage long-term sourcing strategies for palm oil and vegetable oils.

Another noteworthy contribution of this study is its exploration of the biodiesel effect from the demand-side perspective, a less commonly examined angle compared to the traditionally studied supply side. In the literature, the demand side of biodiesels has historically been neglected, but its importance is gaining recognition (Cabrera-Jiménez et al., 2022; Rodionova et al., 2017; Mele et al., 2009). Demand-side analysis plays a crucial role in facilitating forecasting and decision-making processes. The increasing research efforts in this area are crucial for promoting sustainable biodiesel development, ensuring market growth, and navigating the complex interplay between market behaviour, environmental concerns, and policy interventions in Malaysia. Thus, this aspect adds another layer of uniqueness to this study.

Overall, this study contributes meaningfully to Malaysia's national agenda of achieving a balanced and sustainable development pathway by integrating food security objectives with renewable energy ambitions. Specifically, it aligns with key government frameworks such as the National Energy Policy (NEP) 2022–2040 and the National Energy Transition Roadmap (NETR). Both these policies emphasize the importance of transitioning towards cleaner energy sources without compromising economic and social stability. By empirically quantifying the trade-offs between biodiesel demand and food price fluctuations, this study provides critical evidence on how expanding biofuel mandates, if implemented without proper safeguards, could exert inflationary pressure on food markets, particularly in a country where palm oil serves as a major input for both fuel and food. The findings are especially timely as Malaysia seeks to increase its biodiesel blending levels (e.g., B20 and B30) to meet its decarbonization targets under the NETR while also ensuring that vulnerable populations are not disproportionately affected by rising food costs.

This study offers a data-driven framework to help policymakers evaluate the sustainability implications of future biofuel expansions, develop price stabilization mechanisms, and design targeted subsidies or diversification strategies that preserve food affordability without slowing progress toward energy transition goals. In doing so, it strengthens the evidence base needed to guide inter-ministerial coordination between energy, agriculture, and trade policies in Malaysia's climate and food policy landscape.

1.6 Chapter Layout

This research report will be split up into five chapters. Chapter One discussed the issue, the importance of this study, and the background. Chapter two will outline a brief review of empirical and theoretical literature review used to identify the things researched and covered previously in this area. Next, chapter three discusses methodology and data collection. Later, the results of applying the data in the method will be presented in chapter four. Then, chapter five concludes the research findings, and a discussion of the findings will be provided. Lastly, chapter six will provide policy implications and recommendations for future researchers and conclude the research.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter mainly reviews the earlier literature covering similar issues focused on this study. The relationship between food price, biodiesel, commodity market and industrial growth is considered a new research area that got researchers' attention after the Malaysian government introduced the *National Bio-fuel policy* on 21st March 2006. However, minimal studies have been conducted in this area based on the literature review, primarily examining food-bioenergy-commodity relationships. Most studies on biodiesel in Malaysia are mainly very recent published works from 2014 onwards. This is because Malaysia does not have significant biodiesel production before 2006. In this case, worldwide studies on biofuel production and demand are also considered to make the literature review more comprehensive.

This literature review is divided into four parts. The discussion will cover the relationship's theories and empirical support from earlier literature. The first part of the review will discuss the relevant theories and concepts underlying the relationship between the understudied variables. Understanding the theories and concepts that cover the relationship will be helpful in further exploration of the gap which is uncovered. Then, the empirical shreds of evidence from the previous studies will be explored in the second part. This section will give some ideas on how far the previous studies have been discovered and how the upcoming studies can be directed. Based on the empirical and theoretical exploration, the gap in the study will be discussed in the third section. Finally, the discussion will narrow down to the theoretical fundamentals among the variables understudies will be discussed to justify the appropriateness of the variables included in the food price study in Malaysia, which fulfilled the gaps identified earlier. Each relationship will be discussed in detail based on underlying theories or concepts.

2.2 Theoretical and Conceptual Background of the Energy-Bioenergy-Food Market Relationships

This section discussed the theoretical and conceptual background of the energy-biofuel-food market. Janda and Kristoufek (2019) highlighted that theoretical literature on biofuels indicates that biofuel policies have significant roles in the price transmission between the food and fuel markets. This statement supports the statement of Serra and Zilberman (2013), whereby the authors argued that the attempts to model food-energy price links theoretically are relatively new and mainly focus on assessing price level patterns. Thus, the overall structure of energy-biofuel-food price is founded by the *supply-demand framework*, which is widely used in energy-food studies (for instance, Zhang et al., 2009; Serra & Zilberman, 2013; Koizumi, 2015; Al-Maadid et al., 2016; Tanaka et al., 2023). The *supply-demand framework* illustrates that the price of goods and services is determined by market equilibrium, which fulfils supply and demand constraints. Thus, this concept is well fitted for the commodity markets, mainly depending on the production level and demand.

Accordingly, Mueller et al. (2011) indicated that the leading cause of the 2007/08 food crisis was a tight supply of crops, whereby demand was chasing the supply. Based on the authors, the food price increase is mainly due to the agricultural output shortage, creating price pressure on the commodities. This statement is engaged in the *demand and supply framework*. The outputs of agricultural production have been reduced in the past decade, whereby the demand for crops has increased worldwide due to the increasing population. In this case, the price of the crops goes up due to the demand.

Furthermore, emerging markets like China and India have experienced substantial per capita income and population growth. Accordingly, China and India recorded the highest revenue per capita in 2007, 14.088 per cent and 8.557 per cent, respectively (World Bank, 2017)[c]. Due to this, the food demand increased since the income growth changed the consumers' tastes and preferences towards high-value food items. Furthermore, based on the *Malthusian growth theory*, population growth is much faster than food production and availability. Thus, the rising population and urbanisation increase the demand for cereals, putting pressure on the world supply's downward trend. Accordingly, with the limited supply and the high demand, the food price suddenly jumped in 2007/08. This argument is based on the Malthusian and neo-Malthusian models and the demand-supply framework.

Accordingly, Zhang et al. (2009) argued that microeconomic theory illustrated that derived demand for crops influences the good intermediate quantity. Hence, the increased demand for fuel (traditional and biofuel) translates into a higher price, directly impacting crops' prices. Thus, it is reflected in the food prices in the end. Accordingly, the *cost-of-production theory of value* best explains this phenomenon whereby food prices are determined by the resources used in production, such as labour, raw materials, fuels and capital, as illustrated by the *cost-of-production theory of value* (Ruan, 2019). It provides a theoretical justification for the current food versus fuel debate since fuel is an essential component of the production factors.

Accordingly, researchers have developed a *bioenergy model* to narrow the scope of the *law of supply and demand* to biofuel studies. At first, Gardner (2007) claims that the bioenergy model's development originated based on the supply and demand framework. The author uses the vertical integration model to analyse the welfare effects of corn and ethanol subsidies in the US market. Thus, modelling the ethanol market separately from the fuel market is a significant weakness of Gardner’s (2007) model. The author argued that users of fuel are ethanol buyers. Thus, the users' gains through cheaper ethanol and ethanol increase the total fuel supply. In this case, Gardner (2007) assumed that ethanol and fuel are perfect substitutes, and price transmission depends on the cross-price elasticity between these two commodities.

Gardner’s (2007) model is extended by De Garter and Just (2008). Due to the blended mandates, they developed their model by integrating ethanol production into the aggregate fuel market. They argue that ethanol should be treated as a complementary product to gasoline due to the blended mandate. In this case, the demand for biofuel is proportionate to the demand for fuel consumption. De Garter and Just (2008) indicate that this situation has been overlooked. Thus, in another study by De Garter and Just (2009), the model used precisely with the fuel is represented by the ethanol and gasoline mixtures conceptually different from the study of Gardner (2007).

The models of Gardner (2007), De Garter, and Just (2008; 2009) mainly cover the structured relationship of the price transmission between gasoline and biofuel. Those studies focus on the tax and subsidy factors that influence the producers and the production level of commodities. The external factors that lead to the price determination seem to be neglected. However, Saitone et al., 2008) introduced upstream and downstream market power into the model. They argued that the upstream and downstream market power influences the market effect, which may pressure the price transmission between biofuel and agriculture commodity prices. Saitone et al., (2008) model illustrated that the upstream incorporates the seller market power and the downstream, indicating the buyer's market power founded by the supply and demand framework.

Finally, Ciaian and Kancs (2011) extended the existing model of Gardner (2007), De Garter, and Just (2008; 2009) with several dimensions which show the interconnection between energy-bioenergy-food prices and the byproduct market. The authors highlighted two significant drawbacks in the previous models, i.e., the demand function is modelled based on the agricultural commodity in the biofuel production. The indirect price input, which represents biofuel's price effect, is overlooked. The authors urged that discounting this effect could lead to an unfair assessment of the biofuel expansion on agricultural prices. Even the biofuel produced is based on crops. However, both are different sectors. In addition, the authors contended that only one agricultural commodity is used in the previous models, i.e., the commodity used for biofuel production. Thus, this may not be very accurate in measuring the effect of biofuel on agricultural commodities. The authors added that multiple commodities in the model might change the relationship structure, and the model will be general for the global market.

Ciaian and Kancs's (2011) model structure is shown in Figure 2.1. The model is structured based on four segments, i.e., farm input market, representing the production factors; agricultural production described by the crops; the fuel sector linked to the agricultural commodity through biofuel production; and finally, the fuel sector directed to the by-product markets. The authors illustrated the agricultural commodities used for food production and biofuel production. Here, based on the *cost-of-production theory of value*, the final price of the food is determined by the agricultural commodity prices since it is used as the raw materials for food production. Furthermore, biofuel production using the crops creates additional demand for agricultural commodities. Thus, the additional demand created by the biofuel market could impact the price level of the commodities in the equilibrium level in the *demand-supply framework*. This directed the impact of biofuel on the food market, which failed to be illustrated in the bioenergy model of Ciaian and Kancs (2011).

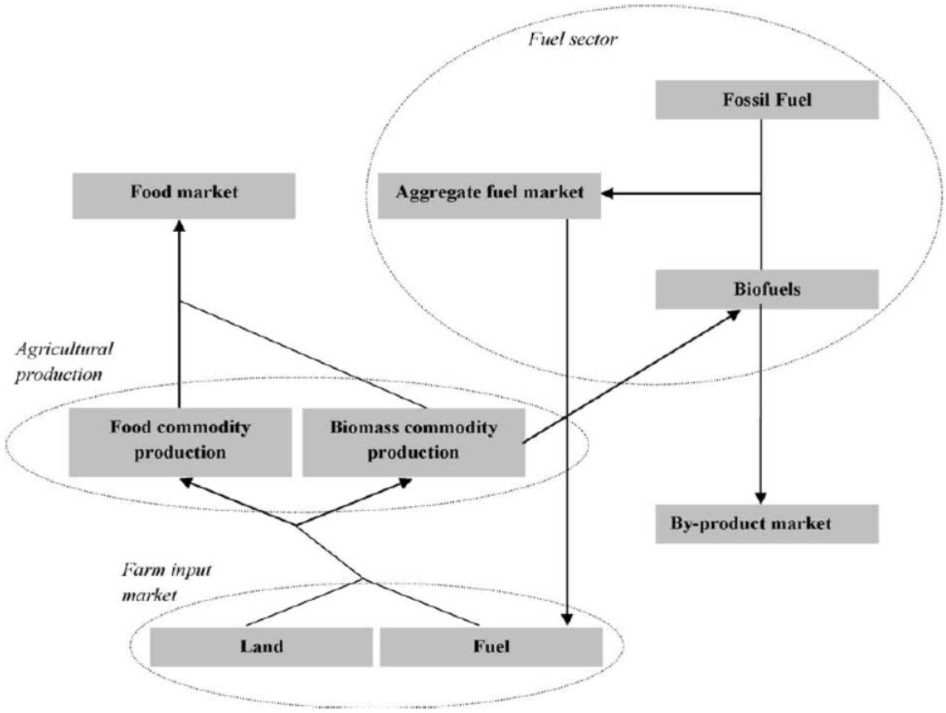
Besides, the blended effect of biofuel into the fossil fuel, introduced in the model, is used as the price input in agricultural commodity production[14]. So, based on the bioenergy model, the fuel market and agricultural markets are interconnected through price input due to the fuel usage as the production factor in the farm and the production of biofuel, which is blended with fuel. The price input of aggregated fuel affects agricultural outputs' production cost and indirectly links to the food. Thus, this direction can be viewed as a biofuel direction towards the food market, which can be considered in the bioenergy model of Ciaian and Kancs (2011). However, there could be another direction of interconnection between the fuel market and food, which the bioenergy model in Figure 2.1 does not explore. Since fuel is used as a factor of food production, it is expected to influence the food prices transmitted by the production and transportation costs.

Finally, based on the bioenergy model, the price input of aggregated fuel affects byproduct production through the industrial sectors and transportation. The increased use of blended biofuel in industrial production increases the fuel market's integration and industrial growth. Ciaian and Kancs (2011) highlighted this direction in the model as a by-product market from the fuel sector. However, the authors failed to see the interconnection between the by-product and the food markets. Fuel is the main element for producing food and industrial outputs. Accordingly, both food industries and non-food industries are competing for fuel. At the same time, additional demand created in the biofuel market, which

[14] Ciaian and Kancs (2011) indicate that fuel is importance for the agricultural production where it is used machineries, which is connected to the cost of production.

comes from industrial growth, could influence the food market by increasing the price pressure on the raw material of the food market, i.e., the agricultural commodities.

Furthermore, based on the unified growth theory proposed by Strulik and Weisdorf (2008), agricultural productivity makes food prices less expensive by increasing the availability in the market. However, industrial productivity makes the food price more expensive. Those authors added that the land limits agricultural production under the unified growth theory, whereby industrial production is not subject to land availability. Based on this concept, industrial growth is not defined by land creates demand for agricultural commodities with production constraints. In addition, Crafts (1996) and Voth (2003) highlighted that the *growth model* stressed that population growth leads to an economic transformation whereby industrial growth will be focused on. Thus, the development of industrial growth will increase the income of the people, and the living standard will improve accordingly (Rahman, 2016). Therefore, this could increase food demand and impact food prices. This could be another channel of price input that will affect the food price, whereby it fails to highlight the bioenergy model of Ciaian and Kancs (2011).

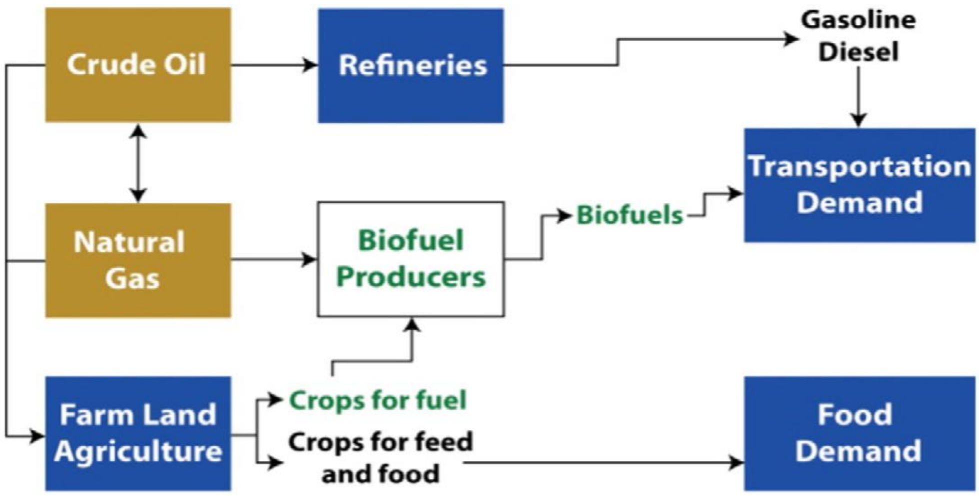


Source: Adapted from Ciaian and Kancs (2011).

Figure 2.1: Interdependencies in the Energy–Bioenergy–Food Market and By-product Market

Accordingly, Dobber et al. (2015) provided a clear conceptual framework (Figure 2.2) on the food-energy linkage overview, highlighting why the food demand has increased recently. The concepts of Dobber et al. (2015) and Ciaian and Kancs (2011) are almost similar. However, Dobber et al. 's (2015) structured model focuses more on the demand side of transportation and food. In this framework, the authors clearly show that agricultural production from farmland agriculture is divided into two usages, i.e., crops for feed (food) and crops for fuel. The crops for feed and food are directed to food production and supply (supported by studies such as Mitchell, 2008; Subramaniam, Masron & Azman, 2019; 2020; Tanaka et al., 2023).

However, crops for fuel are directed to the biofuel producers who supply biofuels for transportation, blended with crude oil (Drabik, Ciaian, & Pokrivcak, 2014; Dodder et al., 2015). In other words, the agricultural sector, which has supplied food and feed for livestock, is now providing biofuels for transportation and industrial production purposes. However, the framework developed by Dobber et al., (2015) is not complex, whereby the natural relationship between food-biofuel-fuel is a bit complex, as Tomei and Helliwell (2016) argued. For instance, the authors highlighted that crude oil impacts farm production. However, the framework does not show the interconnection between crude oil and biofuel. Furthermore, the authors treated crude oil and biofuel as different channels impacting the transportation demand.



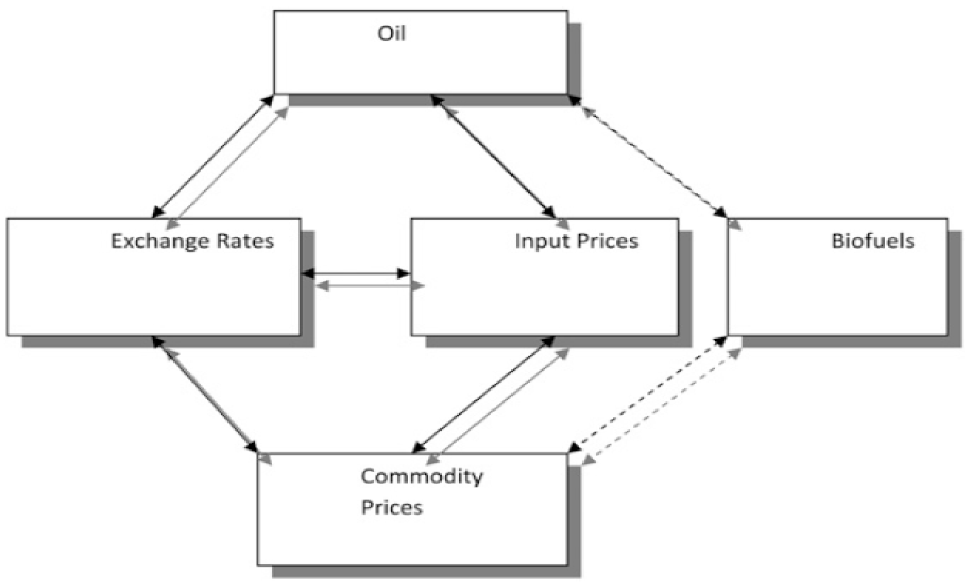
Source: Adapted from Dobber et al. (2015)

Figure 2.2: Overview of Agricultural-Energy Linkage

In addition, some authors developed the “financialisation of commodity markets” concept to interlink the agricultural commodity price fluctuation with crude oil. For instance, Juvenal and Petrella (2015) indicate that the financialisation of commodities increases the integration between oil prices and commodity prices. The concept of the financialisation of commodities tells that the commodities are treated as another investable asset to overcome the heating and creating spillovers in the financial market (Cheng & Xiong, 2013; Ordu-Akkaya & Soytas, 2020; Sun et al., 2023). Due to this issue, traders identified the commodities as high returns investments and treated them as stocks and bonds in the financial markets. Accordingly, some researchers such as Adams and Gluck (2015), Basak and Pavlova (2016) and Ordu-Akkava and Soytas (2020) urged that commodities have started increasing transmission stocks and commodities due to financialisation. This could be another direction in how the fuel market is interlinked to agricultural commodity prices.

Accordingly, Akram (2009) and Harri et al. (2009) represent the agricultural commodities' food prices. Therefore, Akram (2009) argued that the exchange rates could also explain the link between oil prices and agricultural commodity prices because the oil trade is conducted mainly in U.S. dollars and may have an impact on local currencies of all influences the agricultural commodity prices in turn of imports or exports and regional costs of the commodities. Thus, this idea can also be explained using the law of one price, whereby the asset price will be the same across the global market (Haskel & Wolf, 2001; Miljkovic, 1999; Go & Lau, 2024; Go & Lau, 2021; Mohd Amin et al., 2019). Thus, this can be achieved by considering the currency exchange between the countries. So, arbitrage profitability can be ratified with the same value of the assets and commodities across the market. Besides, Harri et al., (2009) concluded that there are two links between oil prices to agricultural commodity prices: price input and exchange rates, shown in Figure 2.3. They argued that the exchange rate affects the commodity price by the dollar's value, and the oil price affects the commodity production by input prices.

Interestingly, Harri et al. (2009) also conceptually illustrated the indirect impact of biofuel on commodity prices, which supports the statement of Ibrahim (2015) and Johari et al. (2015). This indirect relationship is due to biofuel production using agricultural commodities such as palm oil and soybeans. So, based on Figure 2.3, there are two direct relationships, and one indirect relationship is conceptually illustrated. Since there is a strong argument for the oil price influence on the food price (for instance, Timilsina, Mevel & Shrestha, 2011; Wong & Shamsudin, 2017; Dutta et al., 2021; Tanaka et al., 2023), the exchange rate, price inputs, and the biofuel production and demand could impact the commodity prices as well.

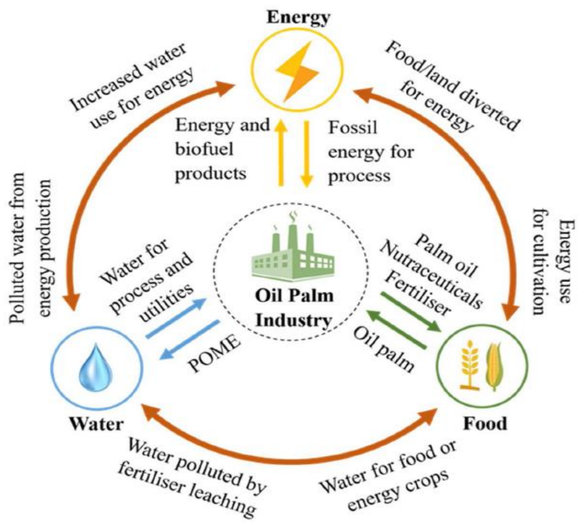


Source: Adapted from Harri et al. (2009)

Figure 2.3: Expected Linkages between Oil, Exchanges Rates, and Commodity Prices

Nevertheless, this situation creates competition between food, fuel, and feed for humans since agricultural lands are limited and the users are increasing. Furthermore, Koizumi (2015) argues that biofuel programs created a new crop market. The author added that most of the demand curve for agricultural commodities is inelastic to price change. As a result, additional demand will increase the demand for crops, increasing the price. This will motivate farmers to increase their production. It could indirectly influence the plantation areas and agricultural investment positively. Consequently, the supply curve's elasticity is critical in determining the agricultural commodity price and the increase in supply resulting from the price change resulting from an increase in biofuel demand. This argument further strengthens Bahel et al., (2014) study by indicating that biofuel production shares the land resources with food production and energy, positively affecting food prices.

Furthermore, the study of Ghani et al. (2019) focuses on the food-energy-water relationship, indicating that the palm oil industry is essential to food and energy. Accordingly, the author developed a framework to show the interrelation between the palm oil industry and the food-energy-water. Figure 2.4 shows how the interlinked palm oil, food and energy markets. Based on the figure, the relationship between energy, oil palm and food is explained following the bioenergy model. The energy market is connected to the palm oil industry due to biofuel production and fuel usage in the production plants. On the other hand, the food market is related to the palm oil industry due to the food crop and vegetable oil production. Finally, the food and energy market is integrated due to food/land diversification for energy and energy usage in cultivation and food production.



Source: Adopted from Ghani et al. (2019)

Figure 2.4: The Interconnection between Oil Palm Industry, Food and Energy

Based on the bioenergy model, the interrelationship between agriculture commodities, biofuel, food price and by-product market has been established theoretically and conceptually. The former study's models and conceptual frameworks are developed based on the widely acknowledged demand and supply frameworks. However, based on the review, it is noted that the theoretical development of the bioenergy model is still young and can be enhanced in various ways, as argued by Serra and Zilberman (2013) and Janda and Kristoufek (2019).

Accordingly, the current study contributes to the enhancement of the existing bioenergy model in several ways. First, it incorporates a broader set of structural demand-side variables such as biodiesel price, investment, vehicle population, and blending policy mandate elements that are often omitted or treated simplistically in earlier models. Second, the study distinguishes between linear, asymmetric, and dynamic effects, providing a more comprehensive understanding of how shocks propagate across the bioenergy–food price system. Lastly, by applying this framework specifically to Malaysia, the study adds regional specificity and policy relevance to what has largely been a theoretical or global discussion. Together, these contributions help advance the empirical and applied dimensions of bioenergy modelling.

2.3 Empirical Evidence of the Variables Understudied

This section will delve into empirical studies examining the intricate interconnections among food prices, commodities, biofuels, and industrial growth. The empirical exploration is structured into two parts. Drawing from earlier literature, the initial segment will scrutinize empirical evidence concerning the interplay between biofuels, agricultural commodity prices, food prices, and industrial growth. Subsequently, the second part will investigate the potential variables incorporated into the conceptual framework, specifically focusing on those influencing biodiesel demand. A thorough analysis of past literature will encompass results, disparities, and underlying causes.

2.3.1 Empirical Shreds of Evidence of the Interrelationship Between Food-Biofuel-Agriculture Commodities and Industrial Growth.

This section will discuss the literature covering the relationship between the variables understudied. The list of the past studies is organised in Table 2.1. thus, the role of the summary table is to show the overall picture of what is already known about the relationship between the variables that have been focused on in this study. Based on Table 2.1, it is clear that the relationship between biofuel, agricultural commodities, and food prices is not consistent, depending on the data used, country and method used.

2.3.1.1 The Food–Fuel Dilemma.

The idea of exploring the interrelationship between the food price and the energy market started in the 1970s after the oil price shocks. In 2008, the global financial crisis revisited the co-movement of crude oil and food prices. Based on reviews, various methodologies have been used to investigate the interconnection between the food and energy market globally and on a single/specific country basis. Accordingly, Esmaeili and Shokoohi (2011) used the principal component analysis to identify the interconnection between crude oil and food prices and found that crude oil prices positively affected food prices from 1961-2005. Similar findings have been achieved by Nazlioglu and Soytas (2012) and Cheng and Cao (2019) using the Vector Error Correction Models (VECM) estimations for 1980-2010 and 1990-2017, respectively.

Besides, Ibrahim (2015) indicates that food price hikes in Malaysia are due to the increasing import bill and crude oil prices. This will directly impact the transportation cost and value chain activities, in the end, the food price. The author attempted to identify the relationship between crude oil and food prices in Malaysia using the non-linear Auto Regressive Distributive Lag (ARDL) model and found that increasing crude oil prices tend to increase Malaysia's food prices in the long run. Besides, the study of Wong and Shamsudin (2017) point out that their study is an extended version of the study of Ibrahim (2015), whereby exchange rate and income are considered as other factors that affect food inflation in Malaysia compared to Ibrahim (2015) which is only used the crude oil price. Accordingly, they added that exchange rate and income are considered in the model since income captures the purchasing power and exchange rate for international trade[15]. The finding indicates that exchange rate, income, and crude oil prices significantly affect Malaysia's food price index.

Razak et al. (2013) added that Malaysia's population is increasing to almost 2.7 million, and changes in the lifestyle resulting from urbanisation have increased the demand for food in Malaysia[16]. Accordingly, Malaysia's food purchasing and consumption patterns are changing due to the growth in income and the population (Arshad & Hameed, 2009; Ghani et al., 2019). Finally, a

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[15] Nazlioglu and Soytas (2012) uses the US exchange rates in their model, urged that weakness of the USD may increase the purchasing power and foreign demand for agricultural commodities. Their finding shows that USD has a positive effect on agricultural prices similar to the study of Wong and Shamsudin (2017).

[16] Razak et al.,'s (2013) study is a review paper whereby no empirical evidence presents. Thus, most of the content and the discussions of the authors are based on the annual reports from Malaysia National Food Security Policy.

panel study conducted by Taghizadeh-Hesary et al. (2019) using Asian countries found that crude oil prices can explain 64 per cent of the food price variance. Thus, those studies show the consistent and robust influence of crude oil prices and exchange rates on food prices regardless of the countries and methodologies used.

2.3.1.2 Commodity Price and Food Price Linkages

There exists a notable distinction between agricultural commodity prices and food prices, even though they are interconnected. Agricultural commodities encompass the prices of raw materials or primary products produced in the agricultural sector. Conversely, food prices pertain to the retail or consumer prices of food products available for direct consumption. The determination of food prices is influenced not only by the costs of raw agricultural commodities but also by factors such as processing, transportation, distribution, marketing, and retailing. There are numerous studies investigated the effect of commodity prices on the food price. For instance, Gua and Tanaka (2022), Sun et al. (2023), and Manogna and Kulkarni (2024).

Sun et al. (2023) indicate that when the demand for oil, such as bioethanol, increases, the demand for agricultural commodities also increases, which upsurges the prices of commodities and creates a significant impact on general food prices. Furthermore, Alnour et al. (2023) studied the asymmetric impact of the energy price, economic policy and the agricultural commodity price index on the food price. The study used agricultural commodities such as grain, vegetable oils, meat, seafood, sugar and other foods to regress to food prices and found that the reaction of the food prices index to the decrease in agriculture commodity prices is greater than its response to the increase in agriculture commodity prices. Thus, the study confirmed the short and long-run asymmetric effect between commodity prices to food prices. Similar to the study of Alnour et al. (2023), Gua and Tanaka (2022) used the same agricultural commodities towards African food prices and found that commodities more constantly affected prices throughout the sample period, including the recent pandemic in 2020.

On the other hand, the literature's interconnection between palm oil and financial variables is well established (refer to Go & Lau, 2024; Go & Lau, 2021), even though studies connecting palm oil prices to food prices are limited. Since palm oil is a highly tradeable oil globally, some researchers argued that the exporting countries have some degree of market power over the tradeable commodities transmitted by the exchange of currencies (Nazlioglu & Soytas, 2012; Balesen & Demirer, 2019). Accordingly, Butt et al. (2021) studied the relationship between Malaysia's exchange rate and commodity prices. The authors used various commodities in their studies, such as palm oil, rubber, crude oil and natural gas. The study’s findings show a long-run relationship between Malaysia’s exchange rate and commodities. Butt et al. (2021) indicated that commodity production is affected by the crude oil price through the input price, which will channel the competition in agriculture output markets or biofuels.

The assertion that crude oil prices directly impact agricultural products and have an indirect influence on the exchange rate aligns with the framework developed by Harri et al. (2009), as illustrated in Figure 2.2. Consequently, this argument robustly supports the connection between palm oil prices and production, as outlined in the conceptual framework of the present study. Although the literature on linking palm oil prices specifically to food prices is limited, numerous studies have explored the association between palm oil prices and overall price inflation.

For example, Sayyed and Issa (2021) investigated the impact of palm oil production on macroeconomic variables in Malaysia, revealing that a 15 percent increase in palm oil prices could potentially lead to corresponding increases in various macroeconomic components. The authors employed the Consumer Price Index (CPI) as an indicator of money holding in their analysis. Additionally, Sharma (2020) utilized the CPI to assess the consumption effects in Indonesia concerning palm oil prices, demonstrating a significant predictive relationship between palm oil prices and the price index using the Flexible-Generalised-Least-Squares (WN-FGLS) method. Another study conducted in Indonesia by Aprina (2014) corroborated these findings, confirming that an increase in palm oil prices contributes to inflation in the country.

2.3.1.3 Biofuel Demand and Its Influence on Food Markets

The revolution in the fuel market started from 2005 onwards with the boom in biofuel production globally. This creates another area of food price exploration in literature, reemphasising that biofuel production is another factor for the food price hikes. Even most of the studies able to establish that biofuel production/demand positively influences food price (for instance, Alnour et al., 2023; Brikman et al., 2020; Martinez-Jaramillo et al., 2019; Paris, 2018; Koizumi, 2015; Bahel, Marrouch, & Gaudet, 2014). Still, some studies argue that biofuel does not significantly impact the food price (for instance, Shrestha et al., 2019; Bastian et al., 2014; and Ajanovic, 2011). Arshad and Hameed (2009) added that palm oil development to fulfil the biofuel demands has made the crisis unique and complicated[17].

For instance, the study of Shrestha, Staab and Duffield (2019) and Bilgili et al. (2020) covered US food prices for 1991-2016 and 1981-2018, respectively. Bilgili et al. (2020) found that biofuel production in the US positively impacts food prices using wavelet-based analysis. Rather than biofuel production, the authors used crude oil price and population as control variables in their study. However, Shrestha, Staab and Duffield's (2019) study indicated that biofuel production in the US does not significantly impact the food price by using similar variables used by Bilgili et al., (2020). Interestingly, Shrestha, Staab and Duffield (2019) included the effect of the agricultural commodity production, i.e., cereal production, in the model and found that biofuel production and crude oil price impact the commodity prices in the US, not the food price index. The variation between the findings could be mainly due to the methodologies used in their respective studies.

[17] Negash and Swinnen (2013) argue that there is a conflicting conclusion in the relationship between the biofuel and food security.

Accordingly, Bahel et al. (2013) studied the impact of biofuel production on food and crude oil prices, land use and production costs in the US and Europe. The author found that biofuel production creates price pressure on the raw material used to produce it. Similar empirical findings come from the study of Tokgoz et al. (2012). The authors indicate that biofuel significantly impacts agricultural commodity prices using the sample of Organisation for Economic Co-operation and Development (OECD) countries. Interestingly, the study of Applanaidu et al. (2011) identified that the increase in biodiesel demand would increase the export of palm oil, the domestic price, and palm oil production in Malaysia. The authors indicate that the cost of raw palm oil will increase by 110 per cent, with biodiesel production increasing by 70 per cent. However, the study did not adequately justify how the export value of palm oil for biodiesel could represent the overall biodiesel demand.

Meanwhile, Rahman et al. 's (2011) study is somehow similar to the study of Applanaidu et al. (2011), where Rahman et al. (2011) focuses more on the impact of biodiesel demand on the price level of palm oil rather than the overall industry. The authors capture the palm oil demand using palm oil, the export of palm methyl ester, and the estimated demand for biodiesel. Thus, there is no clear definition of how the estimated demand for biodiesel is formulated.

Furthermore, another similar study from Abdullah et al., (2007) was found, mainly focused on discussing biodiesel demand's impact on Malaysia's palm oil price. Based on the data, they explain the effects of biodiesel on the palm oil industry and do not provide an empirical discussion on the relationship.

The authors indicate that biodiesel's increasing demand will increase Malaysia's palm oil prices in the coming years. This statement is empirically proved by the recent study of Dutta et al. (2021), indicating that palm oil price is experiencing the time-dependent jumps associated with Malaysia's crude oil and biodiesel price using the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model. The study of Dutta et al. (2021) strengthens the argument of the effect between the commodity and energy markets.

Similar findings come from the study of Subramaniam et al. (2019), whereby the authors empirically proved that biofuels worsen food security in developing countries. Another study by Subramaniam et al. (2020) highlighted that the higher demand for agricultural outputs for biofuel production might adversely affect food availability or supply such as sugarcane, sugar beet, cassava, corn, rapeseed, soya bean, palm oil, wheat, and others if they are switched from production of food to biofuels. Controvert studies such as Negash and Swinnen (2013) and Herrmann et al. (2018) indicate that biofuel production does not influence food security or output. Accordingly, some inconclusive findings can be detected in the past literature.

Interestingly, most studies focus on the production side (supply side), and the demand side seems neglected. Demand-side analysis plays a significant role in facilitating the forecasting and decision-making process. Furthermore, the market economy theory argues that supply and demand drive economic decisions, such as goods and services, investments, pricing, and distribution. However, unbalanced exploration can be identified in biofuel studies, whereby limited earlier literature covers the demand side (Chakravorty et al., 2016). Chakravorty et al. (2016) studied the demand-side effect of biofuel on food prices in the US and European countries. The authors used the US and EU biofuel policy, representing the demand factor for biofuel. The finding shows that food prices will increase by about 32 per cent by 2022, whereby half of the effect may come from the biofuel mandate, and the rest are from population growth and income.

The finding of Chakravorty et al. (2016) is somehow similar to Rosegrant (2008). Thus, Rosegrant (2008) conducted a study to identify biofuel production's impact on the current (or the past) grain prices, which covered 2000 to 2007. The study's findings stated that the policy-driven demand causes biofuel production to change. Accordingly, the market drives the production-weighted average accurate price for grain to increase by about 30 per cent for seven years. However, Rosegrant (2008) did not define the demand model in detail based on the review. As a result, it is unclear how the biofuel demand has been captured in his report.

Furthermore, most studies used biofuel price (refer to Taghizadeh-Hesary, Rasoulinezhad, & Yoshino, 2019) and production (refer to Santos & Szklo, 2016; Larsen, Jepsen & Frederiksen, 2013) to solely represent the demand for biofuel. For instance, Dutta et al. (2021) stressed that crude oil increases Malaysia's biodiesel. However, the authors used the biodiesel price to represent the biodiesel demand in Malaysia study demand solely. By ideology, price and biofuel can be categorised as internal effects of the biofuel market itself. How about the external demand effect that comes from other sectors? Those factors can be treated as the push factors of the biofuel demand. Thus, this is another interesting viewpoint. Besides, there is much room for the effect of the biofuel demand factor to be explored.

Accordingly, those drawbacks have been identified based on the review. Thus, the creditability of those studies in capturing the biodiesel demand needs more validation since the design of the biodiesel demand model is not comprehensive. Better factors are required to seize the biodiesel demand. The current study has been directed from the positivism philosophy to post-positivism. Therefore, picturing the demand factors to capture the biodiesel market in Malaysia is one of the advantages and value-added of this study. Thus, the next section will review the earlier literature covering the demand factors of biodiesel.

2.3.1.4 Industrial Growth as a Driver of Energy and Food Price Dynamics

The theoretical underpinning of the income effect as a crucial determinant in understanding food prices is evident in various studies, reflecting its role as a proxy for food demand and spending levels. Akter and Basher (2014), Chakravorty et al. (2016), Wong and Shamsudin (2017), and Trukhachev and Dzhikiya (2023) have all incorporated the income effect into their food price models. This incorporation allows for a more comprehensive understanding of the dynamics at play in the food market.

Yusuf and Duasa (2010) conducted a study on consumption behaviours among Malaysians, highlighting that an increase in income stimulates economic growth during downturns or recovery periods by boosting private spending. Solaymani and Yusoff (2017) supported this notion, confirming a positive correlation between income increases and food prices in Malaysia using the GMM model.

The use of income as a key measurement to gauge consumers' purchasing power is a recurrent theme in the literature. Applanaidu et al. (2011) leveraged Malaysia's GDP to examine the income effect on biodiesel export demand, finding a significant positive impact. This aligns with Algieri and Kanellopoulou's (2008) earlier study on tourism exports, which demonstrated a positive relationship between income and demand. Algieri and Kanellopoulou employed GDP growth in France, Greece, Spain, and Australia to capture the income effect on demand.

GDP, often used as a proxy for income in food price models (e.g., Ibrahim, 2015; Applanaidu et al., 2014), has been a focal point in understanding the relationship between income and food prices. Wong and Shamsudin (2017) expanded upon Ibrahim's (2015) work, introducing exchange rates and income as additional factors affecting food inflation in Malaysia. Their findings highlight the substantial impact of income on Malaysia's food price index. This resonates with the observations of Razak et al. (2013), who noted that Malaysia's growing population and urbanization-induced lifestyle changes have increased the demand for food, a pattern attributed to the concurrent growth in income and population (Arshad & Hameed, 2009).

In essence, the literature underscores the pivotal role of income as a determinant of food prices, emphasizing its influence on demand, spending patterns, and overall economic dynamics in the context of Malaysia.

In summary, past studies on food prices and inflation in Malaysia point out various factors that lead to food inflation. Some studies have proved this with empirical evidence, and some based on the reports. Interestingly, the study covering the biodiesel demand on the food price is still lacking in Malaysia's context. Even though a few authors argue that biodiesel production could impact food inflation in Malaysia, empirical evidence is still insufficient, although some global studies have empirically proven the relationship. Although Applanaidu et al. *'s* (2011) study can give some insight into biodiesel toward Malaysia's economic growth, the study's scope is more on the palm oil industry. The study does not explore the impact on the commodity or food price.

Moreover, Dutta et al. (2021) stressed that better policies are needed to monitor crude palm oil since this is significant in producing renewable energies and moderating food price volatility in Malaysia. Thus, this is an exciting gap to explore, especially the domestic demand side of biodiesel on food prices. Furthermore, biofuel not only integrates the commodity market and food prices, but it may also increase the integration between industrial growth and food prices. Thus, this is another exciting area to explore.

Table 2.1 : The Summary of the Empirical Studies Covers the Food Price, Agriculture Commodities and Biofuel

Name (Year)	Country Understudied	Period Covered	Methods	Major Findings
Bilgili et al., (2020)	US	1981-2018	Wavelet analyses	Significant relationships between food prices and biofuel production were found in the short and long run.
Brikman et al., (2020)	Ghana	2010-2030	Computable general Equilibrium	Biofuel production is impacted by increasing food prices and import dependency. This is a critical issue in food security in Ghana.
Subramaniam et al., (2019)	51 selected countries	2011-2016	Generalized method of moments	In the early stage, biofuel production may bring competition to food security. However, biofuel may be favourable to the agriculture sector in later stages.
Martínez-Jaramillo et al., (2019)	Colombia	2016-2030	System dynamics model	Biofuels will reduce the food supply and increase food prices due to the changes in land usage and reduce the land supply.
Shrestha et al., (2019)	US	1991-2016	Correlation analysis	There is no significant impact of biofuel production on US food prices.
Weng et al. (2019)	China	2012-2020	Computable general Equilibrium	Biofuel production negatively impacted agricultural land allocation for rice, crops and cereals, forest land, and grassland.
Paris (2018)	US and European countries	1986-2014	Smooth transition regression	The agricultural products prices will increase due to biofuel production.
Ake (2017)	Global	1992-2016	Dynamic conditional correlation and phase synchronization	Oily cereal prices were highly impacted by biofuel production.

Table 2.1: The Summary of the Empirical Studies Covers the Food Price and Biofuel (Continued)

Name (Year)	Country Understudied	Period Covered	Methods	Major Findings
Chakravorty et al., (2016)	Global	2007-2030		Biofuel production positively impacted food prices. The impact is about 50 per cent based on global.
Bayramoglu et al., (2016)	US	1993-2011	3SLS	Bioethanol production and corn prices were positively and significantly correlated.
Enciso et al., (2016)	Global	2015-2024	Recursive-dynamic agricultural multi-commodity model	The closure of biofuel policies has no significant impact on increasing global food security. Without biofuel policies, global biofuel demand would decrease by 25% for ethanol and 32% for biofuel.
Gorter and Drabik (2016)	India, China, and Indonesia	2006-2011		There is little empirical evidence of biofuel policy responses increasing world prices.
Tomei and Helliwell (2016)	Global			The food versus fuel argument resulted from the complexity of and interlinkages between energy and food markets. Food versus fuel most effectively highlights the negative impacts of our consumption, forcing us to face the social priorities reflected by the clear choice between food and fuel.
Koizumi (2015)	Brazil, US, Indonesia, Malaysia, Thailand, and China	1990-2012	Ordinary Least Square (OLS)	Biofuel production negatively affects food safety

Table 2.1: The Summary of the Empirical Studies Covers the Food Price and Biofuel (Continued)

Name (Year)	Country Understudied	Period Covered	Methods	Major Findings
To and Grafton (2015)	Global and U.S.	1981-2013	Vector Autoregressive model (VAR)	Biofuel production and oil price influence the food price.
Applanaidu et al., (2014)	Malaysia	1980-2012	Unrestricted Autoregressive model	Long-run biodiesel production will harm food security. This is mainly due to the competition in terms of land between food and fuel.
Bastian et al., (2014)	US	1987-2012	Asymmetric OLS and Granger causality	There is no significant relationship between biofuel, cattle prices, and field crops in the US.
Bahel et al. (2013)	Global		Decentralized equilibrium model	Biofuel production impacted land scarcity negatively. This will increase food prices.
Thompson and Meyer (2013)	US			The food implications of second-generation biofuel also depend on the context. U.S. biofuel mandates prevented any more significant reduction
Tyner (2013)	US, Brazil, and Europe	2000-2012		There are many causes for increased food commodity prices—not biofuels alone. The supply increases can be induced worldwide via higher commodity prices.
Tokgoz et al., (2012)	OECD	2005-2020	IMPACT analyses	Agricultural commodity prices have an impact on biofuel production.
Ajanovic (2011)	US and European countries	2000-2007	Descriptive statistics and comparative analysis	There is no significant impact of biofuel production on raw material prices. However, oil price fluctuation significantly affects food prices.

Table 2.1: The Summary of the Empirical Studies Covers the Food Price and Biofuel (Continued)

Name (Year)	Country Understudied	Period Covered	Methods	Major Findings
Rahman et al., (2011)	Malaysia	2000-2006	Autoregressive Integrated Moving Average (ARIMA)	The additional demand for biodiesel increases the price and multiplier effects on other palm oil product prices.
Mueller, Anderson, and Wallington (2011)	Global	2007-2008	Statistical comparisons	Biofuel production had a modest (3-30%) contribution to increased commodity food prices observed until mid-2008.
Timilsina, Mevel and Shrestha (2011)	Global	2009-2020	Computable general Equilibrium	The oil price increases reduce agricultural production. The impact is low for the biofuel-producing countries. There is a positive effect of oil prices on the food supply.
Applanaidu et al., (2009)	Malaysia	1980-2007	Nonlinear 2SLS	An increase in biodiesel demand increases the raw palm oil price.
Muller et al., (2008)	Global	1970-2006	Statistical comparisons	Food prices may be impacted negatively or positively due to the growing demand for bio-energy.
Rosegrant (2008)	Global	2000-2007		Increased biofuel demand is estimated to have accounted for 30 per cent of the increase in weighted average grain prices.
Abdullah et al., (2007)	Malaysia	July 2006-Dec2007	ARIMA	Increased demand for biodiesel has increased demand for palm oil and its price.

2.3.2 The Determinant of the Biodiesel Demand Factors

Global demand for biofuels has grown substantially since 2007/08, following the rise in crude oil prices and the creation of mandates in the US. Demand is expected to continue to grow in the near future because of continued mandates in key consuming markets for renewable energy, blending biofuels with transport fuels, and rising crude oil prices. This section will discuss the determinant of the demand model commonly used in the past literature (for instance, Tokgoz & Bhandary, 2011; Kochaphum, Gheewala & Vinithantharat, 2013; Maeda, Tokimatsu & Mori, 2015; Chanthawong et al., 2016; Trypolska, 2024). This is significant and helpful in choosing a variable to represent the biodiesel demand in Malaysia. Since the studies on capturing biodiesel demand are very limited in the literature, some other studies that capture the demand have been discussed. Based on the reviews, the most commonly used determines are listed and discussed in the sub-section below.

2.3.2.1 The Determinant of the Biofuel Demand: Investment

Numerous studies, such as Cho, Lee, and Kim (2007), Flug and Hercowits (1998), and Lanclos, Devadoss, and Guenhner (1997), used investment values as a determinant of demand. Cho, Lee, and Kim (2007) argued that investment in information and communication technology (ICT) enormously impacts productivity. Furthermore, the authors added that the investment has a *substitution effect* and *compensation effect* on the energy demand. In this case, the substitution effect of investment will reduce the demand due to the innovation process created from the investment. On the other side, equipment needs energy to operate, increasing the energy demand. In this situation, the compensation effect occurs. However, the study's finding indicates that the investments increase the demand for electricity in the service sector and decrease the demand in the manufacturing industry in South Korea.

Consequently, the earliest study of Flug and Hercowitz (1998) supported the statement of Cho, Lee, and Kim (2007) by indicating that the investment will make the equipment more advanced. In this case, the workers will become more skilled and increase their wages. On the other hand, Lanclos, Devadoss, and Guenthner (1997) studied the effect of Foreign Direct Investment (FDI) on the export demand of US frozen potatoes. They argued that the FDI could expand the market, increasing the demand for the potato, and the finding indicates a positive relationship between investment and demand. Thus, the study of Kerdan et al. (2020) supported this argument by indicating that investment is essential for energy demand. The authors argued that investment improves the technologies and reduces the capital cost.

2.3.2.2 The Determinant of the Biofuel Demand: Biofuel Policy

Debates on the possible influences of higher demand for crops on changing land use and food production are due to government policies to bring biofuel into the energy mix. Accordingly, Peri and Baldi (2013) argued that the rapid increase in biofuel production is due to the legislative framework. Those authors added that a series of policies implemented helps expand the bioenergy sectors. Findings indicate that the biofuel policies strengthened the relationship between diesel and agricultural crop prices in the long run. It shows that biofuel policies are considered a primary determinant of the development of the bioenergy sector since favourable policies help develop the industry and sectors.

Thus, Chen and Khanna (2012) supported this statement by adding that in the U.S., government policies such as the Renewable Fuel Standard (RFS), volumetric ethanol excise tax credit (VEETC), and tariffs that restrict the imports of sugarcane ethanol rushed the production of biofuel. Furthermore, their study's finding indicates that biofuel policies are harming the food crops in the US. Besides, Gorter and Drabik (2014) studied the effect of the biofuel policies on the food grain commodity prices in the US. Those authors indicated that a 25 per cent increase in the biofuel contribution on price increase is due to the biofuel policies. Their study has considered ten policy scenarios: Tax Credit and Mandate Alone, Mandate and ethanol, corn, production subsidy, etc. Interestingly, the recent research of Cardoso et al. (2019) highlighted that every policy that potentially changes ethanol prices would have spillover effects in demand for gasoline and impact on the fuel market could indeed affect the markets for other fuels. This is supported by Usmani et al., 2023 by investigating the impact of biofuel policy on the biofuel demand from a global perceptive. The study further highlighted that policy changes will significantly influence biofuel production and utilization.

2.3.2.3 The Determinant of the Biofuel Demand: Biofuel and Crude Oil Price

The own price and the substitute price are essential determinants of the demand model. Accordingly, Kouris's (1976) pioneer study indicates that price and income are the main determinants of energy demand. The author argued that this would increase demand for more efficient fuel when the price increases. This is how the price factor influences the demand. This statement is supported by the earliest study of Robinson (1973), who indicated that the price changes are incorporated with the supply and demand of all competing commodities. This statement stresses that the commodities and goods' price directly influences that particular commodity and goods' demand and supply (Sun et al., 2023; Alnour et al., 2023).

Besides, Applanaidu et al. 's (2011) study indicates that the biodiesel export demand function is determined by its own price and soybean price (substitute price). However, the finding shows that the price is significant in determining the biodiesel demand, and soybean is not substantial in Malaysia. The authors indicate that a 30 per cent increase in biodiesel export demand may increase palm oil prices by 13 per cent. Furthermore, they suggest that crude oil price has a significant positive relationship with biodiesel demands in Malaysia. This finding indicated that biodiesel exports would increase when crude oil prices rise. In contradiction, Cardoso et al. (2019) identified that the price and substitute price significantly influence fuel demand in the Brazilian market.

Thus, the authors used the oil price to represent the gasoline demand and sugar price for ethanol demand.

Furthermore, Tokgoz and Bhandary (2011) studied the biofuel demand based on vehicle fleets and prices. Biofuel's price concerning gasoline and diesel has been considered in capturing transportation. The authors argued that biofuel is considered price competitive compared to traditional fuels since the miles driven for ethanol and biofuel are less than the miles driven per gallon diesel. Hence, they argued that biofuel prices are considered more expensive than diesel. Finally, Tokgoz and Bhandary (2011) concluded that the cost of biofuel and traditional transportation fuel are the most critical factors determining consumer demand. This finding is supported by Uchoa et al. (2021) by indicating that the price ratio affects both fuels' demand.

2.3.2.4 The Determinant of the Biodiesel Demand: Population

Robinson (1973) argued that population tends to be the primary determinant of movement in the total demand. Increasing the population rate can increase the consumption level, leading to the demand for goods rising. Hence, Robinson (1973) studied the determinant of demand for fish. Based on the findings, the world population has a significant positive relationship with the demand for fish in the world.

However, most energy demands studies, such as Belhaj (2002) and Tokgoz and Bhandary (2011), Chanthawong et al. (2016), used vehicle populations compared to humans. Since fuel is mainly used in transportation, the vehicles' populations are more significant in capturing fuel demand than humans. This could be why the populations of vehicles are considered in the energy demand model compared to the human population. Furthermore, Cardoso et al., (2019) argued that using people in the fuel model is not a good measure since highly populated countries' vehicles per person are relatively higher than low populated countries[18].

Accordingly, Belhaj (2002) studied the fuel demand in Morocco. The fuel is divided into gasoline demand and diesel demand and is linked to three types of population vehicles, i.e., light, heavy, and diesel. The study's findings reveal that diesel vehicles positively correlate with diesel demand. It indicates that vehicle pollution similarly affects the human population in capturing certain goods' demand. Interestingly, the study of Maaouane et al., (2021) identified some mixed results of people towards the industrial energy demand. The relationship is different based on various sub-sectors investigated in that study.

Accordingly, Table 2.2 summarises all the demand model findings. Commonly used variables in the demand model and their relationship to the previous studies' dependent variables are organised in Table 2.2.

[18] Cardoso et al., (2019) highlighted that, in year 2000 there were 8.4 people/vehicle; 11 years later this ratio was around 4 people/vehicle in Brazil compare, to U.S. has a ratio of approximately 1.25 people/vehicle.

Table 2.2: The Summary of Literature Reviews on the Demand Model

Author (year)	Demand Model	Determinants of Demand Model	Major Findings
Maaouane et al., (2021)	• Industrial energy demand model	• Population • Price index • Purchasing Power Parity • GDP • Household Final Consumption Expenditure	• Mixed results were found based on various sub-industries • Mixed results found • Mixed results found • Mixed results found • Mixed results found
Murshed (2021)	• Energy and electricity demand model	• Per capita real GDP • Real household final consumption expenditure • Industrial value-added • Imported energy • Rural-to-urban migration	• Positive relationship found • Positive relationship found • Positive relationship found • Positive relationship found • Positive relationship found
Sharimakin (2021)	• The industrial energy demand model	• Energy consumption • Real outputs • Real energy price	• Industrial energy demand is characterised by endogenous factors embedded in the asymmetric price effects.

Table 2.2: The Summary of Literature Reviews on the Demand Model (Continued)

Author (year)	Demand Model	Determinants of Demand Model	Major Findings
Kerdan et al., (2020)	• Forecast energy demand	• Investment (advanced technologies) • Land	• Agricultural and land-use models are set to play a significant role
Maeda, Tokimatsu, and Mori (2015)	• Biofuel demand model for woody biofuel	• Income • Price • Production (cultivated land)	• Demand for all main crops is increasing, especially that of soybeans. The most significant increase in demand is occurring in China and South America.
Kochaphum, Gheewala, and Vinitnantharat (2013)	• Biofuel demand	• Commodity price • Farmer income • Commodity production • Socio-economic impact	• Positive relationship found • Positive relationship found • Negative relationship found • Negative relationship found
Sherif and Shaairi (2013)	• Demand model for family takaful	• Income • Inflation rate • Real interest rate • Financial sector development • Education • Muslim population	• Positive relationship found • Negative relationship found • Negative relationship found • Positive relationship found • Positive relationship found • Positive relationship found
Ashford, Hall, and Ashford (2012)	• Consumer demand model	• Financial crisis 2008	• Negative relationship found

Table 2.2: The Summary of Literature Reviews on the Demand Model (Continued)

Author (year)	Demand Model	Determinants of Demand Model	Major Findings
Tokgoz and Bhandary (2011)	• Biofuel Demand model	• Population of vehicles • Prices	• Positive relationship found • Positive relationship found
Algieri and Kanellopoulou (2008)	• Demand for export of tourism	• Income (real GDP) • Price (cost of living and cost of travel)	• Positive relationship found • Negative relationship found
Cho, Lee, and Kim (2007)	• The industrial electricity demand model	• Investment in ICT	• A positive relationship was found in the servicing sector. • The negative relationship found towards the manufacturing sector
Goh (2005)	• Contraction demand model	• Financial crisis 2008	• Negative relationship found
Belhaj (2002)	• Vehicle and fuel demand model	• Population of vehicles • Income (real GDP per capita) • Price	• Positive relationship found • Positive relationship found • Negative relationship found
Kulshreshtha and Parikh (2000)	• Demand model for coal	• Income	• Positive relationship found
Flug and Hercowitz (1998)	• Demand model for skilled labour	• Equipment investment • Non-equipment investment	• Positive relationship found • Negative relationship found

Table 2.2: The Summary of Literature Reviews on the Demand Model (Continued)

Author (year)	Demand Model	Determinants of Demand Model	Major Findings
Lanclos, Devadoss and Guenthner (1997)	• Export demand model for U.S. Frozen Potatoes	• Income (per capita) • Price • Investment (FDI)	• Positive relationship found • Negative relationship found • Positive relationship found
Jones (1997)	• Consumer demand model for carbohydrates	• Income • Own price and Cross-price	• Positive relationship found • Substitute effect found between own price and cross-price
Wohlgemuth (1997)	• Transport energy demand model	• Income • Price	• Positive relationship found • Positive relationship found
Khan (1995)	• Demand for transportation and communication	• Income (gross family income)	• Positive relationship found
Uysal and Crompton (1984)	• Demand model for international tourist flows	• Income (per capita) • Relative price (weighted ratio of price) • Exchange rate • Promotional expenditure	• Mixed relationship found • Negative relationship found • Positive relationship found • Mixed relationship found

Table 2.2: The Summary of Literature Reviews on the Demand Model (Continued)

Author (year)	Demand Model	Determinants of Demand Model	Major Findings
Kouris (1976)	• Energy demand model	• Income (nominal GDP)	• Positive relationship found
		• Price (index)	• A positive relationship was found between Italy, France, Germany, Belgium, and the UK.
			• A negative relationship was found between the Netherlands, France, and Denmark.
		• Temperature	• Negative relationship found
Robinson (1973)	• Demand model for fish	• Income (per capita)	• Positive relationship found
		• World population	• Positive relationship found

2.4 Literature Gaps

This section summarises the gaps in the literature highlighted in previous sections. Studies on energy-biofuel-food have gotten attention from researchers recently. This is due to its importance towards sustainability and the economy. The concepts of bioenergy are relatively new to the energy-food relationship in Malaysia. This is because the significant usage of biodiesel in Malaysia's economic sectors is still premature compared to our neighbouring countries. The studies that cover the food price in the scope of bioenergy in Malaysia are limited.

Bioenergy direction to the food price interlinked the scope of palm oil and biodiesel to the food price in Malaysia. Based on the literature, palm oil is actively investigated with the financial variables such as exchange rate and crude oil price due to palm oil is a highly tradeable oil globally (Nazlioglu & Soytas, 2012; Balesen & Demirer, 2019; Butt et al., 2021; Go & Lau, 2024). Interestingly, some studies used to capture the palm oil effect on the price index, understanding its role in economic growth and overall price impact (Sharma, 2020; Sayyed and Issa, 2021). However, the specific impact of palm oil on food prices remains largely unexplored within the Malaysian context. Despite palm oil's significant role as the primary household cooking oil and a key input in food manufacturing, there is a notable gap in understanding how fluctuations in palm oil prices influence broader food market dynamics. Given its centrality to both household consumption and industrial food production, a more comprehensive assessment of palm oil’s effect on food price behaviour is essential to inform evidence-based policy interventions related to food security and commodity market stability in Malaysia.

Furthermore, researchers such as Khatun et al. (2017) and Ghani et al. (2019) suggest that biodiesel could impact food prices in Malaysia; however, they did not attempt to provide empirical evidence on the potential impact. Ibrahim (2015) pointed out that biodiesel is essential in food price hikes, but he does not provide any empirical proof of biodiesel production's impact on food prices. The same argument comes from Johari et al. (2015) and Abdullah (2015), indicating that biodiesel production could lead to food price competition in Malaysia. This is because some of the food production goes into biofuel production (Subramaniam et al., 2019). However, those studies also failed to provide empirical proof of this statement. At the same time, based on the literature review, there is a clear lack of significant empirical studies that address this issue within the Malaysian context. Accordingly, there remains substantial room to further explore the relationship between biodiesel demand and food prices in Malaysia, particularly in light of the country's expanding biofuel policies and growing energy–agriculture interlinkages. Thus, this is an exciting gap to be explored. Therefore, this study intends to tackle this matter and better understand the nature of the relationship between biodiesel, the commodity market, and food prices in Malaysia's context.

On the other hand, most biofuel-food studies focus on the production side (supply side), and the demand side seems to be neglected (Cabrera-Jiménez et al., 2022; Rodionova et al., 2017; Mele et al., 2009)[19]. Demand-side analysis plays a significant role in facilitating the forecasting and decision-making process. Furthermore, the market economy theory argues that supply and demand drive economic decisions, such as goods and services, investments, pricing, and distribution. However, unbalanced exploration can be identified in the biofuel studies, whereby limited literature covers the demand side. Limited studies on the demand side could be due to the complexity of consumer behaviour since it involves various factors such as preferences, price sensitivity, and willingness to adopt biofuel. On the other hand, data limitations and policy challenges such as carbon pricing, tax incentives, or public awareness campaigns minimise biofuel exploration on the demand side.

For instance, most studies used biofuel price (refer to Taghizadeh-Hesary, Rasoulinezhad, & Yoshino, 2019) and production (refer to Santos & Szklo, 2016; Larsen, Jepsen & Frederiksen, 2013) to solely represent the proxy of demand for biofuel. Thus, the creditability of those studies in capturing the biofuel demand effect needs more validation. Biofuel price or production is more related to the internal factors of the biofuel industry. Thus, external development may also impact biofuel demand, such as investment, vehicle population, and biofuel policy. Those factors can be treated as the push factors of the biofuel demand. Thus, this is another interesting viewpoint. Besides, there is much room for the effect of the biofuel demand factor to be explored. In addition, biodiesel production in Malaysia is still at the beginning level. In this

[19] Chakravorty et al., (2016) indicates that the demand side of biofuel is less explored and there is more room for the investigation can be carried out on the demand side of biofuel. The author used the biofuel policy as the demand factor and found that biofuel policy will impact the food price in US and EU positively.

case, it is not rational to see the impact of biodiesel production on the food price. This is because the effects could be minimal on the food market. Accordingly, the viewpoint of the demand side is much more rational for the case of Malaysia since the potential impact of the growing demand for biodiesel on the food price can be captured. Therefore, picturing the demand factors to capture biodiesel demand in Malaysia is one of the advantages and value of this study.

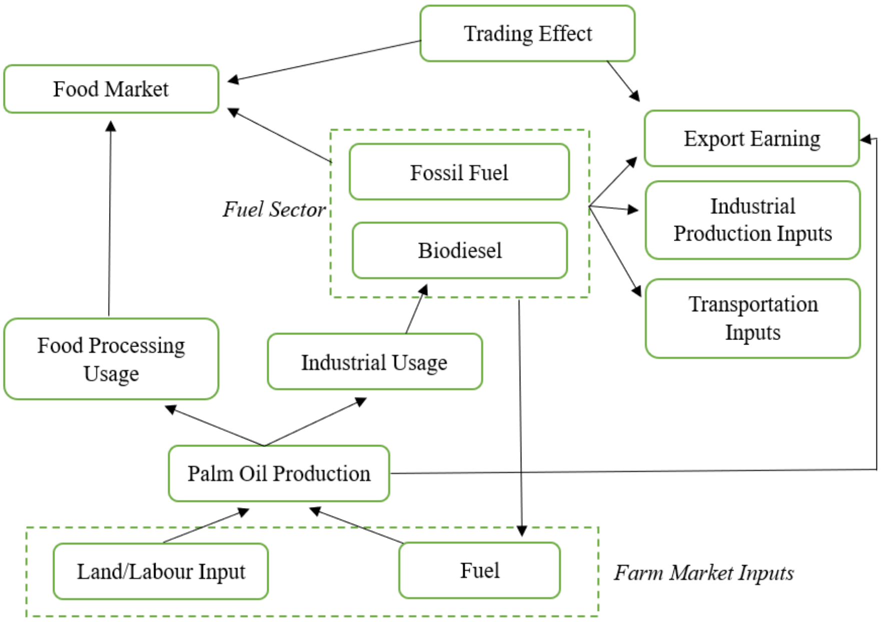
Finally, based on the review, it is noted that the theoretical development in biofuel and food prices is still at the beginning level and can be enhanced in various ways, as argued by Serra and Zilberman (2013) and Janda and Kristoufek (2019). Based on the bioenergy model proposed by Ciaian and Kancs (2011), the price input of aggregated fuel affects the production cost of agricultural outputs and indirectly affects the food and byproduct production through the industrial sectors and transportation. Even at the conceptual level, industrial production is influenced by oil prices and biofuel blending mandates; however, this relationship remains largely unsupported by empirical evidence in the existing literature. This presents a novel and timely research gap, offering an opportunity to generate deeper insights into the role of industrial activity as both a driver of biodiesel demand and a contributor to food price dynamics in the Malaysian context.

Although many studies have investigated the impact of energy prices or palm oil prices on food inflation, few have examined how structural biodiesel demand factors, when combined with industrial development, affect food prices in a major palm oil-producing country like Malaysia. In particular, the existing literature lacks an integrated model that incorporates both linear and non-linear effects and explores dynamic interactions over time using methods like ARDL, NARDL, and IRF. This study fills that gap by providing a multi-dimensional and country-specific analysis.

2.5 Theoretical Foundation of the Study

Based on the above literature review and the identified gap, this section discusses the theoretical foundation of the study. Notably, the interlinkage of bioenergy to the food price model has been absent in previous literature on food prices in Malaysia. Thus, to fill this gap, bioenergy and food price relationships have been investigated in this study. This section is crucial for theoretically justifying the proposed relationship between food prices, biodiesel demand, commodity market prices, industrial growth, and selected control variables in Malaysia. Biodiesel serves as an alternative renewable energy to replace crude oil in transportation and industrial production in Malaysia. This circumstance is visually depicted in the study by Ciaian and Kanc (2011) as a bioenergy model. However, their model primarily focuses on the commodity's production side impacting the food market, neglecting the influence of the demand side on food prices. Therefore, in this study, the bioenergy model has been enhanced by incorporating the demand factors of biodiesel. Figure 2.5 represents the conceptual framework of this study. This flow aims to improve the understanding of the effects of the biodiesel commodity market on food prices, addressing the identified gap in the literature. This enhancement provides a more comprehensive insight into the relationship, which is valuable for policymaking purposes.

Figure 2.5: The Conceptual Framework of the Study



Source: Developed by researcher

This study conceptualizes a multi-stage price and demand transmission process rooted in economic theory. Based on Figure 2.5, conceptually, three different impact channels are drafted on Malaysia's food prices. The first impact is from the palm oil price, representing the commodity market's effect on food prices. Since palm oil is a cash commodity which generates income for Malaysia through exports, its role in the food market is not well established in the literature. The second impact will be from the biodiesel demand factors, the downstream palm oil industry, towards the food price. Rising crude oil prices incentivize a shift toward alternative fuels like biodiesel, increasing biodiesel demand. Since Malaysia's biodiesel is palm oil-based, this intensifies demand for palm oil, exerting upward pressure on its price. Through the price transmission mechanism, palm oil price increases are then reflected in higher food prices, particularly for edible oils and processed goods. Lastly, the industrial production in Malaysia towards the food price is transmitted through biodiesel and fuel usage in the industry. The underlined relationship between the variables will be discussed based on the theoretical justification in the next section.

2.5.1 Law of Demand and Supply in Commodity Market

The conceptual relationships between palm oil prices and food prices in Malaysia are intricately explained by the foundational economic principle known as the law of demand and supply. This principle, widely employed in commodity studies, has been extensively explored by researchers such as Zhang et al. (2009), Koizumi (2015), Al-Maadid et al. (2016), Tadesse et al. (2016), Chen et al. (2019) and Tanaka et al., (2024). It asserts that the production and price of a product are fundamentally shaped by the dynamics of demand and supply levels in the real market. This economic axiom, supported by Moore (1919), Hendry & Morgan (1929), Kargbo (2005), and Weyl (2019), plays a pivotal role in understanding market behaviour. Chen et al. (2019) underscored that the behaviour of food prices, whether at a global, regional, or domestic scale, is intimately tied to the forces of demand and supply. In this context, the growing significance of palm oil in the Malaysian food industry, particularly its widespread use as a cooking oil and a primary ingredient in food production, is noteworthy.

Looking from the demand perspective, the price of palm oil is intricately linked to the price of biofuels, a relationship explained by the law of demand, as discussed by Murshed (2021). While a higher palm oil price may positively impact the economy and the palm oil industry by boosting income, it may concurrently exert a negative influence on food prices. The decision to either export palm oil as edible oil or allocate it for the industrial production of biodiesels hinges on palm oil price levels. When palm oil prices are elevated, the biodiesel industry may experience diminished profit margins due to heightened production costs, potentially affecting export levels. Studies by Palacio-Ciro and Vasco-Correa (2020) and Cali (2018) validate this argument, demonstrating how ethanol production in Colombia has supplanted sugar exports in response to evolving market demands.

The production rate of palm oil not only influences crop stock but also shapes government decisions on biodiesel mandates. Furthermore, the price factor plays a crucial role in determining whether palm oil is earmarked for biodiesel production or export, contingent on the prevailing government policy direction. Considering input costs and the pass-through effect, the palm oil price is anticipated to wield an influence on food prices in Malaysia. Intriguingly, the exploration of this relationship within the Malaysian context appears to be underexplored, presenting a compelling avenue for further research.

2.5.2 Unified Growth Theory to Represent the Income Effect.

Malaysia's industrial growth is anticipated to have a direct impact on both food prices and the demand for biodiesels, primarily driven by the escalating energy demand, as highlighted by research conducted by Fleiter et al. (2011), Fais et al. (2016), and Marouane et al. (2021). This novel insight into the interplay between energy, biodiesels, and food prices can be elucidated by the unified growth theory, as outlined by Rahman (2016). According to this theory, industrial growth contributes to an increase in the population's income, subsequently driving up food demand. The surge in demand, coupled with limited supply, is poised to influence food prices. Industrial growth is intricately linked to oil prices, which are essential for production and influential in transportation costs. Furthermore, the ongoing trend of incorporating blended biodiesels in production plants is expected to enhance the integration of biodiesels and industrial output growth.

Simultaneously, the industrial sector in Malaysia is positioned as both a competitor and collaborator with the palm oil industry. Competition arises concerning land and labour supply, as indicated by Subramaniam et al. (2020), while collaboration is fostered through the creation of demand for biodiesel production. The dynamic interplay between industrial development and agriculture is expected to find synergy, especially in light of the National Agro-Food Policy 2.0 (2021-2030). This government policy envisions a harmonious growth trajectory for both sectors. This perspective introduces a fascinating viewpoint on their relationship. The bioenergy model underscores the significance of the industrial sector as a by-product market, as evident in Figures 2.1 and 2.2. According to the model, the energy market holds sway over the by-product market.

Conversely, the energy market is intricately connected to commodity and food prices. In this scenario, industrial growth is expected to exert a positive impact on food prices in Malaysia. This newfound relationship structure serves as a valuable addition to the bioenergy model. Remarkably, the review reveals a limited exploration of the direct and indirect effects of industrial growth on food prices in this specific manner within the Malaysian context.

2.5.3 Cost of Production Theory of Value to Explain the Expansion of Biodiesel Industry.

Ciaian and Kanc (2011) claimed that the fuel and agricultural markets are interconnected through price inputs[20]. While the bioenergy model proposed by Ciaian and Kanc (2011) simplifies the analysis by considering food crop production and biomass crop production as mutually exclusive, the inclusion of palm oil in this study introduces a dual-use scenario. Unlike the model's assumption of exclusivity, palm oil is not limited to either biodiesel or food production, allowing it to be utilized for both simultaneously. This introduces complexities in the pricing dynamics, as the dual use of palm oil may lead to competition for crucial resources, affecting overall supply and demand.

[20] This relationship is supported by the "cost-of-production theory of value," which indicates that the price of the object (outputs) is determined by the cost of resources that were used in produces it (Gordon, 1959).

Nevertheless, the viewpoint of the authors is based on the supply side. More demand will create pressure on the commodity market from the demand side of biodiesel and lead to food crops' limitations[21].

The amount of feedstock used in biodiesel production and biodiesel's domestic consumption shows an increasing trend in Malaysia due to the favourable biofuel policy that consents to environmental sustainability. Biodiesel usage in the transportation and manufacturing sectors shows significant growth from a 2 per cent mandate of blended diesel to 10 per cent in 2008. Furthermore, biodiesel usage is expected to increase by about 15 per cent on blended diesel for road transportation by 2020, as proposed in the 11th Malaysia Plan (USDA Foreign Agricultural Service, 2016)[22]. Based on the *law of demand and supply,* the increasing biodiesel demand and production using palm oil will create additional demand in the palm oil industry as it is highly tradable vegetable oil (edible oil) (Applanaidu et al., 2011)[23].

Consequently, the additional demand will increase the pressure on the palm oil commodity. This could influence the production rate, price level, and palm oil stock decision-making. This statement is strongly proved by studies

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[21] Ciaian and Kanc (2011) developed the bioenergy model by dividing the agricultural production into two components i.e., food commodity production (grains, vegetables, fruits, and other crops grown to meet the global demand for food) and biomass commodity production (switchgrass, wood, sugarcane bagasse and others source of renewable energy). However, this is not relevant to this study since the palm oil is used in the food production and for the biodiesel production as well.

[22] Further discussion on the biodiesel industry in Malaysia is in the Section 1.1.1, Chapter 1.

[23] According to Abdullah, Hasan and Yosoff (2013), about 40 per cent of the total production of palm oil is used in producing cooking oil, margarine, specialist fats and oleochemicals in Malaysia. Furthermore, the report of the European Union Delegation to Malaysia (2012) indicates that roughly three-quarters of the total palm oil production go into foodstuffs production.

such as Chen et al. (2010), Busse et al. (2011), Nazlioglu and Soytas (2012), and Kapusuzoglu and Ulusoy (2015). Those studies stated that oil prices substantially impact agricultural commodity prices using various sample countries. Accordingly, the biodiesel demand is expected to directly affect the food price of the additional demand created by the biodiesel on the agricultural outputs (Applanaidu et al., 2014; Ibrahim, 2015; Johari et al., 2015; Wong & Shamsudin, 2017; Dutta et al., 2021; Szulczyk et al., 2021; and Karkowska & Urjasz, 2024).

Due to the strong impact of biodiesel production on the palm oil supply and demand, this is expected to influence the food price in Malaysia (Harri et al., 2009; Ghani et al., 2019). Besides, Rajcaniova et al., (2013) supported this statement by indicating that the feedstock prices have become more dependable due to the feedstock's share for biodiesel production increasing. Founded on the *cost of production theory of value* theory and the financialisation concept, palm oil's price could directly influence Malaysia's food price. In addition, the integration is getting strong due to the fuel market, which strongly influences food prices (Tadesse et al., 2016; Dutta et al., 2021).

The effect of biodiesel on the food price is viewed based on the demand perspectives. The main reason is to better understand the structured relationship between the growing demand for biodiesel due to global sustainability consent on food prices. In addition, biodiesel production in Malaysia is still at the beginning level. In this case, it is not rational to see the impact of biodiesel production on the food price. This is because the effects could be minimal on the food market. Accordingly, the viewpoint of the demand side is much more rational for the case of Malaysia since the potential impact of the growing demand for biodiesel on the food price can be captured, which is relevant to the sustainability of the food and biodiesel industry in Malaysia. Hence, four different variables have been used to represent the biodiesel demand in Malaysia. The variables are the number of registered diesel vehicles on the road, the price of biodiesel, investment received in Malaysia's biodiesel industries, and the biodiesel blended mandate policy.

2.5.3.1 Demand-pull Theory to Explain the Effect of the Number of Registered Diesel Vehicles on the Road to Food Price in Malaysia.

The first demand factor in the model is the number of registered diesel vehicles on the road in Malaysia. Studies such as Robinson (1973) and Sherif and Shaairi (2013) capturing the demand factors used populations as one of the demand factors. Thus, this factor is very famous in the demand model's literature since population growth will increase the demand for products and services. This is in line with *Malthusian Theory*, whereby population growth outpaced the ability to produce enough food, leading to a situation where demand for food exceeds supply, causing food prices to rise. In Malaysia's context, technically, the *elasticity of demand and supply* can better explain this situation. The elasticity of demand and supply for food products influences how changes in population affect food prices in Malaysia. Naturally, demand for food is relatively inelastic, meaning people will continue to buy food even as prices rise, and supply is inelastic, prices may increase more significantly in response to population growth with the limited supply and increasing demand for food and non-food products.

However, in this study context, registered diesel vehicles on the road have been used to represent the population. The number of vehicles is expected to reflect the actual biodiesel demand in Malaysia compared to the total human population. An increasing number of diesel vehicles on the road will increase biofuel usage and demand. This is favourable to the blended mandate requirement set by the Malaysian government as well. This is common practice in energy demand studies such as Tokgoz and Bhandary (2011) and Chanthawong et al., (2016). The authors indicate that the vehicle fleet determines the US biofuel demand. Besides, Belhaj (2002) specifies that increasing vehicles will increase petroleum usage in the country.

At the same time, an increasing number of diesel vehicles will be favourable to industrial growth (Maaouane et al., 2021). Transportation is a critical value chain in the production process from the demand side. Wang et al. (2020) argued that transportation infrastructure is highly associated with industrial groups due to China's excessive energy consumption. Besides, the oil used in the production plants will create demand for biofuel, with the favourable government policy on the blended requirement for industrial use in Malaysia. Accordingly, the vehicle population is highly associated with industrial growth. Due to this reason, similar to the effect of industrial growth on food prices, a positive relationship is expected between the registered number of diesel vehicles on the road and food prices in Malaysia. This interconnected relationship underscores the multifaceted impact of transportation dynamics on both biofuel demand and broader economic factors.

2.5.3.2 Price Transmission Effect to Explain the Effect of Biodiesel Price on Food Price in Malaysia.

The second demand factor used in the model is the price of biofuel. The price factor is an essential indicator of the demand function (Robinson, 1973; Kouris, 1976; Uysal & Crompton, 1981; Uchoa, De Jesus et al., 2021; Tanaka et al., 2024). The price of the goods and the substitute goods determines the buyer's decision to purchase the product. You and Hsieh (2007) highlighted that pricing is an obvious strategy to influence demand. The authors added demand with price dependence and multiplicative, additive, and multiplicative demand[24]. Under additive demand, the demand is determined by the stock quantity and the selling price.

Furthermore, biodiesel is treated as a substitute for crude oil in Malaysia since biofuel is a renewable energy source that replaces crude oil usage (Nazlioglu & Soytas, 2011; Ji & Fan, 2012). The price of both fuels will determine the consumers' purchasing whereby, if the biofuel is expensive, consumers and vice versa will prefer the crude oil. This can theoretically be explained by the *price transmission effect*, whereby changes in the prices of

[24] The pioneer study of Petruzzi and Dada (1997) explained the additive and multiplicative demand in detail.

crops used for biofuel production can be transmitted to other related markets, including food markets. This is proved by Tokgoz and Bhandary (2011). The authors identified that the price of biofuel relative to crude oil (transportation fuel) is the most important factor of the consumer’s determinant in choosing the fuel for their transportation in the U.S. and Brazil. In addition, Chong et al. (2021) found that crop quality and crude oil price are the main factors for biofuel production. However, regarding the effect on food prices, biofuel and crude oil prices are expected to be positively impacted. This is due to the price input in production and transportation. Due to this, a positive impact is expected.

2.5.3.3 Demand Pull Impact Explain the Biodiesel Investment on Food Price in Malaysia.

The next demand factor for biodiesel is an investment in the biodiesel industry in Malaysia. Opening a new project or expanding the existing project's capacities is one way to increase biodiesel production capacity in Malaysia. This is because the infrastructure investment could overestimate the demand and underestimate the cost (Proost & Loo, 2010; Kerdan et al., 2020). Besides, Csomos (2014) indicates that a plan to promote renewable energy investment changes the current dependence on fossil fuels. Due to the growing demand for biodiesel in Malaysia, the demand will remain costly in Malaysia due to the overcrowding costs that will increase the demand-over-capacity ratio (Proost & Loo, 2010). This explains the demand-pull impact of the biodiesel investment on the food price in Malaysia. This statement strongly justified that renewable energy investment could increase production and reduce crude oil usage.

Accordingly, the biodiesel industry's investment will increase the number of biodiesel plants, increasing Malaysia's biodiesel productivity. In addition, Lanclos et al. (1997) indicate that foreign direct investment will increase the import demand. This is known as the compensation effect (*income effect*) of investment in the biodiesel industry. Thus, investment plays a vital role in this case, whereby enhancement in technological advancement can increase the productivity of the biodiesel industries. This could increase the demand for raw materials, i.e., palm oil crops. Accordingly, a positive relationship is expected between investments in the biodiesel industry and food prices in Malaysia.

Furthermore, the investment towards the biodiesel industry indirectly complements industrial growth. Besides, industrial development positively influences people's income levels as employment providers. Studies such as Mehic (2018) and Rodrik (2016) indicate that advanced automation industries demand high-skilled workers, which increases the wage differential between high and low-skilled workers. Moreover, the industrial growth will improve energy usage, boosting Malaysia's biodiesel industry. Due to the consistent demand domestically and internationally, more investment can attract the biodiesel industry. Maaoane et al. (2021) argued that the energy industry's demand depends on the tremendous technical diversity of machinery. In this case, industrial growth is expected to influence Malaysia's income per capita and investment. Thus, more investment could increase the biodiesel supply and be projected to impact food prices.

2.5.3.4 Biodiesel Demand: Biodiesel Policy

Finally, biofuel policies, such as the biofuel industry's promotion, the blending mandate, and the tax reliefs, are expected to influence biofuel's domestic demand in Malaysia. The biofuel policy may create a good platform for the biofuel industry to grow in Malaysia. This statement is supported by the study of Peri and Baldi (2013) and Usmani et al. (2023). Those authors argued that the rapid and steady increase in biofuel production in the EU is due to the legislative framework favouring expansion of the bioenergy sector in the EU. Besides, Peri and Baldi (2013) reveal that biofuel policies can strengthen the agricultural and energy markets link. In addition, Gorter and Drabik (2015) and Chen and Khanna (2012) indicate that the biofuel policies will increase the food grain commodity prices due to the demand factor.

Furthermore, Markel et al. (2018) found that uncertainty in the biofuel policy will discourage investment in biofuels. As a result, biofuel policies, especially the mandate policy, can influence the demand for biofuel. Thus, a positive relationship is expected between biofuel policy and food prices.

2.5.4 Financialisation of Commodity Integrated the Commodity, Energy Market to Financial Instruments.

The relationship is channelled through biofuel production and the global oil price, which is highly correlated with the agriculture commodity prices due to the *financialisation of the commodities*. Thus, due to this ideology, the co-movement of the commodities highly correlated to the financial instruments such as exchange rate and crude oil price (Ordu-Akkaya & Soytas, 2020). Adammer et al. (2012) indicate that the increasing financialisation of the agricultural market contributes to food price increases. This could indirectly link palm oil prices to food prices, which are highly integrated with the financial variables (Wong & Shamsudin, 2017). Wong and Shamsudin (2017) found that crude oil prices and the exchange rate have a long-run relationship with food prices in Malaysia. On the other hand, Butt et al. (2021) found a long-run relationship between the exchange rate and palm oil prices in Malaysia.

Since international trade has a relationship with food prices and palm oil prices in Malaysia, palm oil price is also expected to influence the food prices in Malaysia. Kalkuhl (2016) found that international price shock will translate to domestic price shock in the short term (within three months) in developing countries. Thus, a direct connection between the palm oil price and the food price in Malaysia to understand the nature of the relationship between them. Besides, the relationship can be explained through biofuel production, as illustrated by the bioenergy model (Dutta et al., 2021) (refer to Figure 2.1). This is an interesting viewpoint and value-added to the bioenergy model. Thus, the palm oil price is used as one of the independent variables in this framework.

Furthermore, palm oil price represents the demand side of palm oil in Malaysia. Mitchell (2008) stressed that the sudden increase in the feedstock demand for biofuel production from the biofuel industry leads to speculation, export restrictions, and stock effects on the food price. The palm oil production represented by the stock, land availability, and harvest area may influence these crops' price levels. From the supply side, palm oil production and stock represent the availability of palm oil crops for food and industrial usage (non-energy and energy usage). The higher availability of palm oil can increase the obtainability of biofuel in the market and influence fuel usage in vehicles and industries.

Furthermore, the higher availability of palm oil may lead the government to introduce a more advanced blended mandate in the fuel market to protect the palm oil commodity price and increase the export earnings. On the other hand, reduced production and stock may increase the price due to the global demand for edible oil (Murshed, 2021). It may affect exports and indirectly affect Malaysia’s food prices. Besides, higher production could expand the biofuel industry by attracting more investment due to resource availability (Markel et al., 2018; McCarty & Sesmero, 2014). Markel, Sims, and English (2018) argued that uncertainty in biofuel production leads to low investment in the biofuel industry.

2.5.5 Selection of Control Variables for the Study

Regarding control variables, the commonly used variables in the food price studies in Malaysia have been included in the framework. This is mainly to overcome the bias in the model. Based on the review, variables such as oil price, income, and exchange rate play a vital role in explaining food prices and inflation globally and in Malaysia, following the study of Wong and Shamsudin (2017). Besides, those factors are essential in terms of interlinked biodiesel, commodity market, and industrial growth towards the food prices in Malaysia. Accordingly, the crude oil price is the fundamental factor influencing food prices. This is due to the influence of crude oil on the production factor (Ibrahim, 2015). This has been strongly acknowledged in the literature. At the same time, other components under the model, such as biodiesel, agricultural commodity market, and industrial growth, are linked to the food price interlinked by the oil price. This is due to crude oil used in crop harvesting and by-product production (Ibrahim, 2015; Wong & Shamsudin, 2017). Thus, the price of crude oil will replicate the cost of production of the crops and products following the *theory of production cost of value*.

Wong and Shamsudin (2017) point out that exchange rate and income affect food inflation in Malaysia. Accordingly, they added that exchange rate and income are considered in the model since income captures the purchasing power and exchange rate for international trade since Malaysia is a net food importing country. Besides, the exchange rates could also explain the link between oil prices and agricultural commodity prices due to oil trade being conducted mainly in U.S. dollars and may have an impact on local currencies of all influences the agricultural commodity prices in turn of imports or exports and regional prices of the commodities (Akram; 2009; Harri et al., 2009; Go & Lau, 2024). The existing relationship between the exchange rate, biofuel, agricultural commodity, and food price can be explained by the *law of one price* and the concept of *financialisation of the commodities*. However, this study has only used crude oil and exchange rate as the control variable. This is because the income factor has been replicated in industrial growth, whereby it is used as one of the dependent variables in the model. Accordingly, crude oil price and exchange rate have remained in the model as control variables, not to overlook those effects on Malaysia's food price.

2.6 Concluding Remarks

In conclusion, with the help of earlier literary works, the study's scope has been narrowed by highlighting the gap. The theories underlining the relationship between the variables understudied have been further explored. Based on the empirical evidence for the previous studies, the study's gap is identified and helps in value-adding to this study. Finally, the theoretical foundation among the variables understudied was discussed at the end of this chapter. The justification of the variables included in the food price model is based on the literature's strong theoretical and empirical evidence in this chapter's earlier part. Thus, the discussion on the methodology will be carried out in the next chapter.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

The role of this chapter is to discuss in detail the theoretical and empirical modelling of the structured relationship between the examining variables and the methodologies that will be used in this study to accomplish the objectives. This chapter is divided into four sections. The first two sections discussed the developed theoretical and empirical models. The following section will discuss the empirical testing procedures adopted in this study. Each method will be discussed in detail on the role of the technique in achieving the objectives and the advantages of the method. The final section is the description of the data and its sources. The descriptions focus on choosing the variables to be analysed, types of data collected, sources of the data, and lastly, the time frame of the data.

This study's idea is developed based on the positivism philosophy whereby knowledge is gained through observation and purely based on logic and pure mathematics (Crowther & Lancaster, 2008). Positivists believe in a reasonably clear distinction between facts and values and between what is and should be. Due to the factors of food hiking that have been well acknowledged in the past literature (for instance, Rosegrant, 2008; Mueller et al., 2011; Subramaniam et al., 2019) based on theoretical and empirical evidence, it is appropriate to stick with the positivism philosophy for this segment rather than other philosophies such as post-positivism, postmodernism, and others.

3.2 Theoretical Modelling

The fundamental idea to interlink the commodity market price, biofuel demand and the growth in food price are developed from Ricardo's classical theory known as the "*cost of production theory of value*" and other theories such as *"Unified Growth Theory"* and *"Marshallian Demand Function"*. As discussed in Section 2.5.3, Ricardo's classical theory argued that the value of the cost of production determines the value of a commodity, which is a proportion between supply and demand (Shiozawa, 2014). From the supply perspective, the quantity supply depends on the commodity's productivity. Greiff (2015) indicated that in the neoclassical theory, marginal productivities of inputs would determine the commodity's price. Accordingly, the food production input can be defined based on labour input into the production (L), capital (K) and the energy used in the production (E). thus, the food production function can be derived as Eq. (1) below:

$$Q_s = f(L, K, E) \tag{1}$$

Interestingly, Sraffa (1960) critiqued the Neoclassical theory of value and price by indicating that the cost of the capital used in the production factor should be measured based on the prices, not the quantity. This is mainly because the value of the capital depends on the capital itself, whereby machinery usage costs are higher; however, its contribution towards production is also higher. Furthermore, Sraffa (1960) indicates that the cost is the same as the profit rate in the perfect market condition. So, to capture the cost for each of the production factors in food production, Eq. (2) derived as below:

$$TC = uL + hk + bE \tag{2}$$

Whereby u represents the labour cost in the various levels of the food production chain, h represents the rental rate or the interest rate for the capital utilised, and b is defined as the energy price, which represents the oil price in this study. Accordingly, the total revenue can be defined as the quantity of food production (Y) multiplied by the price (P). So, the profit function (π) for the food can be defined as Eq. (3):

$$\pi = PY - (uL + hk + bE) \tag{3}$$

Accordingly, profit maximisation can be achieved when the marginal cost (MC)= marginal revenue (MR) or, in other words, marginal profit equals zero. Thus, Eq. (3) transformed into the first difference condition as below.

$$\frac{\delta\pi}{\delta Y} = \frac{\delta P}{\delta Y} Y + P\frac{\delta Y}{\delta Y} - \left(u\frac{\delta L}{\delta Y} + h\frac{\delta K}{\delta Y} + b\frac{\delta E}{\delta Y}\right) \tag{4}$$

when $\frac{\delta\pi}{\delta Y} = 0$, the Eq. (4) can be rewritten Eq. (5),

$$0 = -\frac{1}{d}Y + P - \left(u\frac{\delta L}{\delta Y} + h\frac{\delta K}{\delta Y} + b\frac{\delta E}{\delta Y}\right) \quad (5)$$

whereby, $\frac{\delta Y}{\delta P}$ is represents the price elasticity of demand for the food. In this case, $\frac{\delta P}{\delta Y}$ in Eq. (4) is illustrated as $-\frac{1}{d}$ in Eq. (5). Besides, the MC of food production is represented by $\left(u\frac{\delta L}{\delta Y} + h\frac{\delta K}{\delta Y} + b\frac{\delta E}{\delta Y}\right)$. So, the Eq. (5) can be transformed into the term of price as below:

$$P = \frac{1}{d}Y + u\frac{\delta L}{\delta Y} + h\frac{\delta K}{\delta Y} + b\frac{\delta E}{\delta Y}$$

$$P = \frac{1}{d}Y + MC \quad (6)$$

Based on Eq. (6), the food price in the supply perspective is determined by the quantity produced and MC representing the cost of labour, capital and energy used. Besides, as Shiozawa (2014) urged, the theory of value cannot be complete without value theory and international value theory. Shiozawa (2014) questioned how the cost of labour and capital in the production function is determined when different workers' wages and qualifications are not uniform. This is the case; the labour cost does not reflect the cost of the product, and the markup principle of the firms mainly determines it.

Accordingly, the foreign exchange market was introduced into the production function of the marginal cost of the labour and capital market. The relationship between the exchange and productivity is well discussed in the study of Leung and Yuen (2005). The authors stress that the exchange rate can affect labour productivity through changes in the relative input price by changing the cost of imported capital. Hence, this idea can be further explained using the law of one price, whereby the asset price will be the same across the global market (Haskel & Wolf, 2001; Miljkovic, 1999). So, arbitrage profitability can be ratified with the same value of the assets and commodities across the market due to the exchange rate's involvement. For instance, if the real exchange rate depreciates, making the local currency weaker, the cost of imported capital increases. This could potentially raise the cost of acquiring foreign machinery and equipment, impacting businesses and commodities that rely on imported capital goods (Aziz & Applanaidu, 2017). This will directly impact the total factor productivity (labour and capital).

Therefore, applying the idea to Malaysia's context, Malaysia depends on imported food, whereby the exchange rate is assumed to impact the food supply significantly. Accordingly, appreciation of the dollar value may increase the cost of food by increasing imported food prices. So, in Malaysia's case, the labour and capital costs are captured in the monetary value using the exchange rate (Leung & Yuen, 2005; Shiozawa, 2014). So, the capital and labour costs are replaced with exchange rate value. Accordingly, the supply function of the food in Malaysia can be derived as below:

$$QS_t = f(FP_t, EXC_t, CO_t) \tag{7}$$

Based on Eq. (7), the supply side of food (QS_t) in Malaysia is defined as the real price of food (FP_{ft}), an exchange rate (EXC_t) and crude oil prices (CO_t).

On the other hand, the demand for food in Malaysia can be defined as the price, income level, and other factors that influence the demand following the *Marshallian demand function* (Zaratiegui, 2002). Utility maximisation concepts play critical roles in the consumer's demand. The consumer theory illustrates that consumers maximise the utility based on their preference for goods, changes in the income and price of the good. Thus, the food demand function for Malaysia can be written as below, following Kargbo (2005).

$$Qd_t = f(FP_t, Y_t, Z_t) \tag{8}$$

Accordingly, based on Eq. (8), the income (Y_t) and price (P_t) play an important role towards the food demand (Qd_t) in Malaysia, income increase will increase the demand for food, following the *unified growth theory*. This has been discussed in detail in Section 2.5.2. Besides, other variables that influence food demand are illustrated by Z_t

Accordingly, at the equilibrium level, the demand and supply equations can be expressed as price as below:

$$Q_{dt} = Q_{st} = FP_t \tag{9}$$

Thus, according to Chen et al. (2019), the equilibrium equation can be stated as follows:

$$FP_t = f(Y_t, CO_t, EXC_t, Z_t) \tag{10}$$

Hence, Eq. (10) accommodates the transmission mechanisms that affect the food price and demand directly or indirectly in Malaysia. The food price in Malaysia is defined as the function of income (Y_t), crude oil price (CO_t), exchange rate (EXC_t), and other relevant variables (Z_t) that can influence the food prices in Malaysia.

So, to achieve the first and fourth objectives of this study, the food price model in Eq. (10) will be used by including the role of the commodity market representing palm oil price and industrial growth using the linear model.

$$\text{Model 1: } FP_t = f(IPI_t, CO_t, EXC_t, PO_t) \tag{11}$$

Eq. (11) represents the food price (FP_t) model whereby commodity market impact, i.e., palm oil price (PO_t) incorporated in the basic model. Palm oil price is expected to play an essential role in the food price in Malaysia. The *cost-of-production theory of value* illustrates that food prices are determined by the resources used in production, such as labour, raw materials, fuels and capital (Ruan, 2019). Thus, the raw materials here are represented by agricultural commodities. The importance of the commodities may differ based on the country. In Malaysia, since palm oil plays a very significant role as one of the major commodities in the food industry and production, the palm oil price is added to the model. This model helps quantify the impact of changes in palm oil prices on food prices. This is crucial for policymakers, economists, and businesses to understand how fluctuations in the palm oil market may ripple through the broader economy, affecting food costs for consumers.

Secondly, industrial growth added to the model one to quantify the effect of industrial growth on the food price in Malaysia. Based on the bioenergy model and *Unified Growth Theory* the integration between the food market and industrial growth increases due to the usage of crude oil and biodiesel blended mandate requirements. Thus, to understand this relationship, industrial growth is added to the food price model in Malaysia[25]. Understanding the statistical relationship allows for a nuanced assessment of how variations in industrial activities may influence the broader economy, particularly the cost of food for Malaysian.

Furthermore, the agricultural sector, including the palm oil industry in Malaysia, is susceptible to asymmetric dynamics due to fluctuations in crop yields, weather events, and global economic conditions, which can directly impact crop prices. The close link between industrial growth and economic development, as explained by Guo et al. (2022), suggests a potential asymmetric relationship with food prices in Malaysia, as noted by Almalki et al. (2022). This asymmetry is driven by economic shocks such as increased investments or economic downturns. The intricate connection between industrial growth and economic conditions adds complexity, manifesting asymmetrically in the relationship with food prices. This emphasizes the need for a nuanced understanding of potential asymmetries within the dynamics of the agricultural

[25] Industrial growth which is captured using the production growth often used in the economic model to capture the income effect (Dogru et al., 2017; Chi, 2018). This is because, industrial production is a component of overall economic activity which can be explain by the *Keynesian Economic Theory*. Expansion of the industry will increase the economic by increasing the employment and income. In this case, to reduce the model misspecification issue, industrial growth used as a proxy of income in this model.

sector, especially regarding how industrial growth and economic fluctuations collectively influence food prices.

Based on the theory of *Nonlinear Supply and Demand Dynamics* there is an assumption on asymmetric effect between the palm oil price and industrial growth on the food price in Malaysia. To test the asymmetric effect between these variables, model two has been developed. Thus, this model helps in achieving the second objective of this study.

$$\text{Model 2: } FP_t = f(IPI_t^{(+)}, IPI_t^{(-)}, CO_t^{(+)}, CO_t^{(-)}, EXC_t^{(+)}, EXC_t^{(-)}, PO_t^{(+)}, PO_t^{(-)}) \quad (12)$$

Based on Eq. (12), the asymmetric linear model is developed to extend a better understanding of the positive and negative changes in the palm oil price and industrial growth on the food price in Malaysia. The crude oil price and exchange rate have been disaggregated into positive and negative changes as well. Since the study by Wong and Shamsudin (2017) has confirmed the asymmetric effect of both variables on the food price in Malaysia. Thus, it is rational to convert those variables into asymmetric form.

Lastly, model three is the extended version of model one. In this model, the palm oil price is replaced by the biodiesel demand factors. Based on the bioenergy model proposed by Ciaian and Kanc (2011), biofuel plays an essential role by creating additional demand for agricultural commodities. Thus, this could impact the price level of the commodities in the equilibrium level in the *demand-supply framework*. Accordingly, this model is developed to test for the relationship and effect of biodiesel demand on food prices in Malaysia, which is relevant to objectives three and four of the study, respectively. The rationale for not including both of these components in the same model is that biodiesel production is a downstream activity of the palm oil industry. In this case, they are not mutually exclusive by nature. Including both variables in the model can lead to model specification bias. Thus, the model three of this study is listed below:

$$\text{Model 3: } FP_t = f(IPI_t, CO_t, EXC_t, BD_{kt}) \quad (13)$$

Based on Eq. (13), all the variables included in the model are the same as model one. However, palm oil price is replaced with biodiesel demand factors (BD_{kt}). Appropriately, BD_{kt} represent the biodiesel demand factors in Malaysia whereby (k = biodiesel price, number of registered diesel vehicles on the road, blended biofuel mandate, investment in the biodiesel industry). Quantifying this model is able to provide better insight into the effect of the energy market, i.e., biodiesel demand, on the food price in Malaysia. This is a significant gap that is missing in the literature on food prices in Malaysia.

3.3 Empirical Modelling

This section discussed the empirical model developed based on the developed theoretical model in the previous section. Accordingly, three extended models have been developed in the earlier section. This section will further discuss the list of the variables in each model and their expected relationship to the food price. Hence, the empirical model of the first model presented by Eq. (14). Eq. (14) is a linear model developed to test this study's first and fourth hypotheses.

$$FP_t = \beta_0 + \beta_1 EXC_t + \beta_2 IPI_t + \beta_3 CO_t + \beta_4 PO_t + \varepsilon_t \tag{14}$$

Based on Eq. (14), FP_t this study's dependent variable represents the food price over time in Malaysia. Furthermore, PO_t is an exploratory variable added to Malaysia's food price model that represents the price of palm oil over time in Malaysia. Including the palm oil price in the food price model could explain and enhance the understanding of the potential impact of the agriculture commodity market on the food price in Malaysia. More production and stock availability on palm oil will motivate the government and the industry to increase the palm oil industry downstream activities, such as introducing a more aggressive biofuel blended mandate requirement to protect the local price of palm oil (Markel et al., 2018). This may increase palm oil's price and positively influence Malaysia's food prices[26]. Accordingly, based on the literature, there is a strong argument for the positive impact of the agriculture commodity market on the food price hike (Samal, 2022; Hung, 2021). Thus, a positive relationship is expected from palm oil to food prices in Malaysia.

[26] Theoretically, more production may reduce the price of the product/commodities. However, since the palm oil industry has additional demand for various usage in the downstream activities such as edible application, non-food product, and animal feeds, price of palm oil remain high in the Malaysian context (Murphy et al., 2021).

On the other hand, based on Eq. (14), IPI_t represent the industrial growth in Malaysia, whereby it captures the effect of income in the model. Income should be a control variable in the model. However, since this study intended to identify the effect of industrial growth on food prices, the income effect is replaced with industrial growth (Yang et al., 2023). The Industrial Production Index (IPI) serves as a gauge for tracking changes in the production levels across various sectors in Malaysia, including manufacturing, mining, construction, and the utilities of electricity, gas, and water. This index accounts for both domestic sales and exports of goods and power, making it a reliable proxy for assessing Malaysia's overall output or GDP (Sek, 2017). Thus, increasing income among Malaysians due to industrial growth will create demand for food. Since Malaysia is a net food importing country, the limited food availability could increase the price of the food. Thus, a positive relationship between industrial growth and food prices is expected in Malaysia. Other control variables, such as crude oil price (CO_t) and exchange rate (EXC_t), which is theoretically justified and a standard indicator of food prices in Malaysia, are also listed in the model.

The effect of the crude oil price on the food price is well acknowledged in the literature. Ibrahim (2015) indicated that crude oil prices are essential to production. Accordingly, crude oil prices are the fundamental factors influencing food prices. This is due to the influence of crude oil on the production factor (Ibrahim, 2015). Thus, the price of crude oil will replicate the cost of production of the crops and products following the *theory of production cost of value*. This has been strongly acknowledged in the literature. Thus, a positive relationship between crude oil prices and food prices is expected in

Malaysia. Besides, Wong and Shamsudin (2017) argued that the exchange rate is an essential component in the food price since Malaysia depends on imported food traded in the international currency. Accordingly, in a good market, when there is an appreciation in the exchange rate, the imports tend to be cheaper. This may lead to the overall price level going down. Thus, a negative relationship is expected between Malaysia's exchange rate and food prices. Besides, β_1, β_2, β_3, and β_4 represent the parameters of the independent variables. Finally, ε_t represent the error term for Eq. (14).

Accordingly, Eq. (15) represents the asymmetric linear model for the food price in Malaysia, which helps in testing the asymmetric effect of palm oil prices and industrial growth towards the food price in Malaysia. Asymmetric effects refer to situations where economic variables or relationships do not respond equally or symmetrically to changes in certain conditions or factors. These asymmetric effects are often observed in various economic contexts and have significant implications for economic analysis and policy. The advantages of the method will be discussed in the coming section.

$$FP_t = \beta_5 + \beta_6 EXC_t^{(+)} + \beta_7 EXC_t^{(-)} + \beta_8 CO_t^{(+)} + \beta_9 CO_t^{(-)} + \beta_{10} IPI_t^{(+)} + \beta_{11} IPI_t^{(-)} + \beta_{12} PO_t^{(+)} + \beta_{13} PO_t^{(-)} + \phi_t \quad (15)$$

Based on Eq. (15), FP_t is the dependent variable of this study, representing the food price over time in Malaysia. Furthermore $EXC_t^{(+)}$, $CO_t^{(+)}$, $IPI_t^{(+)}$ and $PO_t^{(+)}$ represent the positive exchange rate changes, crude oil, industrial growth, and palm oil prices, respectively. On the other hand, $EXC_t^{(-)}$,

$CO_t^{(-)}$, $IPI_t^{(-)}$ and $PO_t^{(-)}$ represent the negative exchange rate changes, crude oil, industrial growth, and palm oil prices, respectively. Besides, β_6, β_7, β_8, β_9, β_{10}, β_{11}, β_{12}, and β_{13} represent the parameters of the independent variables. Finally, ϕ_t represent the error term for Eq. (15). The analysis using this model strengthened the understanding of how the positive and negative changes in the independent variables influenced the food price in Malaysia.

Lastly, Eq. (16) represent the extended version of Eq. (14) by including biodiesel demand's effect on Malaysia's food prices. Since the biodiesel demand is disaggregated into four sub-components, four independent variables are added to the extended model. The disaggregation of the biodiesel demand factors allows for a more nuanced and precise analysis of trends, patterns, and relationships within the data. Accordingly, the study produced deeper insights into biodiesel demand on the food price in Malaysia. However, it is understood that disaggregation of the data is more vulnerable to statistical issues and sample size (Asian Development Bank, 2021, pp. 10-12). However, it fits better to this study whereby the sub-components selected to capture the biodiesel demand are not highly associated with each other and have a big sample size, which could eliminate the low statistical power of the regression.

$$FP_t = \beta_{14} + \beta_{15}EXC_t + \beta_{16}IPI_t + \beta_{17}CO_t + \beta_{18}BP_t + \beta_{19}Inv_t + \beta_{20}Policy_t + \beta_{21}VP_t + \varrho_t \quad (16)$$

Since Eq. (16) is an extended version of Eq. (14), the variables such as exchange rate, industrial growth, crude oil price and palm oil price are expected to have a similar effect on the food price in Malaysia, as discussed earlier (Eq. 14). ε_{3t} represent the error term for Eq.(16) and with common control variables remaining as Eq. (14), BP_t represent the biodiesel price whereby Uysal and Crompton (1981), Algieri and Kanellopoulou (2008) and Dumortier et al. (2020) argued that the price of biofuel is expected to have a negative relationship with the demand for biofuel.

This is because if the price of biofuel increases, consumption of substitute products such as gasoline and diesel increases to protect the cost efficiency in the production. Cost competitiveness is always crucial in the consumers' decision-making (Hanaysha, 2018). Furthermore, biofuel prices indicate market penetration whereby economies of scale and efficiency improvements help lower production costs and increase demand. In this case, biodiesel prices are expected to influence Malaysia's demand negatively. Since this study hypothesised that biodiesel demand positively impacts the food price in Malaysia, biodiesel price is expected to have a negative relationship with food price.

The next demand factor is Inv_t, represent the investment received in the biodiesel industry over time in Malaysia. Investment can improve the biodiesel industry's development and boost biodiesel production facilities in Malaysia. Markel, Sim and English (2018) indicated that producing the raw material could expand the biodiesel industry by attracting more investment due to resource availability. In addition, high investment can upgrade the technology in the production field, which could increase the production and export earnings to

Malaysia. At the same time, investment contributes to the industry's Research and Development (R&D) to improve cost competitiveness. The cost of producing and delivering biodiesels is crucial in determining their demand.

Investments in cost-reduction strategies, such as scale economies, energy efficiency, and waste reduction, can make biodiesels more competitive with conventional fossil fuels, thereby boosting demand. Increasing demand to fulfil the production requirement, more palm oil feedstocks are needed. Investments help in the biodiesel market growth in domestic and foreign countries. This could indirectly impact the food price in Malaysia. Due to this, a positive relationship between investment in the biodiesel industry and food prices is expected. Due to the young biodiesel industry in Malaysia, technical data such as investment value is limited. In this case, to understand the effect of the investment on the food price, the production value of biodiesel has been used in this study follows Hasan et al. (2023), Noriega and Narvaez (2020) and Hartley et al. (2019). The investment effect indirectly can be transmitted to increasing the production level of biofuel by developing new production facilities and boosting the R&D and marketing strategies (OECD-FAO Agricultural Outlook 2000-2029).

Subsequently, biofuel policy ($Policy_t$) used as another demand factor in Eq. (16), representing the effect of the biofuel blended mandate implemented in Malaysia over time. Biofuel/biofuel policies are closely related to its demand in the market. Policies such as RFS and mandates, flexibility and market integration and subsidies and taxations provide the regulatory framework, economic incentives, and market conditions that can either encourage or constrain the production and consumption of biofuel. As governments worldwide continue to set and revise their biofuel/biofuel policies, these regulations will play a vital role in shaping the future of the biofuel industry and its level of demand in the market domestically and internationally. Accordingly, to capture the effect of the biofuel policy on food prices, a blended mandate of B7 implemented by Malaysia in the transportation sector will be used, covering January 2016 to January 2019[27]. Since the biofuel blended mandate is expected to increase the demand in the market, a positive relationship is expected between biofuel policy and food prices in Malaysia.

The last biodiesel demand factor used in the model is the number of diesel vehicles registered on the road over time (VP_t). These variables are used as the population proxy, an essential indicator of the demand model (Gao et al., 2023; Rahman et al., 2019). As argued by Tokgoz and Bhandary (2011), fuel is mainly used in transportation, and the vehicles' populations are more significant in capturing fuel demand than humans. Government policies and regulations on the increasing blended mandate due to global trend requirement on alternative energy usage, the vehicles and the economic sectors started to demand more biodiesel. As the number of vehicles on the road continues to increase, particularly in urban areas and developing economies, the demand for biodiesel in Malaysia and other importing countries is likely to rise, provided that supportive policies and infrastructure are in place. When the population

[27] Since the blended mandate in manufacturing sector is still not largely implemented, thus, blended mandate in transportation sector has been used to capture the effect of biodiesel policy in Malaysia.

increases, the food demand and prices increase due to limited offers, which is the *demand-pull effect*, where increased industrial and transportation-related demand pulls limited agricultural resources away from the food supply chain. Thus, a positive relationship is expected between the number of registered diesel vehicles and food prices in Malaysia. Finally, ϱ_t represent the error term for Eq. (16).

3.4 Econometrics Methodology

This section discussed in detail the methodologies employed in this study to achieve the study's objectives. A quantitative approach has been proposed to achieve this study's four objectives. In the beginning, the unit root test will be employed to check for the stationarity of the variables understudied. Next, the variables' short- and long-run relationship will be identified using the Auto Regressive Distributive Lag (ARDL) model approach. Followed by the Toda Yamamoto non-causality test will be carried out. The causality direction is essential to show the structural impact between the palm oil price, domestic biodiesel demand factors, industrial growth, and other control variables on the food price in Malaysia (Engle & Granger, 1987). These two methods are important to achieve the first and third objectives of this study.

Besides, to achieve the second objective of this study, the non-linear ARDL method has been utilized. The advantages and the reason for the chosen method for this study will be discussed in detail in the following section. Since the study’s motif on addressing sustainability, the result should be robust and reliable for solid policy implications. Thus, tests such as Dynamic Ordinary Least Squares (DOLS) and Fully Modified Ordinary Least Squares (FMOL) are used to test for the robustness of the ARDL and NARDL analysis. Lastly, the impulse response function (IRF) and forecast error variance decomposition (FEVD) were added to the package to test for the shock effect of the food price in Malaysia. With additional advantages from both analyses, better insight can be generated into the effect and response between the variables under study, which is very important for sustainable policy making.

3.4.1 Unit Root Tests

Checking for the stationarity of the variables is essential in the time series data analysis. Since this study uses the ARDL method to investigate the short- and long-run relationship, it is necessary to make sure the variables are non-stationary in I(2) and the dependent variable is integrated with I(1) (Narayan, 2005; Ozturk et al., 2010). Accordingly, stationarity indicates that the mean and variance of the dataset are constant over time, and the covariance depends only on the gap between two time periods (Gujarati & Porter, 2009). So, if the mean and variance are not constant over the period, the sample data series will be generalized to another period of the same variable. This type of time-series data is known as non-stationarity time series (Gujarati & Porter, 2009).

Due to this importance, most of the time series analysis in literature will pass through the unit root test to check for the stationarity (non-stationarity) of the data series. By the way, there are two other ways to check for the stationarity of the time series, i.e. (1) Graphical analysis and (2) Autocorrelation Function (ACF) and correlogram (Gujarati & Porter, 2009). To check for the unit root problem in the series, the Random Walk Model (RWM) is used, as below:-

$$PO_t = \rho PO_{t-1} + u_t \qquad -1 \leq \rho \leq 1 \tag{17}$$

whereby, based on Eq. (17), PO_t and u_t are Malaysia's palm oil price over time and the white noise error term, respectively. ρ is used to check for the unit root problem in the data series, where if ρ = 1, there is a unit root problem in the series, which indicates that PO_t is non-stationarity. To check for the stationarity of the series, Eq. (18) was modified by subtracting PO_{t-1} both sides, as below:-

$$PO_t - PO_{t-1} = \rho PO_{t-1} - PO_{t-1} + u_t \tag{18}$$

Eq. (18) can be simplified as below:-

$$\Delta PO_t = (\rho - 1)PO_{t-1} + u_t \tag{19}$$

Which can be derived as below:-

$$\Delta PO_t = \delta PO_{t-1} + u_t \tag{20}$$

Where Δ is the first difference and δ = $\rho - 1$. To check for the stationarity, Eq. (20) will be estimated using the null hypothesis of $\delta = 0$ and the alternative hypothesis of $\delta < 0$ since δ is equal to $\rho - 1$, if $\delta = 0$, then $\rho = 1$, which indicates that the time series is not stationary. To make the series stationary, the ρ must be less than 1. Alternatively, δ must be in negative value.

Let's say $\delta = 0$, then based on Eq. (20), the time series will become non-stationary in level (since the $\rho = 1$, refer to Eq. (19)). But the random walk time series become stationary in first differences since $\Delta PO_t = u_t$, where u_t white noise error term, which is stationary. So, according to Gujarati and Porter (2009), the basic idea behind the unit root test is to take the first difference of PO_t and regress on PO_{t-1}. Furthermore, check for the slope coefficient (δ). If the slope coefficient is zero, then the price of palm oil is non-stationary, and if it is a negative value, then the price is stationary.

Unit roots tests have become popular over the past several years. Chebbi and Boujelbene (2008) indicate that the unit root test will have low power for the small observation dataset. Due to this reason, the authors applied two different tests in their study, i.e., Augmented Dickey-Fuller (ADF) (to test the null of the unit root) and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) (to test the null of stationary). Furthermore, Tang and Lau (2008) added that univariate unit root tests like ADF and Phillips-Perron (PP) are sensitive to small sample data. This statement is supported by Costantini and Martini (2010). However, this could not be an issue in this study since this study employed high-frequency sample data. However, this study will use Dickey-Fuller Generalized Least Squares (DF-GLS) and Phillips-Perron (PP) as a precaution. The difference between DF-GLS and PP tests is how both tests deal with serial correlation and heteroskedasticity in the errors; the PP test overlooks any serial correlation in the test regression. The selected unit root test will be further discussed in the following sub-section.

3.4.1.1 Dickey-Fuller GLS (DF-GLS) Unit Root Test

The DF-GLS test has advantages compared to ADF since DF-GLS is more powerful in testing the stationarity compared to ADF, whereby the ADF test argued to over-reject the null hypothesis (Shahbaz et al., 2009; Haug & Basher, 2007). In this case, the modified DF-GLS has the best overall performance in the small sample and improved power when an unknown mean or trend is present (Shahbaz *et al.,* 2009). Thus, the general regression of the DF-GLS test is as follows:

$$\Delta PO_t = \propto + \delta_t + \beta PO_{t-1} + \sum_{i=1}^{k} PO \Delta PO_{t-1} + \varepsilon_t \qquad (21)$$

Based on Eq. (21), t and k are the time trend term and the number of lags, respectively. Those terms are included in the model to ensure that the residuals. ε_t are white noise. This means ε_t has zero mean and constant variance uncorrelated with ε_t for $t \neq s$. The null and alternative hypotheses for a unit root for palm oil price (PO_t) are:

$$H_0: \beta = 0, \qquad H_1: \beta < 0 \qquad (22)$$

The null hypothesis was added into the order of one, *I(1),* indicating the variable as stationary in order one. The optimum lag length selection will be based on the Schwarz Information Criterion (SIC).

3.4.1.2 Phillips-Perron (PP) Unit Root Tests

The advantage of the PP tests over the ADF tests is that the PP tests are robust to general manifestations of heteroskedasticity in the error term u_t. An alternate preference is that the client does not need to tag a lag length for the test regression (Gujarati & Porter, 2009). The general regression for the PP test is as follows:

$$\Delta PO_t = \mu + \beta \left[t - \frac{n}{2} \right] + \delta PO_{t-1} + \varepsilon_t \quad (23)$$

Eq. (23) is the general model for the PP test. This test is an alternative unit root test for the ADF test, which had to solve serial correlation in error term using nonparametric statistical methods without adding lagged difference term in the dependent variable (Gujarati & Porter, 2009, p.758). The number of lags in the nonparametric tests will not impact the estimated parameters, as if the autocorrelation coefficients tend towards zero, they are at best with little impact on the estimated variance (Kirchgassner & Wolters, 2007).

Meanwhile, these PP test features can solve the reduction power in the ADF test aroused from too many lagged differences. The too-small number of lags also affects the ADF test's accuracy because of the autocorrelation in estimated residuals (Kirchgassner & Wolters, 2007). On top of that, the PP test also performs an additional function by solving heteroscedasticity in the error terms (Phillips & Perron, 1988). PP test has the same null hypothesis as DF-GLS. The optimum lag length for PP tests was automatically selected based on the Newey-West Bandwidth. Accordingly, each variable in this study will be tested for the unit root using the DF-GLS and PP test before investigating the cointegration relationship among the variables. The unit root test results revealed the stationarity level of the variables to confirm that there is no I(2) and that the dependent variable is integrated with I(1), which fulfilled the requirement of the ARDL method.

3.4.2 Co-integration Test (Auto-Regressive Distributive Lag (ARDL) Bound Testing)

After checking the stationarity properties of the variables, the analysis can be further extended to identify the short- and long-run relationship. The concept of co-integration states that if a long-run relationship exists between two variables, then deviations from the long-run equilibrium path should be bounded. If this is the case, the variables are said to be co-integrated. Traditionally, if the variables are to be co-integrated, two conditions must be satisfied: (1) the series for the individual variables must have the same statistical properties, and (2) the variables must be integrated in the same order. So, if the variables have mixed results of I (0) and I (1), the commonly used Johansen and Juselius (1990) cointegrating procedure cannot be employed in finding the co-integration relationship (Baharumshah et al., 2009, and Ghatak & Siddiki, 2010).

Accordingly, ARDL-bound testing is widely used in empirical testing to tackle this limitation. This testing approach is developed by Pesaran and Shin (1999) and Pesaran *et al.,* (2001). Thus, this approach is widely used in energy-related studies. Lee (2010) argued that many previous studies used this method in examining the co-integration relationship with less than 30 observations. This method is fit for short sample data as well as large. It is a general dynamic specification model which includes the lags of the endogenous variable and the lags of exogenous variables to directly estimate the short-run effects and the long-run equilibrium relationship (Royfaizal, 2009). In addition, Yusof and Usman (2015) indicated that the ARDL model is robust against the simultaneous equation bias. Thus, the autocorrelation problem in the model can be ratified based on the proper model selection based on the Akaike Information Criterion (AIC) or Schwarz-Bayesion Criterion (SBC). This is mainly due to ARDL being the most general dynamic unrestricted model, as Ghouse et al. argued (2018). Accordingly, the authors claimed this method could tackle misspecification and autocorrelation issues and generate the most fitting interpretable model[28].

With many advantages and flexibility available in the ARDL, it is appropriate to adopt this method to test for cointegration in this study since financial and economic variables are highly demonstrations of nonstationary or trending behaviour (Ghouse et al., 2018). Accordingly, the general ARDL model specification is given as follows:

[28] The lag selection plays a significant role in the econometric analysis whereby short lag length may lead to the serial correlation errors in the model and large lag can reduce the power of the test, both could affect the co-integration result (Agunloye et al., 2014; Carrasco et al., 2009). Thus, ARDL deals better with this issue because the variable in the model is expressed based on lag and current value.

$$\phi(L,p)y_t = \sum_{i=1}^{n} \beta_i\,(L,q_i)x_{it} + \delta' w_t + \mu_t \qquad (24)$$

where,

$$\phi(L,p) = 1 - \phi_1 L - \phi_2 L^2 - \cdots - \phi_p L^p;$$

$$\beta_i(L,q_i) = 1 - \beta_{i1} L - \beta_{i2} L^2 - \cdots - \beta_{qi} L^{qi}$$

Based on Eq. (24), L refers to the lag operator where $L^1 y_t = y_{t-1}$; w_t indicates a $s \times 1$ vector of deterministic variables, including the intercept term, seasonal dummies, time trends or exogenous variables with fixed lags. Meanwhile, all available values of $p = 0,1,2,\dots,m;\ q_i = 0,1,2,\dots,m; i = 1,2,\dots,n$ with a total of $(m+1)^{n+1}$ OLS can estimate ARDL models. An optimal lag selection is based on information criteria such as the AIC, SBC, or the Hannan-Quinn criterion (HQC)[29]. With an appropriate lag length and asymptotic inferences, the long-run and short-run parameters can be obtained through OLS regardless of whether the independent variables studied in this study are exogenous.

Thus, the ARDL model approach for the cointegration testing of models one and three is presented in Eq. (25) and Eq. (26), respectively[30]. The details of the variables included in the ARDL model have been discussed in the previous section:

$$\Delta FP_t = \alpha_0 + \sum_{i=1}^{n_1} \beta_0 \Delta FP_{t-1} + \sum_{i=1}^{n_2} \beta_1\,\Delta PO_{t-i} + \sum_{i=1}^{n_3} \beta_2\,\Delta IPI_{(t-i)} +$$
$$\sum_{i=1}^{n_4} \beta_3\,\Delta EXC_{(t-i)} + \sum_{i=1}^{n_5} \beta_4\,\Delta CO_{(t-i)} + \delta_0 FP_{t-1} +$$

[29] The lag selection criterion will be chosen later, based on outcomes of the ARDL model.
[30] There is another one more model which is modified from the model one will be presented in chapter 4. This is to check for the sensitivity of the model one by palm oil price will be replace with domination value of the palm oil price towards the USD. This is mainly to check for the robustness of the model one.

$$\delta_1 PO_{t-1} + \delta_2 IPI_{(t-1)} + \delta_3 EXC_{(t-1)} + \delta_4 CO_{(t-1)} + \varepsilon_t$$

(25)

$$\Delta FP_t = \alpha_1 + \sum_{i=1}^{n_1} \beta_5 \Delta FP_{t-1} + \sum_{i=1}^{n_2} \beta_6 \, \Delta EXC_{(t-i)} + \sum_{i=1}^{n_3} \beta_7 \, \Delta CO_{(t-i)} + \sum_{i=1}^{n_4} \beta_8 \, \Delta BP_{t-i} + \sum_{i=1}^{n_5} \beta_9 \, \Delta Inv_{(t-i)} + \sum_{i=1}^{n_6} \beta_{10} \, \Delta Policy_{(t-i)} + \sum_{i=1}^{n_7} \beta_{11} \, \Delta VP_{(t-i)} + \delta_5 FP_{t-1} + \delta_6 EXC_{(t-1)} + \delta_7 CO_{(t-1)} + \delta_8 BP_{t-1} + \delta_9 Inv_{(t-1)} + \delta_{10} lnPolicy_{(t-1)} + \delta_{11} VP_{(t-1)} + \varrho_t \quad (26)$$

Based on Eq. (25) and Eq. (26), Δ is the first-difference operator; n_1, n_2, n_3, n_4, and n_5 (Eq. 25) and $n_1, n_2, n_3, n_4, n_5, n_6$, and n_7(Eq. 26) are the lag lengths; β_0, β_1, β_2, β_3, and β_4 (Eq. 25) and β_5, β_6, β_7, β_8, β_9, β_{10}, β_{11}(Eq. 26) represent the short-run dynamics of the model; δ_0, δ_1, δ_2, δ_3, and δ_4 (Eq. 25) and δ_5, δ_6, δ_7, δ_8, δ_9 δ_{10}, δ_{11}, and δ_{12} (Eq. 26) represent the long-run relationship, respectively. ε_t and ϱ_t is a white noise error term for Eq. (25) and Eq. (26), respectively.

The F-test will be used to test the long-run cointegration relationship between the variables under study. The null and alternative hypotheses to test for the long-run relationship among the variables in model one are as follows:

$$H_0: \delta_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = 0 \quad (27)$$

$$H_0: \delta_0 \neq \delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq 0 \quad (28)$$

The null and alternative hypotheses to test for the long-run relationship among the variables in model three are as follows:

$$H_0: \delta_5 = \delta_6 = \delta_7 = \delta_8 = \delta_9 = \delta_{10} = \delta_{11} = \delta_{12} = 0 \quad (29)$$

$$H_0: \delta_5 \neq \delta_6 \neq \delta_7 \neq \delta_8 \neq \delta_9 \neq \delta_{10} \neq \delta_{11} \neq \delta_{12} \neq 0 \quad (30)$$

Accordingly, the computed F-test value generated by the OLS technique will be compared with the critical value in the table. By comparing, the null hypothesis (Eq. 27 and Eq. 29) will be rejected if the computed F-test value exceeds the critical value's upper bound. This rejection can conclude that there is a long-run relationship between the food price and the independent variables. On the other hand, non-rejection of the null hypothesis indicates no co-integration relationship among the variables. Another possibility is that the computed F-test may fall in lower and upper bound test critical values, concluding it inconclusive (Pesaran et al., 2001).

Furthermore, the error correction factors are integrated into the ARDL model. Wang (2009) indicates that the error correction terms (EC_t) and lag difference terms can be used to test the model's short-term and long-term relationships. By recalling Eq. (25) and Eq. (26), the general error correction model (ECM) formulated is as follows:

$$\Delta FP_t = \alpha_0 + \sum_{i=1}^{n_1} \beta_0 \Delta FP_{t-1} + \sum_{i=1}^{n_2} \beta_1 \Delta PO_{t-i} + \sum_{i=1}^{n_3} \beta_2 \Delta IPI_{(t-i)} + \sum_{i=1}^{n_4} \beta_3 \Delta EXC_{(t-i)} + \sum_{i=1}^{n_5} \beta_4 \Delta CO_{(t-i)} + \partial EC_t + \mu_{1t} \quad (31)$$

$$\Delta FP_t = \alpha_1 + \sum_{i=1}^{n_1} \beta_5 \Delta FP_{t-1} + \sum_{i=1}^{n_3} \beta_6 \Delta IPI_{(t-i)} + \sum_{i=1}^{n_4} \beta_7 \Delta EXC_{(t-i)} + \sum_{i=1}^{n_5} \beta_8 \Delta CO_{(t-i)} + \sum_{i=1}^{n_6} \beta_9 \Delta BP_{t-i} +$$

$$\sum_{i=1}^{n_7} \beta_{10} \Delta Inv_{(t-i)} + \sum_{i=1}^{n_8} \beta_{11} \Delta Policy_{(t-i)} +$$

$$\sum_{i=1}^{n_9} \beta_{12} \Delta VP_{(t-i)} + \vartheta EC_t + \mu_{2t} \quad (32)$$

Where ∂ and ϑ is the speeds of the adjustment parameter for Eq. (31) and Eq. (32), respectively. This parameter should be negative and statistically significant. It indicates how fast the current differences independent variable responds to the EC_t in disequilibrium in the previous period, which is derived from the estimated co-integration model of Eq. (25) and Eq. (26), respectively (Wang, 2009).

3.4.3 Asymmetric Test [Non-linear Autoregressive Distributive Lag Bound Testing].

The role of the ARDL method is to measure the long and short-run cointegration relationship between the variables under study. However, this method ignores the asymmetric effect investigation in the model (Malik et al., 2020). An asymmetric effect refers to a situation where the impact of a variable or an event on a time series is not the same for both positive and negative changes. In other words, the effect of an increase in the variable differs from that of a decrease in the same variable on the time series data. This is important for understanding the real-world dynamics of various economic and financial phenomena. This analysis is common in the financial markets, among economic indicators and commodity market volatility. Thus, the effect of asymmetric should not be ignored for the food price study of Malaysia as well. Understanding and modelling asymmetric effects in time series data is important for accurate forecasting and decision-making. However, traditional linear models may not adequately address asymmetric effects. Therefore, more complex models such as GARCH models (Fathian et al., 2019), threshold models (Benito et al., 2023), and other nonlinear models are often employed to represent the data better. Accordingly, this study uses the non-linear ARDL (NARDL) method to understand the asymmetric linear relationship between the understudied variables.

Thus, the NARDL test proposed by Shin et al. (2014) will be used to test for the asymmetric relationship between the variables under study. This method helps in achieving the second objective of this study. Studying the asymmetric effect in the model creates better insight and a deeper understanding of the relationship. There are several advantages of NARDL; for instance, similar to the ARDL model, the NARDL model does not require all variables to be integrated in the same order (Malik et al., 2020). Furthermore, NARDL models can be robust against misspecification of functional form assumptions (Nsor-Ambala & Amewu, 2023). This makes them valuable when there is uncertainty about the exact nature of the relationship between variables. Finally, this method is flexible in dealing with data that does not conform to linear assumptions, which is common in economics and finance.

Accordingly, NARDL is developed by considering an asymmetric long-run regression as below:

$$FP_t = \beta_1^+ IPI_t + \beta_1^- IPI_t + \beta_2^+ EXC_t + \beta_2^- EXC_t + \beta_3^+ CO + \beta_3^- CO_t + \beta_4^+ PO_t + \beta_4^- PO_t + \phi_t \quad (33)$$

whereby industrial growth (Y_t), exchange rate (EXC_t), crude oil price (CO_t) and palm oil price (PO_t), are decomposed as $IPI_t = IPI_0 + IPI_t^{+} + IPI_t^{-}$, $EXC_t = EXC_0 + EXC_t^{+} + EXC_t^{-}$, $CO_t = CO_0 + CO_t^{+} + CO_t^{-}$, and $PO_t = PO_0 + PO_t^{+} + PO_t^{-}$, respectively. The partial sum components of the asymmetric cointegration of each variable are as follows:

$$IPI_t^{+} = \sum_{j=1}^{t} \Delta IPI_j^{+} = \sum_{j=1}^{t} \max\left(\Delta IPI_j, 0\right);\ IPI_t^{-} = \sum_{j=1}^{t} \Delta IPI_j^{-} = \sum_{j=1}^{t} \max\left(\Delta IPI_j, 0\right) \tag{34}$$

$$EXC_t^{+} = \sum_{j=1}^{t} \Delta EXC_j^{+} = \sum_{j=1}^{t} \max\left(\Delta EXC_j, 0\right);\ EXC_t^{-} = \sum_{j=1}^{t} \Delta EXC_j^{-} = \sum_{j=1}^{t} \max\left(\Delta EXC_j, 0\right) \tag{35}$$

$$CO_t^{+} = \sum_{j=1}^{t} \Delta CO_j^{+} = \sum_{j=1}^{t} \max\left(\Delta CO_j, 0\right);\ CO_t^{-} = \sum_{j=1}^{t} \Delta CO_j^{-} = \sum_{j=1}^{t} \max\left(\Delta CO_j, 0\right) \tag{36}$$

$$PO_t^{+} = \sum_{j=1}^{t} \Delta PO_j^{+} = \sum_{j=1}^{t} \max\left(\Delta PO_j, 0\right);\ PO_t^{-} = \sum_{j=1}^{t} \Delta PO_j^{-} = \sum_{j=1}^{t} \max\left(\Delta PO_j, 0\right) \tag{37}$$

The positive and negative partial sums (Eq. 34-37) are incorporated into the linear ARDL model (recalled Eq. 25) to capture the short- and long-run asymmetric effect of the independent variables on the food price in Malaysia.

$$\Delta FP_t = \alpha_0 + \beta_0 FP_{t-1} + \beta_1 IPI_{t-1}^{+} + \beta_2 IPI_{t-1}^{-} + \beta_3 EXC_{t-1}^{+} + \beta_4 EXC_{t-1}^{-} + \beta_5 CO_{t-1}^{+} + \beta_6 CO_{t-1}^{-} + \beta_7 PO_{t-1}^{+} + \beta_8 PO_{t-1}^{-} + \sum_{i=1}^{n_1} \delta_1 \Delta FP_{t-i} + \sum_{i=0}^{n_2} \delta_2^{+} \Delta IPI_{t-i}^{+} + \sum_{i=0}^{n_3} \delta_3^{-} \Delta IPI_{t-i}^{-} + \sum_{i=0}^{n_4} \delta_4^{+} \Delta EXC_{t-i}^{+} + \sum_{i=0}^{5} \delta_5^{-} \Delta EXC_{t-i}^{-} + \sum_{i=0}^{n_6} \delta_6^{+} \Delta CO_{t-i}^{+} +$$

$$\sum_{i=0}^{n_7} \delta_7^- \Delta CO_{t-i}^- + \sum_{i=0}^{n_8} \delta_8^+ \Delta PO_{t-i}^+ + \sum_{i=0}^{n_9} \delta_9^- \Delta PO_{t-i}^- + \phi_t \quad (38)$$

Based on Eq. (38), n_1, n_2, n_3, n_4, n_5, n_6, n_7, n_8 and n_9 are the lag orders. Besides, $\delta_1, \delta_2, \delta_3, \delta_4, \delta_5, \delta_6, \delta_7, \delta_8$, and δ_9 represent the short-run influence of increase and decrease of the industrial growth, exchange rate, crude oil price and palm oil price on the food price, respectively. Besides, β_0, β_1, β_2, β_3 β_4, β_5, β_6, β_7, β_8 represent the long-run parameters. Based on Eq. (38), the cointegration among the variables will be captured using the bound test approach similar to the ARDL method discussed earlier.

Furthermore, to check for the asymmetric short- and long-run effect of palm oil price, crude oil price, exchange rate and industrial growth on food price in Malaysia, the standard Wald test is used based on the assumption below:

Based on Eq. (38), short-run assumption:

H_0: $\left(\delta_i^{(+)} = \delta_i^{(-)} = 0\right); i = 2, 3, 4, \ldots..9$ absence of asymmetric, (39)

H_1: $\left(\delta_i^{(+)} \neq \delta_i^{(-)} \neq 0\right); i = 2, 3, 4, \ldots..9$ presence of asymmetric (40)

Based on Eq. (38), long run assumption:

H_0: $\left(\beta_i^{(+)} = \beta_i^{(-)} = 0\right); i = 1, 2, 3, 4, \ldots..9$ absence of asymmetric, (41)

H_1: $\left(\beta_i^{(+)} \neq \beta_i^{(-)} \neq 0\right); i = 1, 2, 3, 4, \ldots .9$ presence of asymmetric (42)

The asymmetric effect in the short- and long-run is confirmed by the rejection of the null hypothesis, which is rejected when the calculated probability is greater than 10 per cent. This process will be tested for each of the independent variables under investigation. After the confirmation of the asymmetric cointegration relationship using the NARDL, the long-run and short-run asymmetries between the independent variables and food price can be explored in the final stage using the cumulative dynamic multipliers as follows:

$$m_{Y,h}^{+} = \sum_{j=0}^{h} \frac{\vartheta FP_{t+j}}{\vartheta IPI_t^{+}} \quad , \text{ and } \quad m_{Y,h}^{-} = \sum_{j=0}^{h} \frac{\vartheta FP_{t+j}}{\vartheta IPI_t^{-}} \quad , \text{ whereby } h = 0,1,2, \ldots \ldots \tag{43}$$

Based on Eq. (43), when $h \rightarrow \infty$, then $m_{Y,h}^{+} \rightarrow \varphi_{Y^+}$ and $m_{Y,h}^{-} \rightarrow \varphi_{Y^-}$, where $\varphi_{Y^+} = \frac{-\beta_1^{+}}{\beta_0}$ and $\varphi_{Y^-} = \frac{-\beta_2^{-}}{\beta_0}$ are the positive and negative asymmetric long-run coefficients of industrial growth on Malaysia's food prices, respectively.

$$m_{EXC,h}^{+} = \sum_{j=0}^{h} \frac{\vartheta FP_{t+j}}{\vartheta EXC_t^{+}} \quad , \text{ and } \quad m_{EXC,h}^{-} = \sum_{j=0}^{h} \frac{\vartheta FP_{t+j}}{\vartheta EXC_t^{-}} \quad , \text{ whereby } h = 0,1,2, \ldots \ldots \tag{44}$$

Based on Eq. (44), when $h \rightarrow \infty$, then $m^{+}_{EXC,h} \rightarrow \varphi_{EXC^{+}}$ and $m^{-}_{EXC,h} \rightarrow \varphi_{EXC^{-}}$, where $\varphi_{EXC^{+}} = \frac{-\beta_3^{+}}{\beta_0}$ and $\varphi_{EXC^{-}} = \frac{-\beta_4^{-}}{\beta_0}$ are the positive and negative asymmetric long-run exchange rate coefficients on Malaysia's food prices, respectively.

$$m^{+}_{CO,h} = \sum_{j=0}^{h} \frac{\vartheta FP_{t+j}}{\vartheta CO_t^{+}} \ , \ \text{and} \quad m^{-}_{CO,h} = \sum_{j=0}^{h} \frac{\vartheta FP_{t+j}}{\vartheta CO_t^{-}} \ , \ \text{whereby} \ h = 0,1,2,\ldots\ldots \tag{45}$$

Based on Eq. (45), when $h \rightarrow \infty$, then $m^{+}_{CO,h} \rightarrow \varphi_{CO^{+}}$ and $m^{-}_{CO,h} \rightarrow \varphi_{CO^{-}}$, where $\varphi_{CO^{+}} = \frac{-\beta_5^{+}}{\beta_0}$ and $\varphi_{CO^{-}} = \frac{-\beta_6^{-}}{\beta_0}$ are the positive and negative asymmetric long-run coefficients of crude oil price on Malaysia's food price, respectively.

$$m^{+}_{PO,h} = \sum_{j=0}^{h} \frac{\vartheta FP_{t+j}}{\vartheta PO_t^{+}} \ , \ \text{and} \quad m^{-}_{PO,h} = \sum_{j=0}^{h} \frac{\vartheta FP_{t+j}}{\vartheta PO_t^{-}} \ , \ \text{whereby} \ h = 0,1,2,\ldots\ldots \tag{46}$$

Based on Eq. (46), when $h \rightarrow \infty$, then $m^{+}_{PO,h} \rightarrow \varphi_{PO^{+}}$ and $m^{-}_{PO,h} \rightarrow \varphi_{CO^{-}}$, where $\varphi_{PO^{+}} = \frac{-\beta_7^{+}}{\beta_0}$ and $\varphi_{PO^{-}} = \frac{-\beta_8^{-}}{\beta_0}$ are the positive and negative asymmetric long-run coefficients of palm oil prices on Malaysia's food prices, respectively.

3.4.4 Diagnostic Testing for Model Stability and Validity

After the Short- and long run analysis for the food price models proposed, the diagnostic testing should be further proceeded. This is to ensure the validity and reliability of the ARDL model. Thus, few diagnostic tests have been conducted to assess its appropriateness and effectiveness in capturing the dynamics of the variables under investigation. Diagnostic tests play a crucial role in identifying potential issues or violations of model assumptions, allowing for a more robust and accurate interpretation of the results. In total, three diagnostic tests, i.e., autocorrelation, heteroscedasticity, and normality test, and one stability test, i.e., Cumulative Sum (CUSUM) and Cumulative Sum of Squares (CUSUMSQ) tests have been conducted to make sure the model is well fitted to be interpreted.

At first, the autocorrelation test is a diagnostic tool employed to assess the presence of autocorrelation in the residuals of a time series model. Autocorrelation refers to the correlation between the residuals at different lags. In the context of time series analysis, the assumption is often that the residuals are independent and do not exhibit any systematic patterns over time. To conduct the autocorrelation test, the residuals from the estimated model are examined for any discernible correlation at different lag intervals. The absence of autocorrelation is crucial for the validity of the model, as the presence of systematic patterns in the residuals can lead to biased parameter estimates and inflated standard errors (Gaspard et al., 2019; Dormann, 2007).

Addressing autocorrelation is important as it ensures that the model captures the underlying patterns in the data accurately, leading to more reliable and efficient parameter estimates. If autocorrelation is detected, corrective measures such as adjusting the model specification or incorporating lagged variables may be necessary to improve the model's performance and overall validity (Gaspard et al., 2019). Following this, we conducted tests for serial correlation in the residuals, including the Breusch-Godfrey Lagrange Multiplier (LM) test.

Following the autocorrelation test, the next diagnostic step involves conducting a heteroscedasticity test to assess the homogeneity of variance across observations. Homoscedasticity is a crucial assumption in regression analysis, signifying consistent variability in the residuals. To examine whether the variance of the residuals is constant across observations, the White's test is employed. This test is a statistical procedure that evaluates whether there are significant differences in the variances of the residuals. A rejection of the null hypothesis in White's test suggests the presence of heteroscedasticity, indicating that the variability of residuals varies across observations. Addressing heteroscedasticity is crucial for obtaining unbiased and efficient parameter estimates (Caudill & Jackson, 1993; Scott et al., 2000). Failure to account for varying variances in the residuals may lead to incorrect standard errors and, consequently, inaccurate hypothesis testing. By conducting the heteroscedasticity test, employing White's test, and implementing robust standard errors, we enhance the reliability and validity of our model, contributing to the overall robustness of the empirical findings.

Next, the normality test will be conducted to check for the normality of residuals, which is a crucial assumption in regression analysis, as it plays a pivotal role in ensuring unbiased and efficient parameter estimation (Barker & Shaw, 2015; Ghasemi & Zahediasl, 2011). When residuals follow a normal distribution, it implies that the errors or unobserved factors influencing the model are symmetrically and randomly distributed around zero. A normal distribution of residuals is essential for unbiased estimation because it indicates that, on average, the model's predictions are equally likely to overestimate or underestimate the actual values. This symmetry is fundamental for the accuracy of parameter estimates, contributing to the overall reliability of the model (Barker & Shaw, 2015).

Efficient parameter estimation is facilitated when residuals are normally distributed. In a normal distribution, the majority of observations cluster around the mean, and extreme values are less likely. This characteristic allows for more precise and efficient estimation of the model parameters, leading to narrower confidence intervals and more reliable hypothesis testing. While normality is a desirable assumption, it is important to note that some regression models can tolerate departures from normality, especially with large sample sizes (Jarantow et al., 2023). In summary, the normality of residuals is a critical assumption that contributes to the unbiased and efficient estimation of model parameters, ultimately enhancing the overall statistical validity and reliability of the regression analysis.

Lastly, in order to evaluate the temporal stability of our model, we implemented the Cumulative Sum (CUSUM) and Cumulative Sum of Squares (CUSUMSQ) tests. These statistical tools play a pivotal role in detecting structural breaks or shifts in the relationship between variables over the sample period (Bani-Mustafa et al., 2019). The CUSUM test involves the cumulative summation of the estimated residuals or changes in parameter values. Large deviations from zero in the CUSUM graph can signal structural changes in the model. The CUSUMSQ test, an extension of the CUSUM test, incorporates the squares of these cumulative sums, providing additional sensitivity to subtle shifts in the data.

Detecting structural breaks is crucial as it helps identify points in time where the relationship between variables undergoes significant changes. Structural breaks can result from various factors, such as policy interventions, economic shocks, or changes in underlying dynamics (Kapetanios & Tzavalis, 2010). By employing the CUSUM and CUSUMSQ tests, we gain insights into the stability of the estimated coefficients and the overall integrity of the model over the entire sample period. A stable model is characterized by consistent and reliable parameter estimates that remain robust over time. Ensuring stability is essential for valid inference and reliable predictions, particularly in the presence of changing economic conditions. The use of CUSUM and CUSUMSQ tests enhances our ability to detect and account for structural breaks, contributing to the credibility and robustness of our empirical analysis.

The results from these diagnostic tests collectively contribute to the reliability of our ARDL and NARDL models, assuring that the estimated coefficients are unbiased and efficient. Any identified issues were appropriately addressed, ensuring the validity and robustness of our empirical analysis.

3.4.5 Robustness Test: Dynamic Ordinary Least Squares (DOLS) and Fully Modified Ordinary Least Squares (FMOL)

In order to assess the robustness of the findings, a series of robustness tests are conducted to ensure the reliability and consistency of the results obtained in the primary analysis. These tests are crucial in validating the robustness of the food price model and confirming the stability of the key findings in the face of alternative specifications and methodologies.

Firstly, the sensitivity analysis is performed by varying key model parameters and assumptions to assess the impact on the primary results based on the food price model. For instance, the denomination value of palm oil price in terms of USD is used to replace the local palm oil price in models one and two. This conversion to USD provides a standardized benchmark that facilitates communication and transactions in the global palm oil market. Anyhow, the ARDL and NARDL models will be used similarly to models one and two. The main objective is to examine whether the primary conclusions of palm oil prices on food prices have remained consistent under different scenarios and parameterizations (Ibrahim, 2015).

Additionally, the study used the DOLS and FMOLS to perform alternative model specifications analysis to ARDL and NARDL (Olorogun, 2023). Employing different econometric techniques and statistical models to examine the resilience of the results to different modelling approaches. This helped to ascertain the robustness of the primary findings and whether they are sensitive to the specific modelling choices made in the primary analysis of food prices in Malaysia. The robustness tests not only confirmed the consistency of the primary findings but also provided additional insights into the reliability of the food price model. These tests contribute to the overall validity of the research and enhance the confidence in the robustness of the relationships identified in this study.

Accordingly, DOLS was used as one of the robustness test analyses. DOLS is an econometric technique designed to address issues related to non-stationarity and endogeneity in time-series data. It is particularly valuable in estimating cointegrating relationships among variables, allowing for a more accurate representation of long-run dynamics (Kamalu & Ibrahim, 2021; Yshyaoui et al., 2019; Tursoy, 2019). This is well fitted for this study, which has combined I(0) and I(1) variables in the model. One key feature of DOLS is its ability to incorporate lagged values of variables, offering a dynamic perspective on the relationships under investigation. This is especially beneficial when dealing with economic time series data where variables may exhibit persistence over time (Merlin & Chen, 2021). The inclusion of lagged terms allows DOLS to capture the evolving nature of relationships, providing a more nuanced understanding of the underlying economic mechanisms.

While the ARDL model effectively addresses endogeneity concerns and captures both short- and long-run dynamics, incorporating DOLS as a supplementary analysis provides a complementary approach. This is essential for obtaining unbiased and efficient parameter estimates in the presence of correlated errors (Hamit-Haggar, 2012). DOLS is particularly advantageous in situations where variables are cointegrated, implying a stable long-term relationship. By estimating the cointegrating vector consistently, DOLS allows researchers to uncover the equilibrium relationships among variables, offering valuable insights into their long-run dynamics (Othman & Masih, 2015; Tugcu, 2018). Utilizing both ARDL and DOLS ensures the consistency of the results and strengthens the overall validity of the econometric approach.

Similar to DOLS, the FMOLS is an advanced econometric technique specifically designed to handle the challenges associated with non-stationary time-series data. The ARDL model inherently addresses potential endogeneity issues and captures the short- and long-run dynamics among the variables. However, to fortify the primary results on food price, the FMOLS is implemented, which extends the analysis by considering additional factors such as the endogeneity of regressors and cointegration. FMOLS extends the Ordinary Least Squares (OLS) method by incorporating the lagged levels of variables in the model. This allows FMOLS to capture the evolving nature of economic relationships over time, providing a more accurate representation of the underlying dynamics (Philips & Hansen, 1990). The inclusion of lagged terms is especially crucial when dealing with persistent time-series data, where the history of variables influences their current values.

One of the key advantages of FMOLS is its ability to estimate the cointegrating vector consistently. This is important when studying variables that are cointegrated, indicating a long-term equilibrium relationship (Himansu, 2007; Pedroni, 2000). By ensuring the consistent estimation of the cointegrating vector, FMOLS helps researchers uncover the stable long-term relationships among variables, contributing to a more comprehensive understanding of economic phenomena. Moreover, FMOLS addresses endogeneity concerns by transforming the model in a way that the estimated coefficients remain consistent in the presence of correlated errors (Olorogun, 2023; Rukhsana & Shahbaz, 2008). This feature enhances the reliability of parameter estimates, making FMOLS a valuable tool for researchers dealing with potentially endogenous variables. This dual-method approach not only ensures the robustness of our primary ARDL model but also enriches the depth of our analysis, providing a more comprehensive perspective on the economic relationships under investigation.

3.4.6 Non-Granger Causality Test (Toda Yamamoto Procedure)

After the long-run relationship had been identified, the Toda Yamamoto causality test was used to investigate the causal relationships among the variables. This is because the co-integration test can only detect the long-run relationship, not the direction of causality (Ozturk & Acaravci, 2010). According to Engle and Granger (1987), the basic concept of Granger Causality is if the past value of X_t can predict the Y_t value, which is defined as X_t Granger cause Y_t or Y_t can Granger cause the future value of X_t. The null hypothesis of the Granger causality test is that X_t does not Granger cause Y_t and vice versa.

New advances in econometrics offer the error correction model (because of Engle & Granger, 1987) and the vector autoregression error-correction model (because of Johansen & Jesulius, 1990) as options for testing non-causality between economic time series. Shockingly, these tests are lumbering and delicate to the ideas of the aggravation parameters in limited samples and in this way, their results are problematic (Toda & Yamamoto, 1995; Zapata & Rambaldi, 1997). Due to this reason, Toda and Yamamoto (1995) proposed a basic methodology obliging the estimation of an 'augmented' VAR when there is co-integration, which ensures the asymptotic dissemination of the MWald statistic. The advantage of this procedure is that the co-integration test is not essential, and transforming VAR into ECM is unnecessary. It makes the Granger causality tests easier by building into a Seemingly Unrelated Regression (SUR), as proven by Rambaldi and Doren (1996) in the previous study. Thus, the SUR form for model one can be written as below:

$$\begin{bmatrix} FP_t \\ CO_t \\ Y_t \\ EXC_t \\ PO_t \end{bmatrix} = A_0 + A_1 \begin{bmatrix} FP_{t-1} \\ CO_{t-1} \\ Y_{t-1} \\ EXC_{t-1} \\ PO_{t-1} \end{bmatrix} + \ldots + A_k \begin{bmatrix} FP_{t-k} \\ CO_{t-k} \\ Y_{t-k} \\ EXC_{t-k} \\ PO_{t-k} \end{bmatrix} + A_{k+1} \begin{bmatrix} FP_{t-k-1} \\ CO_{t-k-1} \\ Y_{t-k-1} \\ EXC_{t-k-1} \\ PO_{t-k-1} \end{bmatrix} +$$

$$\cdots + A_{k+d} \begin{bmatrix} FP_{t-k-d} \\ CO_{t-k-d} \\ Y_{t-k-d} \\ EXC_{t-k-d} \\ PO_{t-k-d} \end{bmatrix} \tag{47}$$

Accordingly, the SUR form for model three can be written as below:

$$\begin{bmatrix} FP_t \\ CO_t \\ Y_t \\ EXC_t \\ PO_t \\ BP_t \\ Inv_t \\ Policy_t \\ VP_t \end{bmatrix} = A_0 + A_1 \begin{bmatrix} FP_{t-1} \\ CO_{t-1} \\ Y_{t-1} \\ EXC_{t-1} \\ PO_{t-1} \\ BP_{t-1} \\ Inv_{t-1} \\ Policy_{t-1} \\ VP_{t-1} \end{bmatrix} +\ldots+A_k \begin{bmatrix} FP_{t-k} \\ CO_{t-k} \\ Y_{t-k} \\ EXC_{t-k} \\ PO_{t-k} \\ BP_{t-k} \\ Inv_{t-k} \\ Policy_{t-k} \\ VP_{t-k} \end{bmatrix} +$$

$$A_{k+1} \begin{bmatrix} FP_{t-k-1} \\ CO_{t-k-1} \\ Y_{t-k-1} \\ EXC_{t-k-1} \\ PO_{t-k-1} \\ BP_{t-k-1} \\ Inv_{t-k-1} \\ Policy_{t-k-1} \\ VP_{t-k-1} \end{bmatrix} + \cdots + A_{k+d} \begin{bmatrix} FP_{t-k-d} \\ CO_{t-k-d} \\ Y_{t-k-d} \\ EXC_{t-k-d} \\ PO_{t-k-d} \\ BP_{t-k-d} \\ Inv_{t-k-d} \\ Policy_{t-k-d} \\ VP_{t-k-d} \end{bmatrix} \tag{48}$$

Eq. (47) and Eq. (48) represent the variables investigated in this study. k is the optimum lag length, and d represents the order of integration of the variable. SUR form in Eq. (47) and Eq. (48) can identify the causality relationship among any two variables. Let's say we want to see if food price affects the price of palm oil. The null hypothesis with the chi-square statistics is as below:

$$H_0: \delta_1^{(1\ 2)} = \delta_2^{(1\ 2)} = \cdots = \delta_k^{(1\ 2)} = 0 \tag{49}$$

where $\delta^{(1\ 2)}$ are the coefficients of food price. If the null hypothesis is rejected, then a one-way causality effect exists from food prices towards palm oil prices. The alternative hypothesis test reverses the precise direction as below:

$$H_0: \delta_1^{(2\ 1)} = \delta_2^{(2\ 1)} = \cdots = \delta_k^{(2\ 1)} = 0 \tag{50}$$

where $\delta^{(2\ 1)}$ are the coefficients of palm oil prices. If the hypothesis is rejected, it shows two-way causality among the variables. Everything one needs to do is to focus on the maximal integration $d$max, which hopes to happen in the model and build a VAR in their levels with a sum of (k + dmax) lags. Toda and Yamamoto call attention to the fact that, for d=1, the lag selection process is continuously valid, at least asymptotically; subsequently, k> =1= d. If d=2, then the procedure is valid unless k=1. Furthermore, according to Toda and Yamamoto, the MWald statistic is valid regardless of whether a series is I*(0),* I*(1)* or I*(2)*, non-co-integrated or co-integrated of a random order.

3.4.7 Impulse Response Function (IRF) and Forecast Error Variance Decomposition (FEVD).

The Impulse Response Function emerges as a powerful analytical tool, providing a nuanced understanding of dynamic system responses to shocks, particularly within the framework of VAR. In contrast to cointegration tests that focus on establishing long-run equilibrium relationships, IRF stands out for its capability to unravel the intricate ways in which variables respond to shocks, offering invaluable insights into both short and long-term dynamics (Usman et al., 2022). Abed et al. (2016) emphasized that IRF enhances the predictive capacity of a time series system. This test is very important to achieve the last objective of this study.

The incorporation of IRF analysis into this study is justified by its multifaceted advantages. Firstly, its ability to visually represent the short and long-term effects of shocks proves instrumental, facilitating clear communication of results to both technical and non-technical audiences. Secondly, the role of IRF extends beyond visualization; it serves as a crucial tool for unravelling causal relationships between variables, thus reinforcing the robustness of the earlier proposed Toda-Yamamoto analysis (Uddin, 2023). Lastly, its dynamic nature empowers researchers and policymakers with forecasting capabilities, simulating the potential impacts of future shocks. Duasa (2007) underscores the significance of IRF in tracing directional responses to standard deviation shocks, enriching the understanding of the variables under scrutiny.

With the aim of the study in addressing the sustainable growth in the palm oil industry, environment, economics and food, the application of IRF in observing the persistence and directional impact of these variables on food prices in Malaysia assumes paramount importance. IRF's capacity to assess forecasting performance becomes a cornerstone and is able to provide valuable insight into the scope of shaping sustainable policy under this study (Uddin, 2023). IRF analysis not only provides insights but also empowers researchers and policymakers to craft effective responses by comprehending how changes in one variable reverberate across the system. For instance, it is assessing the impact of a policy shock, such as a heightened blended mandate in transportation and industry, on food prices, or gauging the long-term efficacy of policies, IRFs serve as invaluable guides.

Furthermore, this analysis aids in predicting potential unintended consequences, allowing policymakers to design interventions with foresight, steering clear of short-sighted solutions with negative long-term repercussions. This can create a situation whereby sustainable policies under palm oil industries and the food market can be developed without harming any parties. The intricate understanding of dynamic interactions facilitated by IRFs informs a strategic approach to policy sequencing, crucial for achieving enduring sustainability goals in the bioenergy model in Malaysia[31].

Forecast Error Variance Decomposition (FEVD) serves as a pivotal component in structural analysis, providing a robust method to gauge the resilience of a model against shocks. Employing Cholesky decomposition, this analysis dissects the strength of shocks within the overall model, shedding light on the percentage of forecast error attributed to specific shocks over time. In essence, it reveals the extent to which the variability in a dependent variable is driven by its shocks in comparison to those of other variables. In the context of Malaysia's economic landscape, the significance of FEVD is particularly highlighted as it delves into the repercussions of sudden fluctuations caused by supply and demand constraints, policy influences, and monetary policy shocks on food prices. This analysis not only discerns the nuanced reactions of variables within the model but also quantifies their contributions to forecast errors.

[31] Usman et al., (2022) study the Effects of domestic material consumption, renewable energy, and financial development on environmental sustainability using the IRF. Based on the findings sustainable consumption and production is suggestion as policy insight for EU countries. Furthermore, study of Zhang and An (2018) proposed a sustainable policy to enforce innovations in the energy production process in Shanxi to manage the industrial pollution using the IRF as main method in their analysis.

The inherent advantage of FEVD lies in its ability to elucidate how variables respond to distinct shocks, especially those related to the complex interplay of supply and demand dynamics, policy interventions, and monetary influences on food prices in Malaysia. Beyond this, FEVD emerges as an invaluable tool for policy analysis and risk assessment, providing a roadmap for policymakers to craft sustainable policies that safeguard economic interests without unduly harming any sector. This analytical approach proves indispensable in the examination of the impact of palm oil prices, industrial growth, and biodiesel demand on the fluctuation of food prices in Malaysia. By undertaking such a meticulous analysis, one can unravel the intricate web of influences and determine the extent to which these variables contribute to the fluctuations in food prices, offering crucial insights for informed decision-making and the formulation of effective, sustainable economic strategies.

3.5 Data Description

This section will discuss the dataset used to represent the variables in the model. Table 3.1 shows the list of data sets that are used in this study. The frequency of the monthly data collected from 2013 (January) until 2022 (May). The time frame is selected based on the availability of the data[32]. Accordingly, 113 observations will be available for each series. The data used in this study

[32] The MPOB only able to supply the data of biodiesel price from 2013 only. Due to this the starting point of the data is fix at 2013 January.

were sourced from a range of official and reliable government and institutional sources to ensure accuracy, consistency, and credibility. The food price index (FP) is collected from the DOSM, which is a primary source of the national economy. This index represents Malaysia's food prices. The food price index in Malaysia measures the average change over time in the prices of a basket of food and non-alcoholic beverage items purchased by Malaysian households. The food price index is calculated using the Laspeyres formula, a weighted average price index. The formula's weights are based on Malaysian households' expenditure patterns on food and non-alcoholic beverages in a base year. The base year for the Malaysian food price index in this study is set at 2010.

Furthermore, for the palm oil price and biodiesel price (export price), data is gathered from the MPOB which is the main agency in charge of palm oil and biodiesel in Malaysia. Both variables are measured in MYR million. The palm oil price is the average price of crude palm oil (PO) traded in Malaysia on a given day. The MPOB calculates it based on the prices of PO transactions reported to the MPOB by licensed traders. The CPO is updated on the MPOB website daily. At the same time, the average price of biodiesel exports from Malaysia is calculated by the MPOB based on the prices of biodiesel transactions reported to the MPOB by licensed exporters. This is updated on the MPOB webpage daily as well.

The data on the control variables, such as crude oil price and real exchange rate (MYR/USD), is gathered from the World Bank database and Refinitiv, respectively. The Brent crude oil price was used as the representative measure of international oil prices which is measured based on US Dollars per Metric Tonne. Brent is used as the global pricing benchmark and is relevant for Malaysia’s fuel pricing structure and international trade (Ministry of Finance Malaysia, 2022). The real exchange rate used in this study for better comparability with the FPI and better reflects the impact of trade on the economy (Ekanayake & Dissanayake, 2022). The real exchange rate (EXC) of Malaysia is the ratio of the nominal exchange rate to the price level differential between Malaysia and its trading partners. It measures the Malaysian ringgit (MYR)'s purchasing power relative to its trading partners' currencies. The EXC is calculated using the following formula:

$$EXC = Nominal\ exchange\ rate \text{ x } \left(\frac{Price\ level\ in\ Malaysia}{Price\ level\ in\ trading\ partners}\right)()/ \quad (47)$$

Next, the Industrial production index (IPI) is gathered from the DOSM, representing the effect of income in this study. IPI is measured based on the volume of industrial production in Malaysia using the weighted average of producing a basket of industrial products. IPI is calculated using the following formula:

$$IPI = \frac{Sum\ of\ the\ weighted\ production\ of\ industrial\ products**}{Weighted\ production\ of\ industrial\ product\ in\ the\ base\ year} \text{ x } 100 \quad (48)$$

** The weights used in the formula are based on the importance of each industrial product to the Malaysian economy.

The IPI is an important economic indicator because it can be used to track the manufacturing sector's performance, a significant contributor to the Malaysian economy. A rising IPI indicates that the manufacturing sector is growing, while a falling IPI indicates that the manufacturing sector is shrinking. Thus, it justifies the usage of IPI in this study to capture the income effect (similar to Yang et al., 2023), and the base year was fixed in 2010.

Investment in the biodiesel industry is one of the demand factors for biodiesel. However, the exact investment data is limited and unavailable in Malaysia. Accordingly, to capture the effect of biodiesel investment, the production level of biodiesel in Malaysia is used (Noriega & Narvaez, 2020; Mohd & Mohd, 2019; Budi & Agus, 2018). Production is a measure of the output of a firm, and it is assumed that investment will lead to increased production (Noriega & Narvaez, 2020). The data on biodiesel production is gathered from the MPOB and measured in metric tonnes.

Besides, the monthly number of newly registered diesel vehicles in Malaysia is gathered from the Road and Transport Department of Malaysia (JPJ). The data is converted into cumulative value to capture the overall vehicle population on the road. Later on, the data is converted into the index, based year 2010, for comparability purposes. It is acknowledged that this cumulative proxy may overstate the actual number of active vehicles on the road, as data on vehicle de-registration or inactivity is not publicly available. Despite this limitation, the approach provides a useful approximation of biodiesel-related transport demand trends in Malaysia.

Lastly, the biofuel policy is captured using the blended mandate requirement implemented in Malaysia. The dummy effect represents the effect of the Blended mandate (B7) on the food price. A dummy variable is a binary variable that takes on a value of 1 if a particular condition is met and zero if it is not. In policy analysis, a dummy variable can represent the presence or absence of a policy intervention (Bevilacqua et al., 2023; Borozan & Cipcic, 2022). The period covered for the B7 implementation is from 2015 (January) to 2018 (December) based on the report from the USDA Foreign Agricultural Service, Biofuel Annual Report (2020).

In this analysis, the choice to represent variables as index values, normalized to a 0 to 100 scale, is driven by the necessity to create a unitless framework that facilitates visual comparison across diverse data sets. This approach aligns with the study's primary objective of examining the influence of the selected independent variables on the FPI, which serves as the dependent variable. This is common practice in food price studies (Norazman et al., 2018; Shrestha et al., 2019; Al-Rousan et al., 2024). Utilizing index values allows for the integration of disparate data types, which originally vary in units and scales, into a cohesive analysis. This is particularly critical given the diverse nature of the independent variables involved. By transforming these variables into relative values, we normalize the data, thereby enabling a direct comparison of relative changes over time. Such a transformation is crucial for maintaining consistency in visual data comparisons and enhancing the interpretability of the economic relationships under study.

Moreover, indexing simplifies the comparison of economic indicators across different periods or datasets. It converts absolute values into a relative scale, which is particularly useful in economic analyses where understanding growth rates and proportional changes is essential. This method provides a clear, intuitive means of assessing economic trends without the complications introduced by varying units of measurement. Additionally, the use of index values circumvents the complexities associated with logarithmic transformations, especially when dealing with dummy variables. Logarithmic transformations, while useful in certain contexts, can complicate the interpretation of results when dummy variables are included. This is because the logarithm of zero (often representing the absence of a condition in dummy variables) is undefined, which can lead to analytical difficulties (Young & Young, 1975).

Supporting the selected methodology, Banerjee et al. (2008) suggest that indexing may be more appropriate in scenarios where understanding relative changes is paramount. Given that the primary aim of this study is to explore relative changes and their impacts, the indexing method is not only suitable but essential. It provides a robust framework for analyzing how shifts in the independent variables influence the FPI, thereby offering valuable insights into economic dynamics. A standard Min-Max scaling formula method is used to normalise the variables' scaling, following Shrestha et al., (2019). The Min-Max formula is as follows:

$$Relative\ index\ value = \frac{Actual\ value - Min.\ value}{Max.\ value - Min.\ value} \text{ x } 100 \quad (49)$$

Based on the normalization model in Eq. (49), all the variables in this study have been converted into an index for comparability except the variables which are already in index form, such as FPI, IPI, and real exchange rate. This crucial step contributes to the model's stability, accuracy, and interpretability, ensuring that the model is better equipped to handle variables with different units and scales. Thus, Table 3.1 summarises the variables used in the study.

Table 3.1: List of Variables in Details

Variables	Unit measurement	Source
• Food Price (FP)	Food Price Index (2010=100)	Department of Statistics Malaysia
• Palm oil price (PO)	MYR Million	Economic and Industry Development Division, Malaysian Palm Oil Board (MPOB).
• Investment in the biodiesel industry (INV)	Metric Tonnes	Ministry of International Trade and Industry
• Numbers of registered diesel vehicles on the road (VP)	Number of active vehicles on the road (diesel vehicles).	Road and Transport Department of Malaysia (JPJ)
• Price of Biodiesel (BP)	Export value of the biodiesel (MYR million).	MPOB
• Biofuel Blended Mandate (Policy)	Dummy 1 (blend mandate B7).	USDA Foreign Agricultural Service, Biofuel Annual Report, 2020
• Industrial production (IPI)	Industrial Production Index (2010=100)	Department of Statistics Malaysia
• Price of Crude Oil (CO)	US Dollars per Metric Tonnes (Brent Oil Price)	World Bank Database
• Real Exchange Rate (EXC)	MYR/USD (2010=100)	Refinitiv Database

CHAPTER FOUR

FINDINGS AND INTERPRETATIONS

4.1 Introduction

This chapter presents the empirical findings and detailed interpretations of the results. There will be nine sections in this chapter. The first section (current section) is the introduction of this chapter. Followed by section 4.2 represents the results of descriptive statistics and the correlation analysis results. This section helps understand the nature of the study's secondary data, followed by unit root test results in section 4.3. The motif of this section is to confirm the stationary of the variables. The following sections will discuss the bound testing results (in section 4.4) and short- and long-run relationships (in section 4.5) among the variables understudied for models one and three.

Accordingly, section 4.6 will present the findings on asymmetric results for model two. A detailed discussion of the short- and long-run asymmetric and symmetric effects of the selected variables on food prices will be discussed in this section. Subsequent, section 4.7 presents a robustness test for all three models. Next, under section 4.8, the granger causality test results, followed by impulse response function and variance decomposition analysis results in section 4.9. The final sections of the chapter represent the concluding remarks.

4.2 Descriptive Statistics and the Correlation Test Results

The descriptive statistics and the correlation test among the variables understudied are presented in Table 4.1. The role of descriptive statistics is to show the data summary and the variables' statistical behaviour. Thus, before estimating the model for the food price in Malaysia, the summary of statistics for all the variables used in the food price model will be described in this section. Table 4.1 is divided into two panels, i.e., panel A to demonstrate the descriptive statistics analysis results and panel B to present the correlation analysis results.

The descriptive statistic results are presented in Panel A. The mean value of food price in Malaysia is 126.76, whereby the minimum value and maximum value for the food price are 109.90 and 143.40, respectively. The data shows that the gap between the mean, minimum, and maximum values is not huge. This is mainly due to the food price index in Malaysia showing consistent gradual increments in the price level, and there are no higher fluctuations or structural breaks in the dataset for the period covered by this study[33]. Interestingly, Malaysia's economic shutdown in 2010 due to the pandemic did not create a considerable break in the food price data series, which is evidenced by the study of Ibrahim (2015). This could be due to proper government policy management, such as subsidy allocation for food and cooking oil in controlling Malaysia's food prices (Ibrahim, 2015). As a result, the standard deviation value seems small, i.e., 9.07.

[33] Structural break analysis has been conducted and found there is not any significant structural break in the food price index of Malaysia for the period understudied.

At the same time, Malaysia's industrial growth and exchange rate have a more minor standard deviation than food prices. The industrial growth standard deviation is 11.17, given that the mean value is 127.51 and the minimum and maximum values are 100.46 and 153.32, respectively. The exchange rate mean value is 88.90; the minimum (81.70) and maximum (103.45) values are very near the mean value. This led to the standard deviation value of the exchange rate tending to be the lowest, i.e., 5.72, among other variables in the study[34]. This is reasonable due to Malaysia having low variability or volatility in the exchange rate. This is mainly due to the Central Bank's intervention in controlling and stabilising the exchange rate by buying and selling the MYR in the foreign exchange market (Bank Negara Malaysia, 2021). This shows evidence of Malaysia's solid industrial growth and stable economic progress for the period covered by this study.

On the other hand, crude oil's average price is 61.39, and the maximum and minimum values are 100.00 and 18.50. The gap between the mean value and the maximum value is small. However, there is a considerable gap in the minimum value. This dataset makes the standard deviation big, i.e., 21.76. the same data structure can be observed for Malaysia's palm oil and biodiesel prices. The standard deviation value for palm oil and biodiesel prices is 15.37 and 14.03, respectively. This indicates that the dataset has a high spread as well. This could be due to the global crude oil price fluctuation due to various factors and incidents. Accordingly, the similar trend between crude oil prices and palm oil

[34] The biofuel policy shows the lowest standard deviation value i.e., 0.50. However, the biofuel policy in this study is captured using the dummy variable. This led to the smaller standard deviation value whereby exchange rate is represent the real statistical values. Thus, the standard deviation of biofuel policy is not considered as lowest in this situation.

prices due to the “*financialisation of commodities*” whereby the commodity market and energy market are highly associated with each other, as proven by studies such as Natoli (2021), Nazlioglu and Soytas (2011), Harri, Nally and Hudson (2009).

The average investment value in the biodiesel industry is 69.43, with a minimum value of 34.93 and a maximum value of 100.00. The standard deviation value is 15.29. The high standard deviation in the investment in the biodiesel industry could be due to the instability among the investors in the biodiesel industry in Malaysia because this industry is still young, and the potential growth of the biodiesel industry in Malaysia is still not stressed well. Next, the vehicle population shows the highest standard deviation, i.e., 29.13. This is the highest standard deviation value among all the series. This is due to the minimum value for the vehicle population in Malaysia having dramatic drops to a minimum of 0.98 during the COVID-19 lockdown period due to the enormous impact of the transportation sector due to the economic shutdown. Lastly, the biodiesel policy is captured using the blended mandate requirement, which covers a certain period of the overall sample period. This effect is captured using the dummy variable, so there is not much variation in the dataset of biodiesel policy. To summarise, all the variables’ understudies had lower standard deviations compared to the mean value for the period covered by this study. This indicates that the observations seem to be normally distributed.

Besides, Panel B in Table 4.1 presents the correlation test results among the variables understudied. Correlation analysis shows the association of the variables understudied to each other. Since the disaggregated data has been used to capture the biodiesel demand effect in the model, it is essential to ensure the variables are not highly correlated to avoid unnecessary statistical issues in the regressions. Accordingly, Table 4.1 shows that most variables are not highly correlated (< 80%) with independent variables in the models. However, biodiesel and palm oil prices have a strong positive correlation, i.e., 89.08 per cent. This high positive correlation is due to biodiesel production, one of the palm oil industry's downstream activities. Thus, the price fluctuation will positively influence the product's price in both industries. Another high positive correlation is found between industrial growth and the diesel vehicle population on the road, which is reported at 88.43 per cent. This high correlation is reasonable since logistics is an essential segment of industrial growth. Industrial activities will also increase transportation (Ina et al., 2022).

Next, followed by a moderate correlation from the exchange rate towards industrial growth (-69.55%), crude oil (66.89%), and vehicle population (-61.27). This indicates the strong influence of the Malaysian currency's value on the economic activities of Malaysia. The remaining variables correlating less than 60 per cent can be considered low. Hence, the variance inflation factor (VIF) value has been estimated to validate the multicollinearity issue among the independent variables. The VIF value for the crude oil price is 4.8022; the exchange rate is 9.1219; industrial growth is 5.9680; palm oil price is 13.0888; biodiesel price is 9.6046; biofuel policy is 2.6046; vehicle population is 13.3295; and finally, investment in biodiesel industry is 1.1213. The results indicate that there is a severe multicollinearity issue among some variables. This is because the VIF value for vehicle population and palm oil price seems higher than 10, indicating multicollinearity among the variables (Vu & Agalgaonkar, 2015).

Serious multicollinearity issues exist when the model's selected independent variables are highly correlated. Even though the model with serious multicollinearity does not affect its coefficient estimation, it will overestimate the standard error, contributing to a significant P-value (Wooldridge, 2012; Bento & Moutinho, 2016). Thus, this issue can be minimised using the ARDL model (Koop, 2009; Bento & Moutinho, 2016). According to Bento and Moutinho (2016), including sufficient lags in the dependent and independent variables in the modelling approach minimised the multicollinearity issue in the model. Thus, this justified the adoption of the ARDL model in this study.

However, the ARDL model is robust to multicollinearity but not immune to it. If the multicollinearity is severe, it can still lead to unreliable coefficient estimates and difficulties interpreting the model (Nkoro et al., 2017). Thus, one of the highly correlated variables should be removed from the model to tackle this issue. Based on the model specification, palm oil price and biodiesel price will not be used simultaneously in the model. Palm oil price will be used in model one to capture the commodity price effect on food price, whereby biodiesel price will be used in model three to determine the biodiesel demand on food price. So, this does not create any statistical issues in both models. However, in model three, industrial growth has been removed from the model, whereby vehicle population can capture the effect of industrial growth in model three[35]. The removal of the industrial growth from model three is reasonable since this model is mainly used to capture the effect of biodiesel demand on the food price in Malaysia and overcome the issue of multicollinearity whereby the estimated VIF become smaller than 10. With this justification, the analysis will proceed further to the stationary testing in the next section.

[35] Removing palm oil price and industrial growth will not impact the model significantly since the model three is mainly form to capture the biodiesel demand effect on the food price. In addition, the removal of these two variables from the model, overcome the issue of multicollinearity whereby the estimated VIF become smaller than 10.

Table 4.1: Descriptive Statistics and the Correlation Test Results

	Food Price	Industrial Growth	Crude Oil Price	Exchange Rate	Palm Oil Price	Biodiesel price	Biodiesel Investment	Biofuel Policy	Vehicle Population
Panel A: Descriptive Statistics of the Variables									
Mean	126.7584	127.5128	61.3924	88.8967	40.9278	52.7767	69.42721	0.4248	53.1402
Maximum	143.4000	153.3150	100.0000	103.4490	100.0000	100.0000	100.0000	1.0000	103.5410
Minimum	109.9000	100.4630	18.4957	81.6950	26.2992	29.9501	34.93042	0.0000	0.9896
Std. Dev.	9.0693	11.1673	21.7640	5.7193	15.3719	14.0250	15.29050	0.4965	29.1296
Obs.	113	113	113	113	113	113	113	113	113
Panel B: Correlation Test									
Food price	1.0000	0.8966	-0.3902	-0.8436	0.5518	0.3016	-0.0176	-0.0968	0.8867
Industrial Growth	-	1.0000	-0.2182	-0.6955	0.5592	0.3437	-0.0061	-0.0912	0.8843
Crude Oil Price	-	-	1.0000	0.6689	0.2245	0.4305	-0.0382	-0.4778	-0.3577
Exchange Rate	-	-	-	1.0000	-0.4150	-0.1020	0.0646	-0.2095	-0.6127
Palm Oil Price	-	-	-	-	1.0000	0.8908	-0.1931	-0.2988	0.5751
Biodiesel price	-	-	-	-	-	1.0000	-0.2065	-0.4678	0.3520
Biodiesel Investment	-	-	-	-	-	-	1.0000	0.0.214	0.0140
Biofuel Policy	-	-	-	-	-	-	-	1.0000	-0.2026
Vehicle Population	-	-	-	-	-	-	-	-	1.0000

Source: Various institutions, see Table 3.1, calculated by the author using EViews 12.
Note: Std. Dev. and Obs. are the standard deviation value and Observation, respectively.

4.3 Unit Root Test Results

Tables 4.2 and 4.3 demonstrate the unit root test results of DF-GLS and PP. The tests aim to investigate the stationarity properties of the variables understudied. The detailed discussion on the unit root test has been discussed in Chapter 3, section 3.4. Thus, the investigation of unit roots is essential to check for the ability and forecasting power of the variables in the model to capture the future food price changes in Malaysia. Accordingly, it is crucial for the policy suggestion and implications. The consistency of the parameters in the regression model is validated when the variables are stationary, which will help forecast accurately (Mahadeva & Robinson, 2004).

In testing for the unit root among the variables, the variables were individually tested for the level and first difference. At first, the series will be analysed using the constant with a trend in level to check for a significant trend value. If the trend value is insignificant, this shows that the series does not have a significant trend. So, the series will be examined with constant terms only, in level form. Accordingly, the first difference will examine the series in constant and non-form (Long & Luo, 2022)[36]. This practice will reduce the overfitting in the series. Using this practice, the DF-GLS and PP unit root tests have been analysed, and the results are reported in Tables 4.2 and 4.3.

[36] The DF-GLS test not able to be test with the none of constant term. In this case, the series will be tested only with constant in first difference. However, PP test is examined the series in both constant and none.

The DF-GLS unit root test results are presented in Table 4.2, whereby all the variables are stationary in the first difference except for investment in the biodiesel industry. For instance, the food price index of Malaysia is tested for a unit root in level form with constant and no trend values due to insignificant trend values in the series[37]. The t-statistic value of food price is 2.9596 in level. This value is lower than the critical value of ten, five and one per cent. In this case, the null hypothesis that the series has a unit root cannot be rejected. Accordingly, the series tested with the first differences under the constant term. The t-statistic value is -8.3604, higher than the critical value of one per cent. As a result, the null hypothesis can be rejected and concluded that food prices in Malaysia are stationary in the first difference. All other variables were tested for unit root using a similar process.

The biodiesel price, vehicle population, crude oil price and industrial growth in Malaysia were examined using the constant with trend value, and the rest of the variables were examined only with constant due to the non-significant trend value in the series. The results of DF-GLS summarised that all the variables rejected the null hypothesis of non-stationary properties in their first difference at a one per cent significant level, except for the investment in the biodiesel industry and industrial growth. This indicates that all the variables are stationary in the first difference, indicating that the regressors can forecast future food price changes in Malaysia. However, Malaysia's investment in the biodiesel industry and industrial growth are stationary at a five per cent and one

[37] The result of the trend value is not reported. The process undergoes manually while doing the analysis.

per cent significance level, respectively. Thus, the DF-GLS unit root test results confirm that all the variables, including the dependent variable, i.e., Malaysia's food price index, are integrated with I(1) except for investment in the biodiesel industry and industrial growth, which is integrated with *I(0)*.

Besides, to validate the DF-GLS unit root test results, the PP unit root test was used, and the results of the PP test are presented in Table 4.3. The same practice as DF-GLS in examining the variables using the constant and trend values has been adopted here. Accordingly, the PP unit root test suggests crude oil price, industrial growth, biodiesel price, and vehicle population to be examined using the constant and trend values. However, the remaining variables are examined using the constant only due to the insignificant trend value in the series. The PP unit root test findings confirm the DF-GLS test results whereby all the variables reject the null hypothesis of non-stationary in the first difference at a one per cent significance level. However, the investment in the biodiesel industry and industrial growth is rejecting the non-stationary in the level form. This indicates that all the variables are integrated with *I(1)*, except for investment in the biodiesel industry and industrial growth, which is integrated with *I(0)*.

Table 4.2: Unit Root Test Results for DF-GLS

Dickey-Fuller Generalized Least Squares (DF-GLS) Test					
Variables	In Level		In First Difference		Conclusion
	Constant	Constant with trend	None	Constant	
Food price$_t$	2.9596 (1)	-	-	-8.3604 (0)***	*I(1)*
Crude oil price$_t$	-	-1.0949 (1)	-	-6.8414 (0)***	*I(1)*
Industrial growth$_t$	-	-4.1975 (2)***	-	-	*I(0)*
Palm oil price$_t$	3.1036 (0)	-	-	-7.7118 (0)***	*I(1)*
Exchange rate$_t$	-0.6420 (1)	-	-	-6.0055 (0)***	*I(1)*
Biodiesel Demand Factors					
Biodiesel price$_t$	-	-0.5512 (0)	-	-7.9042 (0)***	*I(1)*
Biofuel policy$_t$	-1.2249 (0)	-	-	-10.4881 (0)***	*I(1)*
Investment$_t$	-1.8665 (12)**	-	-	-	*I(0)*
Vehicles population$_t$	-	-1.6456 (1)	-	-5.2859 (0)***	*I(1)*

Source: Author’s calculations using EViews 12.

Note: (***) and (**) represent significance at 1 and 5 per cent levels, respectively. The lag length auto-selection is based on the AIC for the ADF test. The maximum lag is auto-fixed by EViews at 12. The value in ( ) represents the optimum lag selection. *I(1)* indicate that the series is integrated with the first difference, and *I(0)* indicates that the series is integrated with the level form.

To conclude, the findings of the unit root test, the DF-GLS and the PP test indicate that the variables understudied in this research are integrated with *I(1)*, except for the investment in the biodiesel industry and industrial growth, which is *I(0)*. This shows the models' mixed I(1) and I(0) variables. However, the unit root test confirms that no variable is integrated with *I(2)*. Most importantly, the food price, which is this study's dependent variable, is integrated with I(1) (Ozturk et al., 2010). Thus, the unit root test fulfilled the essential requirement of integration level for the ARDL method to undergo testing for short- and long-run relationships. Accordingly, the following section will conduct a cointegration analysis using the bound testing approach.

4.4 ARDL Bound Testing (Cointegration Results)

This section will present the results of the cointegration relationship among the variables under investigation. Accordingly, the ARDL bound testing approach has been utilised to confirm the existence of cointegration in the models. The adoption of the ARDL method in this study is justifiable due to the mixed integration of the variables in *I(1)* and *I(0)* based on the unit root test in the previous section. Testing for the cointegration relationship is crucial since it indicates that the food price index in Malaysia and the explanatory variable in this study have a long-run association. The existence of a long-run relationship between the variables possesses the explanatory variable's ability to predict future changes in the food price in Malaysia. Thus, this contributes well to better policy measurement. The detailed discussion of the ARDL model is explained in Chapter 3, section 3.5.

Table 4.3: Unit Root Test Results for PP

Phillips-Perron (PP) Test					
Variables	In Level		In First Difference		Conclusion
	Constant	Constant with trend	None	Constant	
Food price$_t$	-0.3673 (8)	-	-6.2151 (2)***	-8.2730 (13)***	*I(1)*
Crude oil price$_t$	-	-0.7929 (5)	-7.4814 (7)***	-7.4438 (7)***	*I(1)*
Industrial growth$_t$	-	-5.0255 (8)***	-	-	*I(0)*
Palm oil price$_t$	3.0974 (4)	-	-8.6005 (4)***	-8.7977 (4)***	*I(1)*
Exchange rate$_t$	-2.1106 (5)	-	-8.1434 (8)***	-8.1200 (8)***	*I(1)*
Biodiesel Demand Factors					
Biodiesel price$_t$	-	-0.1879 (0)	-9.1631 (2)***	-9.2096 (2)***	*I(1)*
Biofuel policy$_t$	-1.4535 (2)	-	-10.4881 (0)***	-10.4403 (0)***	*I(1)*
Investment$_t$	-3.4827 (8)**	-	-	-	*I(0)*
Vehicles population$_t$	-	-2.2753 (5)	-5.6892 (2)***	-5.7187 (2)***	*I(1)*

Source: Author's calculations using EViews 12.

Note: (***) and (**) represent significance at the 1 and 5 per cent levels, respectively. The bandwidth is auto-selection based on the Newey-West for the PP test. The value in ( ) represents the optimum lag selection. *I(1)* indicate that the series is integrated with the first difference, and *I(0)* indicates that the series is integrated with the level form.

To achieve the objectives of this study, three models have been developed. The first model is to test for the cointegration of the factors influencing the food price in Malaysia in linear form. This model can demonstrate the significant role of palm oil price, crude oil price, exchange rate and industrial growth on the food price in Malaysia. After confirming the existence of cointegration in the linear model, the asymmetric model, which is the extension of the linear ARDL model, will be tested for cointegration in model two. The non-linear model advances the linear ARDL model by incorporating the asymmetric effect of positive and negative changes in the explanatory variables on food prices in Malaysia (Shin *et al.,* 2013). In other words, it enhanced the understanding of the independent variables of the food price in Malaysia. Lastly, the third model extends the first model by capturing the effect of the biodiesel demand factors on the food price in Malaysia.

Table 4.4: Optimum Lag Selection Structure using AIC Lag Selection Criterion

Lag	Model 1	Model 2	Model 3
0	33.4780	54.3867	53.7450
1	22.2803	32.0271	31.9790
2	22.0831	31.9818	31.3084
3	22.3218	32.3031	31.6410
4	22.5346	32.6040	31.0888
5	22.7885	32.5812	31.1370
6	22.0131	32.1190	30.9671
7	22.0071	30.6916	30.1399
8	22.2490	29.2548	29.5894
9	22.2937	25.0511	25.4279
10	21.9186	15.3252*	17.4753*
11	21.6537	NA	NA
12	21.4135*	NA	NA

Source: Author’s calculations using EViews 12.
Note: Akaike information criterion (AIC). (*) indicates lag order selected by the criterion. NA stands for “not available”.

Besides, lag selection plays an essential role in the ARDL method, and Table 4.4 shows the optimum lag selection structure for the three models. The lag selection for the models in this study is based on the Akaike information criterion (AIC). This study's extensive sample data (113 observations) justified the adoption of the AIC lag section criterion, whereby AIC is better in the extensive sample dataset[38] (Ozturk et al., 2010; Nkoro et al., 2017). The lag selection for models 1-3 will be based on the VAR model framework. Based on the AIC criterion, the optimum lag suggested for model one is 12, followed by lag ten for model two and model three, respectively[39].

Accordingly, Table 4.5 demonstrates the results of the bound test for the three models. Table 4.5 is divided into two panels, i.e., Panel A represents the bound testing results for each model, and Panel B represents the models' diagnostic test results. The decision on whether the model has cointegration or not will be determined by the bound testing value (F-statistics) generated. If the bound test value is higher than the critical value at one, five or ten per cent, then the model can be concluded to have cointegration. Furthermore, the diagnostic test results illustrated the fitness of the models. The short- and long-run results cannot be interpreted when the model suffers from a statistical issue such as autocorrelation model specification bias and is not normally distributed.

[38] AIC lag section criterion penalizes more heavily for additional lag orders compare to other lag selection criteria such as SIC and HQC, which can lead to overfitting in extensive sample datasets.
[39] Due to higher explanatory variables in the model two and three, the maximum lag to consider in those models are ten. More than lag ten is not allowed to be estimated by EViews 12.

For model one, food price in Malaysia is the dependent variable, whereby industrial growth, exchange rate, crude oil price and palm oil price are the independent variables projected to influence the food price in Malaysia. Based on the AIC lag selection criterion, the optimum lag selection is (11, 7, 11, 12, 1), respectively. The calculated F-statistics value for model one is 7.9613, which is significant at a one per cent level. This is because the computed F-statistics value is higher than the upper critical value of one per cent significance level (7.96 > 5.06). As a result, a cointegration relationship exists between the variables in model one.

Besides, the R-squared and adjusted R-squared values for model one are 0.9487 and 0.9477, respectively. This indicates that the independent variables can explain about 94.87 per cent of the food price variability in Malaysia in model one. However, due to the multiple regression, the adjusted R-square is valuable (Fox, 2016). After adjusting for the degree of freedom, the independent variables could explain Malaysia's food price variation by 94.77 per cent[40]. Besides, the one per cent significant level of F-statistic value, i.e., 930.7062, indicates the overall model is significant in explaining the food price in Malaysia.

In Panel B, the diagnostic test results are reported. Based on Panel B, model one does not suffer from any statistical issues since the null hypothesis of all the diagnostic tests cannot be rejected at ten per cent. An insignificant F-

[40] There is a possibility for model with a higher R-squared to be overfitting the data depending on the complexity of the model. Overfitting can lead to inaccurate predictions. Thus, the residual should be randomly distributed around zero. The evidence from the serial correlation and heteroskedasticity test confirming that models are not suffering from the overfitting issue.

statistic value of the serial correlation test indicates that the model is not suffering from collinearity. Thus, these results are validated by the Durbin-Watson statistic, which is 2.3075. The value shows that the model has low multicollinearity. Besides, the insignificant F-statistic value in the model specification shows that the model is correctly specified. This indicates that valid independent variables are added to the model explaining Malaysia's food prices. At the same time, the model is normally distributed since the probability value is more than a ten per cent significant level, resulting in non-rejection of the model's null hypothesis. Finally, model one does not suffer from the heteroskedasticity issue since the F-statistic value (1.1000) is insignificant, indicating that the error terms are normally distributed.

Accordingly, Model Two represents the asymmetric linear form of Model One. Food price in Malaysia is the dependent variable, whereby industrial growth, exchange rate, crude oil price and palm oil price are the independent variables decomposed into positive and negative partial sums that validate the asymmetric effect on the food price in Malaysia. Based on the AIC, the optimum lag selection is (2, 0, 0, 4, 1, 0, 0, 1, 4). The calculated F-statistics value for model two is 6.8636, which is significant at a one per cent level. This is because the computed F-statistics value is higher than the upper critical value (6.86 > 4.10) of one per cent significance level. These results confirm the cointegration relationship between the variables in model two.

Besides, model two's R-squared and adjusted R-squared values are 0.9485 and 0.9482, respectively. This indicates that the independent variables can explain about 94.85 per cent of the variation in model two. Furthermore, after adjusting for the degree of freedom, the independent variables could explain the food price variation by 94.82 per cent. The one per cent significant level of F-statistic value, i.e., 2961.512, indicates the overall model is significant in explaining the food price in Malaysia.

In Panel B, the diagnostic test results for model two are reported. Based on Panel B, model two does not suffer from any statistical issues since the null hypothesis of all the diagnostic tests cannot be rejected at ten per cent lower. An insignificant F-statistic value of the serial correlation test indicates that the model is not suffering from collinearity. Thus, these results are validated by the Durbin-Watson statistic, 2.0130. The value shows that the model has low multicollinearity. Besides, the insignificant F-statistic value in the model specification shows that the model is correctly specified. This indicates that valid independent variables are added to the model explaining Malaysia's food prices. At the same time, the model is normally distributed since the probability value is more than a ten per cent significant level, resulting in non-rejection of the model's null hypothesis. Finally, model one does not suffer from the heteroskedasticity issue since the F-statistic value (0.5986) is insignificant, indicating that the error terms are normally distributed for model two.

Besides, model three is an extension of model one, whereby food price in Malaysia is the dependent variable. Other than the control variables from the model, factors of biodiesel demand are included in this model. Those factors are the biodiesel price, investment in the biodiesel industry, biofuel policy and finally, the vehicle population in Malaysia. Noticeably, the palm oil price is replaced with the biodiesel price, and the vehicle population replaces industrial growth to remedy the dataset's multicollinearity issue. Thus, model three is essential in answering the question of biodiesel demand's role in Malaysia's food price. Based on the AIC, the optimum lag selection is (2, 4, 0, 1, 2, 1, 4). The calculated F-statistics value for model three is 5.5298, which is significant at a one per cent level. This is because the computed F-statistics value is higher than the upper critical value of one per cent significance level. These results confirm the cointegration relationship between the variables in model three.

Besides, the R-squared and adjusted R-squared values in model three are 0.9487 and 0.9483, respectively. This indicates that the independent variables can explain about 94.87 per cent of the variation in model three. However, the adjusted R-square is valuable due to the multiple regression. In this case, after adjusting for the degree of freedom, the independent variables could explain the food price variation by 94.83 per cent. Comparing the adjusted R-square value in models one and two, the adjusted R-square of model three increases after biodiesel demand factors are included. The increased value of the adjusted R-square indicates that the biodiesel demand factors added to the model could capture the food price trend in Malaysia. Thus, including biodiesel demand factors in the model helps explain Malaysia's food price variation. The one per cent significant level of F-statistic value, i.e., 2394.882, indicates the overall model is significant in explaining the food price in Malaysia.

In Panel B, the diagnostic test results for model three are reported. Based on Panel B, the model is not suffering from any statistical issues since the null hypothesis of all the diagnostic tests cannot be rejected at ten per cent lower. An insignificant F-statistic value of the serial correlation test indicates that the model is not suffering from collinearity. Thus, these results are validated by the Durbin-Watson statistic, 2.0825. The value shows that the model has low multicollinearity. Besides, the insignificant F-statistic value in the model specification shows that the model is correctly specified. This indicates that valid independent variables are added to the model explaining Malaysia's food prices. At the same time, the model is normally distributed since the probability value is more than a ten per cent significant level, resulting in non-rejection of the model's null hypothesis. Finally, model one does not suffer from the heteroskedasticity issue since the F-statistic value (0.8458) is insignificant, indicating that model three's error terms are normally distributed.

Figure 4.1 shows the Cumulative Sum (CUSUM) and CUSUM of Squared analysis results. This result is in graphical form to show the stability of the ARDL models in this study. This analysis detects changes in a process, such as changes in the mean, variance, trend and seasonal pattern of the data over time. Figure 4.1 shows that all three models are stable, whereby the CUSUM and CUSUM of Squared lines for models one, two and three are overtly in between the five per cent significant level over time. The findings of CUSUM and CUSUM of Squared analysis demonstrated that the selected independent variables could control the food price in Malaysia. In addition, the stable lines indicate an absence of evidence of a structural break in the data. After confirming the long-run relationship among the variables understudied, the short- and long-run analysis will be carried out in the coming section.

4.5 Short and Long-run Relationship

This section will discuss the short-run and error correction model. The value explained the speed of adjustment for the proportion of shock or imbalance of food price towards the long-run equilibrium. After that, the long-run relationship among the three models will be interpreted. After bound testing results in the earlier section confirmed the existence of cointegration among the variables in all the models, the short- and long-run relationship can be analysed and discussed. Accordingly, Table 4.6 demonstrates the short-run relationship for the three models proposed. In addition, the error correction term (ECT_{t-1}) is reported for each model in Table 4.6, which explains the short-term effect of the selected independent variables on food prices in Malaysia.

Table 4.5: Results of the Bounds Test (F-Tests)

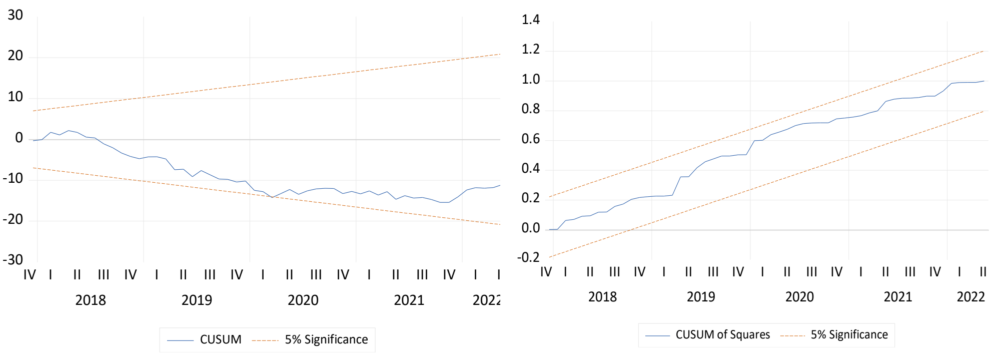
	Model 1		Model 2		Model 3	
Panel A: Bound Test Results						
Estimated Model	$FP_t = f(Y_t, EXC_t, CO_t, PO_t)$		$FP_t = f(Y_t^{(+)}, Y_t^{(-)}, EXC_t^{(+)}, EXC_t^{(-)}, CO_t^{(+)}, CO_t^{(-)}, PO_t^{(+)}, PO_t^{(-)})$		$FP_t = f(EXC_t, CO_t, VP_t, BP_t, INV_t, POLICY_t)$	
Optimal Lag Length (AIC)	(11, 7, 11, 12, 1)		(2, 0, 0, 4, 1, 0, 0, 1, 4)		(2, 4, 0, 1, 2, 1, 4)	
F-Statistics (Bound Test)	7.9613***		6.8636***		5.5298***	
Significance Level	Pesaran et al., (2001)[a] Critical Values					
	Lower Band	Upper Band	Lower Band	Upper Band	Lower Band	Upper Band
1%	3.74	5.06	2.79	4.10	2.79	4.10
5%	2.86	4.01	2.22	3.39	2.22	3.39
10%	2.45	3.52	1.95	3.06	1.95	3.06
R-squared	0.9487		0.9485		0.9487	
Adjusted R-squared	0.9477		0.9482		0.9483	
Durbin-Watson statistics	2.3075		2.0130		2.0825	
F-Statistics	930.7062***		2961.5120***		2394.882***	
Panel B: Diagnostic Test Results						
Serial correlation	1.1975 (0.3164)		0.2780 (0.7579)		1.2110 (0.3033)	
Model specification	0.0547 (0.8160)		1.1247 (0.2658)		0.0721 (0.7890)	
Normality	0.6291 (0.7301)		0.0312 (0.9845)		1.8703 (0.3925)	
Heteroskedasticity	1.1000 (0.3727)		0.5986 (0.4409)		0.8458 (0.4995)	

Source: Author's calculations using EViews 12.

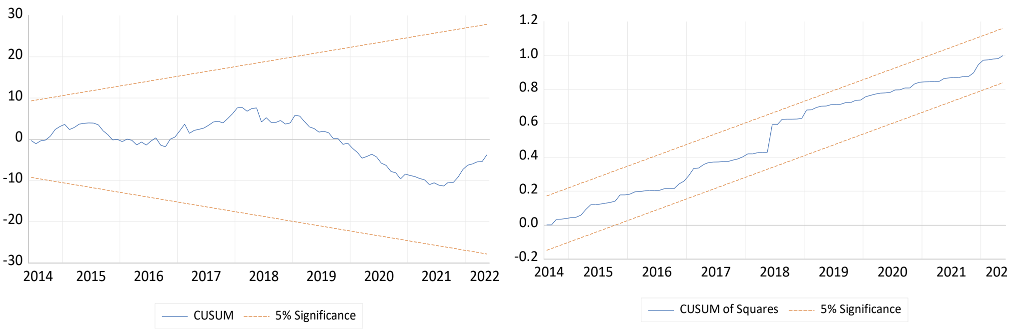
Note: Critical values are obtained from Pesaran *et al.* (2001), Table CI (iii) Case III: Unrestricted intercept and no trend, p. 300. (***) represents significance at 1%. The lag length is auto-selected based on the Akaike info criterion (AIC), and the maximum lag (K) is set at 12 (Model 1) and 4 (Model 2 & 3). The LM, ARCH and Ramsey RESET test statistics are based on F-statistics.

Figure 4.1: CUSUM and CUSUM of Squares Analysis Results

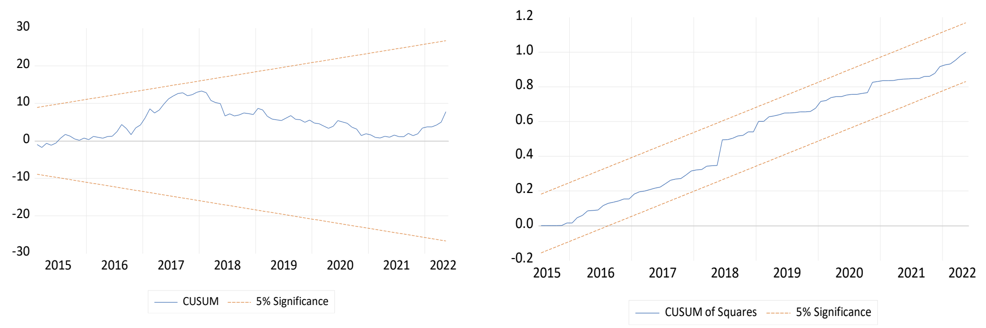
Model 1: $FP_t = f(Y_t, EXC_t, CO_t, PO_t)$



Model 2: $FP_t = f(Y_t^{(+)}, Y_t^{(-)}, EXC_t^{(+)}, EXC_t^{(-)}, CO_t^{(+)}, CO_t^{(-)}, PO_t^{(+)}, PO_t^{(-)})$



Model 3: $FP_t = f(EXC_t, CO_t, VP_t, BP_t, INV_t, POLICY_t)$



Source: Illustration by EViews 12.

Thus, the coefficient value of ECT_{t-1} for all the models are significant and have negative signs, as expected. These ECT_{t-1} values validate the bound testing cointegration results in the previous section. The coefficient of ECT_{t-1} for model one is -0.2077 and significant at one per cent level indicates that about 20.77 per cent of the previous period shock will be converted back to long-run in the current period. Thus, it has required about five months to return to equilibrium. Interestingly, palm oil prices do not significantly affect Malaysia's food prices in the short run. Besides, the own lagged value for food prices, crude oil prices and industrial growth negatively affect the food prices, whereby the exchange rate positively influences the food price in the short-run. The error correction model's R-squared and adjusted R-squared values are 0.6517 and 0.3996, respectively. Hence, after adjusting for the degree of freedom, the independent variables can explain the food price variation by 39.96 per cent in the short run. The one per cent significant level of F-statistic value, i.e., 2.5844, indicates the overall model is significant in explaining the food price of Malaysia in the short term.

Accordingly, model two tested the same model in an asymmetric linear form. The short-run results for model two are reported in Table 4.6. The coefficient of ECT_{t-1} for model two is -0.5247 and significant at one per cent level indicates that about 52.47 per cent of the previous period shock will converge to long-run in the current period. Thus, it has required about two months to return to equilibrium. Accordingly, the ECT_{t-1} for model two has a quicker adjustment to equilibrium, indicating that the asymmetric model captures more complex dynamics that are possibly inherent in the data, such as different responses to increases versus decreases in prices, which a simple linear model might miss (Sek, 2017; Cheng & Cao, 2019; Zmani & Ben-Salha, 2019). Zmami and Ben-Salha (2019) highlight that this kind of asymmetry is particularly relevant in sectors like agriculture, where input costs (such as energy) can have varying effects on output prices depending on whether they are increasing or decreasing.

The adjusted R-squared value confirms this in model two, whereby after adjusting for the degree of freedom, the independent variables can explain the short-run food price variation by 43.57 per cent. This figure is slightly higher than the adjusted R-squired value in model one, showing that the asymmetric linear model performs better than the linear model. The NARDL results for model two reveal distinct short-run dynamics. Positive changes in exchange rate, crude oil and palm oil prices contribute positively to food prices, while negative changes have the opposite effect, reducing food prices. Conversely, positive changes in industrial growth result in a decrease in food prices in Malaysia. Notably, the coefficient for industrial growth is found to be insignificant. Additionally, negative changes in industrial growth are associated with a reduction in food prices in the short run. It is essential to highlight that these findings provide valuable insights into the intricate relationships between key economic variables and food prices in the Malaysian context during the short term.

Lastly, model three is the extension of model one, whereby biodiesel demand factors are included in the model. The coefficient of ECT_{t-1} for model three is -0.2303 and significant at one per cent level indicates that about 23.03 per cent of the previous period shock will be converged back to the long-run in the current period. Thus, it has required about four months to return to equilibrium. Thus, the ECT_{t-1} value of model three is comparatively higher than the ECT_{t-1} value of model one. The same goes for the adjusted R-squared value, i.e., 0.4420. This indicates that, after adjusting for the degree of freedom, the independent variables can explain the food price variation by 44.20 per cent in the short run.

This justifies the additional variable, i.e., biodiesel demand factors in the model increase the exploration power of the model. Accordingly, biodiesel prices and policy positively affect food prices in the short run, whereby investment in the biodiesel industry seems to impact the food prices in Malaysia negatively. The control variables, i.e., crude oil price and exchange rate, positively influence the food price in the short run. Interestingly, the diesel vehicle population, which replaced the industrial growth in model three, negatively affected the food price, similar to industrial growth in model one. However, the effect is not statistically significant in model three.

Table 4.6: Short run Results with Error Correction Model

Variable	Model 1	Model 2	Model 3
Short run coefficients (dependent variable: ΔFP_t)			
$\Delta FP_t(-1)$	0.0585 [0.5619]	0.3328 [4.2378]***	0.1862 [2.0417]**
$\Delta FP_t(-2)$	-0.2698 [-2.5786]**	-	-
$\Delta FP_t(-3)$	-0.0986 [-0.9525]	-	-
$\Delta FP_t(-4)$	-0.2397 [-2.3405]**	-	-
$\Delta FP_t(-5)$	-0.1756 [-1.5910]	-	-
$\Delta FP_t(-6)$	-0.0130 [-0.1180]	-	-
$\Delta FP_t(-7)$	-0.2623 [-2.5706]**	-	-
$\Delta FP_t(-8)$	-0.1702 [-1.5718]	-	-
$\Delta FP_t(-9)$	-0.3053 [-2.8704]***	-	-
$\Delta FP_t(-10)$	-0.2451 [-2.3294]**	-	-
ΔCO_t	0.0044 [0.4862]	-	0.0090 [2.0058]**
$\Delta CO_t(-1)$	-0.0599 [-5.4953]***	-	-
$\Delta CO_t(-2)$	-0.0353 [-2.8506]***	-	-
$\Delta CO_t(-3)$	-0.0382 [-3.0071]***	-	-
$\Delta CO_t(-4)$	-0.0177 [-1.4682]	-	-
$\Delta CO_t(-5)$	-0.0390 [-3.2314]***	-	-
$\Delta CO_t(-6)$	-0.0384 [-2.8867]***	-	-
$\Delta CO_t(-7)$	-0.0518 [-3.9375]***	-	-

Table 4.6: Short-run Results with Error Correction Model (Continued)

Variable	Model 1	Model 2	Model 3
$\Delta CO_t(-8)$	-0.0232 [-1.6985]*	-	-
$\Delta CO_t(-9)$	-0.0471 [-4.0968]***	-	-
$\Delta CO_t(-10)$	-0.0197 [-1.5947]	-	-
$\Delta CO_t(-11)$	-0.0277 [-2.4800]**	-	-
ΔCO_Pos_t	-	-0.0064 [-0.6794]	-
ΔCO_Neg_t	-	0.0477 [5.0504]***	-
$\Delta REER_t$	-0.0183 [-0.4289]	-	-0.0121 [-0.3128]
$\Delta REER_t(-1)$	0.2117 [3.6726]***	-	-0.0299 [-0.8411]
$\Delta REER_t(-2)$	0.2288 [3.9677]***	-	0.0668 [2.0100]**
$\Delta REER_t(-3)$	0.1598 [2.8633]***	-	0.0981 [2.9292]***
$\Delta REER_t(-4)$	0.1713 [3.3962]***	-	-
$\Delta REER_t(-5)$	0.0944 [2.0135]**	-	-
$\Delta REER_t(-6)$	0.1067 [2.3499]**	-	-
$\Delta REER_t(-7)$	0.1009 [2.5762]**	-	-
$\Delta REER_t(-8)$	0.0317 [0.8242]	-	-
$\Delta REER_t(-9)$	0.0749 [2.0611]**	-	-
$\Delta REER_t(-10)$	0.1052 [2.9149]***	-	-
$\Delta REER\_Pos_t$	-	0.1241 [1.6708]	-
$\Delta REER\_Neg_t$	-	0.0120 [0.2441]	-

Table 4.6: Short-run Results with Error Correction Model (Continued)

Variable	Model 1	Model 2	Model 3
$\Delta REER\_Neg_t(-1)$	-	0.0115 [0.2519]	-
$\Delta REER\_Neg_t(-2)$	-	0.1438 [3.1714]***	-
$\Delta REER\_Neg_t(-3)$	-	0.0802 [1.7641]*	-
ΔIPI_t	0.0282 [2.5568]**	-	-
$\Delta IPI_t(-1)$	-0.0328 [-2.4835]**	-	-
$\Delta IPI_t(-2)$	-0.0553 [-3.8744]***	-	-
$\Delta IPI_t(-3)$	-0.0313 [-2.1128]**	-	-
$\Delta IPI_t(-4)$	-0.0528 [-3.8428]***	-	-
$\Delta IPI_t(-5)$	-0.0227 [-1.8444]*	-	-
$\Delta IPI_t(-6)$	-0.0252 [-2.0656]	-	-
ΔIPI_Pos_t	-	-0.0064 [-0.6794]	-
ΔIPI_Neg_t	-	0.0477 [5.0504]***	-
ΔPO_t	-0.0003 [-1.3153]	-	-
ΔPO_Pos_t	-	0.0012 [0.0490]	-
$\Delta PO\_Pos_t(-1)$	-	0.0625 [2.6018]**	-
$\Delta PO\_Pos_t(-2)$	-	0.0141 [0.5393]	-
$\Delta PO\_Pos_t(-3)$	-	0.0561 [2.0685]**	-
ΔPO_Neg_t	-	-0.0322 [-1.1171]	-
$\Delta POLICY_t$	-	-	0.3504 [1.1968]

Table 4.6: Short-run Results with Error Correction Model (Continued)

Variable	Model 1	Model 2	Model 3
$\Delta POLICY_t(-1)$	-	-	-0.4100 [-1.4361]
$\Delta POLICY_t(-2)$	-	-	0.1965 [0.6486]
$\Delta POLICY_t(-3)$	-	-	0.6061 [2.0568]**
$\Delta INVESTMENT_t$	-	-	-0.0117 [-4.2934]***
$\Delta VEHICLES_t$	-	-	-0.3335 [-1.4957]
ΔBP_t	-	-	0.0357 [2.2515]**
$\Delta BP_t(-1)$	-	-	0.0457 [2.7523]***
$Constant$	45.7844 [6.5761]***	58.3841 [8.2307]***	27.4440 [4.490]***
ECT_{t-1}	-0.2077 [-6.5388]***	-0.5247 [-8.2130]***	-0.2303 [-7.3908]***
R-squared	0.6517	0.4990	0.5349
Adjusted R-squared	0.3996	0.4357	0.4420
Durbin-Watson stat	2.3075	2.0130	2.0824
F-Statistics	2.5844 (0.0000)***	7.8854 (0.0000)***	5.7503 (0.0000)***

Source: Author's calculations using EViews 12.

Notes: The significance at the 1, 5 and 10 per cent levels are denoted by the asterisks (***), (**) and (*). Value in [ ] represents the t-statistic.

Accordingly, Table 4.7 shows the long-run relationship results for all three models. Based on model one, crude oil price, industrial growth and palm oil price positively impact Malaysia's food price, whereas the exchange rate has a negative impact. The coefficient of crude oil price is 0.1992 and significant at a one per cent level, showing that, on average, a one-point increase in crude oil price will increase the food price of Malaysia by approximately 0.20 points in the long run, holding all other variables constant. Besides, on average, a one-point increase in the industrial growth and palm oil price will increase the food price by approximately 0.33 points and 0.06 points, respectively, in the long run, by holding other variables constant. The effect of Malaysia's industrial growth on the food price is higher than the crude oil price. However, the palm oil price has the minimum effect on the food price in the long run. For the exchange rate, the appreciation of Malaysia's currency value by one point, on average, will decrease the food price by 1.64 points in the long run, holding other variables constant. Thus, the exchange rate plays a powerful influence on the food price in Malaysia.

Model two shows the long-run results of the asymmetric model, which indicate that positive and negative changes in crude oil and palm oil prices statistically significantly impact Malaysia's food prices in the long run. For instance, the coefficient of positive changes in the crude oil price is 0.0360. This indicates that when the price of crude oil, on average, increases by one point, Malaysia's food price will increase by 0.04 points in the long run, holding other variables constant. On the other hand, the coefficient of adverse changes in the crude oil price is -0.0209. Interestingly, this indicates that a one-point reduction in crude oil price, on average, increased Malaysia's food price by 0.02 points, holding other variables constant. The palm oil price has a similar finding to the crude oil price, whereby, on average, a one-point increase in the palm oil price will increase the food price by 0.07 points in the long run by holding other variables constant. On the other hand, on average, a one-point decrease in the palm oil price will increase Malaysia's food price by 0.15 points in the long run by holding other variables constant.

Furthermore, only the negative changes in the exchange rate and industrial growth significantly influence the food price, and there is no significant effect of positive changes in industrial growth and exchange rate on the food price in Malaysia in the long run. This indicates that, on average, a one-point appreciation in the exchange rate will decrease the food price of Malaysia by 0.21 points in the long run, holding other variables constant. However, the exchange rate depreciation does not significantly influence the food price in the long run, even though a significant positive impact is found in the short run. This indicates that the depreciation of the MYR will immediately affect food prices in Malaysia, even though it is compromised in the long run. Lastly, deindustrialization in Malaysia seems to have a positive effect on the food price in Malaysia, where, on average, a one-point reduction in industrial growth will increase the food price by 0.09 points, holding other variables constant. However, industry growth does not significantly influence food prices in the long run.

Besides, model three shows long-run results for the model with the additional biodiesel demand variables. Based on model three, crude oil price, vehicle population, biofuel policy and investment in the biodiesel industry significantly impact Malaysia's food price in the long run. The coefficient of crude oil price is 0.0390, and significant at a one per cent level shows that, on average, a one-point increase in crude oil will increase the food price of Malaysia by approximately 0.04 points in the long run, holding other variables constant. Besides, on average, an increase in the investment in the biodiesel industry and vehicle population by one point will increase the food price by approximately 0.05 points and 0.27 points, respectively, in the long run, holding other variables constant. Notably, vehicle population in this model is substituting the effect of industrial growth in model one. The effect of vehicle population is similar to the effect of industrial growth, which is positive towards the food price in Malaysia. This finding validates the decision to use the diesel vehicle population in model three to represent the effect of industrial growth.

As expected, Malaysia's biofuel policy significantly impacts the food price in the long run. A shift of higher blended mandate requirement, on average, will increase the food price by 1.15 points. Thus, this shows that the biofuel policy has a strong influence in increasing the food price in Malaysia. On the other hand, the exchange rate and biodiesel price significantly negatively impact the food price in the long run. By the way, the coefficient of exchange rate and biodiesel price is -0.2404 and -0.1769, and a significance at five per cent and one per cent levels, respectively. This indicates that, on average, a one-point increase in the exchange rate and biodiesel price will decrease the food price of

Malaysia by approximately 0.24 points and 0.18 points in the long run, holding other variables constant. The biodiesel price in model three is replaced with the effect of the palm oil price in model one. The negative relationship between biodiesel and food prices is justifiable due to the substitute effect of biodiesel with crude oil. The higher biodiesel prices are expected to reduce demand, easing pressure on palm oil and consequently reducing food price inflation. This is the case; the negative relationship between biodiesel and food prices in Malaysia is rational. This will be further discussed in chapter five in detail.

4.6 Asymmetric and Symmetric Analysis

This section will discuss the asymmetric and symmetric effects of the independent variables in the asymmetric linear form represented by model two. Besides, Table 4.8 presents the asymmetric and symmetric analysis results. The asymmetric and symmetric investigation is essential to understand better the effect of the exchange rate, crude oil price, industrial growth, and palm oil price on the food price in Malaysia. The existence of the asymmetric effect illustrated that positive and negative changes will have different effects on the food price in Malaysia depending on the direction of the change, whereby the symmetric effect tells the story another way round (Shin et al., 2014).

Table 4.7: Long-run Results

Variable	Model 1	Model 2	Model 3
Long run coefficients (dependent variable: FP_t)			
CO_t	0.1992 [4.9038]***	-	0.0390 [2.1618]**
CO_Pos_t	-	0.0360 [2.2052]**	-
CO_Neg_t	-	-0.0209 [-2.3415]**	-
$REER_t$	-1.6433 [-7.4323]***	-	-0.2404 [-2.0456]**
$REER\_Pos_t$	-	-0.0411 [-0.5580]	-
$REER\_Neg_t$	-	-0.2057 [-4.9946]***	-
IPI_t	0.3317 [5.1481]***	-	-
IPI_Pos_t	-	-0.0123 [-0.6912]	-
IPI_Neg_t	-	0.0908 [5.7346]***	-
PO_t	0.0618 [2.4000]**	-	-
PO_Pos_t	-	0.0724 [4.6000]***	-
PO_Neg_t	-	-0.1522 [-4.6522]***	-
BP_t	-	-	-0.1769 [-3.6117]***
$INVESTMENT_t$	-	-	0.0510 [3.6251]***
$VEHICLES_t$	-	-	0.2736 [12.035]***
$POLICY_t$	-	-	1.1474 [1.8926]*

Source: Author's calculations using EViews 12.

Notes: The significance at the 1, 5 and 10 per cent levels are denoted by the asterisks (***), (**) and (*). Value in [ ] represents the t-statistic.

Based on the Wald statistics probability value, the decision on whether the series has asymmetric or symmetric effects will be decided. Accordingly, exchange rate and industrial growth are asymmetric in Malaysia's short- and long-run food prices. The F-statistic exchange rate value is 2.7090 and 10.8261 for short- and long-run, respectively. It is statistically significant at ten per cent and one per cent level, respectively. The same finding is applied to industrial growth in Malaysia, whereby the F-statistic value is 6.1204 (short-run) and 2.7440 (long-run), which is significant at a five per cent level. This indicates that asymmetric effect has existed between exchange rate and industrial growth towards food price in both short- and long-run.

However, crude and palm oil prices seem to have an asymmetric effect in the long run only since the F-statistic values 2.04144 and 4.7626, respectively, are significant at ten and five per cent significant levels in the long run. On the other hand, a symmetrical effect exists in the short run for both variables. This is due to the F-statistic is not significant in the short run. The results show that changes in palm oil prices and crude oil prices have a similar effect on Malaysia's food prices in the short run. This could be due to the lags in the transmission of variable changes. The delayed (lags) asymmetric effect could be due to the price control policies implemented by the Malaysian government, which protect food prices from energy market fluctuation. However, in the long run, changes in both variables have asymmetric impacts on Malaysia's food prices.

Table 4.8: Asymmetric and Symmetric Analysis Results in Short- and Long-run for Model Two

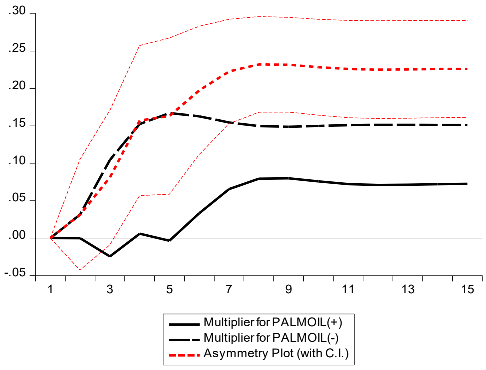
Variables	Wald Statistics (F-statistics)		Decision	
	Short-run	Long-run	Short-run	Long-run
Crude Oil Price	0.5873 (0.4459)	2.04144 (0.0828)*	Symmetric	Asymmetric
Exchange Rate	2.7090 (0.0513)*	10.8261 (0.0015)***	Asymmetric	Asymmetric
Palm Oil Price	1.8496 (0.1285)	4.7626 (0.0323)**	Symmetric	Asymmetric
Industrial Growth	6.1204 (0.0157)**	2.7440 (0.0185)**	Asymmetric	Asymmetric

Source: Author's calculations using EViews 12.
Notes: The significance at the 1 and 5 per cent levels is denoted by the asterisks (***) and (**). The value in ( ) represents the probability value.

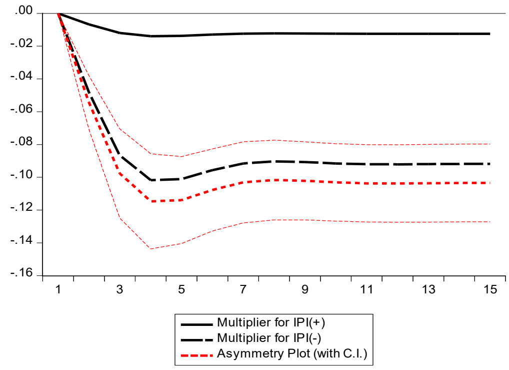
In Figure 4.2, the dynamic effects of industrial growth, exchange rate, palm oil, and crude oil prices on food prices in Malaysia are illustrated. Figure 4.2(a) specifically portrays the dynamic multiplier plot of palm oil prices on food prices. The results confirm the presence of an asymmetric effect, indicating that a negative shock in palm oil prices exerts a more pronounced impact on food prices compared to a positive shock. Similar asymmetric effects are replicated in the cases of industrial growth (Figure 4.2(b)) and exchange rates (Figure 4.2(c)), both demonstrating that negative shocks have a more substantial influence on food prices than positive shocks.

However, the dynamic effects of crude oil prices (Figure 4.2(d)) reveal a different pattern. Positive shocks in crude oil prices are notably more prominent compared to negative shocks concerning their impact on food prices in Malaysia. The overall findings from the dynamics of the multiplier effect consistently affirm the asymmetric impact of all studied variables on food prices. These results reinforce the long-run relationship established by the asymmetric model, as presented in the preceding section. The confirmation of these asymmetric effects provides valuable insights for understanding the nuanced dynamics influencing food prices in the Malaysian context.

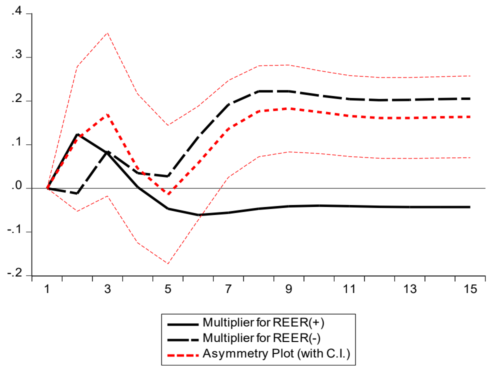
Figure 4.2: Dynamics of the Multiplier Effect of Industrial Growth, Exchange Rate, Palm Oil and Crude Oil Price on Food Price in Malaysia.



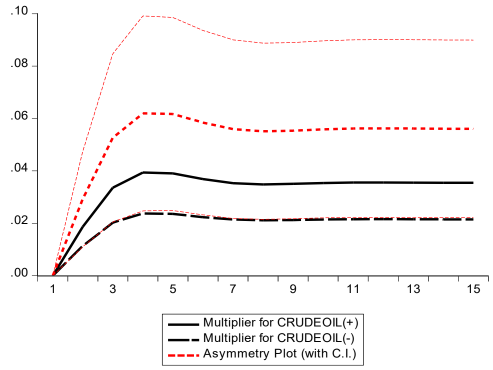
(a) Cumulative Palm oil Price on Food Price



(b) Cumulative Industrial Growth on Food Price



(c) Cumulative Exchange Rate on Food Price



(d) Cumulative Crude oil Price on Food Price

Source: Illustration by EViews 12.

4.7 Robustness Checking

Since the study is concerned with sustainability, the robustness of the result is very important for the policy-making process. In this case, some sensitivity analysis has been conducted to make sure the results of the models are robust to the changes within the variables. Alternatively, the DOLS and FMOLS tests were used to reanalyse the models to ensure the results are reliable and consistent with the primary findings of this study.

4.7.1 Robustness Checking for Model One

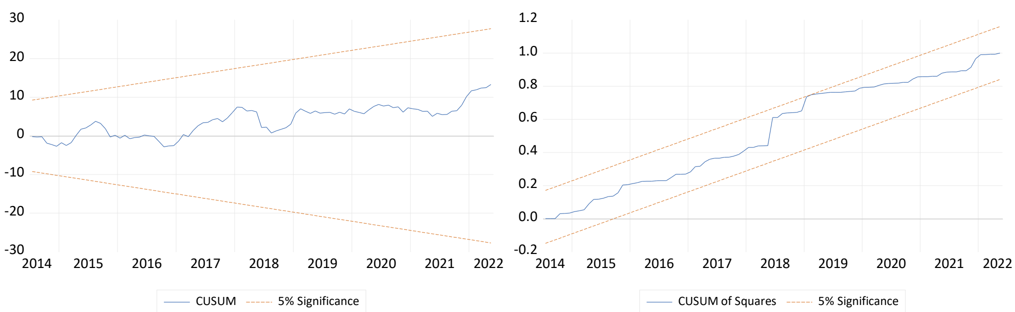
To explore the international trade effect, a sensitivity analysis is conducted by replacing the local palm oil price with its denomination value. This involves multiplying the nominal exchange rate of Malaysia (USD/MYR) by the local palm oil price, resulting in the USD-denominated palm oil price. However, it is crucial to note that attributing changes in this price to palm oil alone may be erroneous, as exchange rate fluctuations can stem from non-oil factors. The results of the sensitivity analysis are reported in Table 4.9. Employing the ARDL method to assess co-integration, the F-statistic value of 7.9947 is observed, significant at the one percent level. This significant F-statistic indicates the presence of co-integration within the model, affirming the interconnectedness of the variables considered in the analysis.

Table 4.9: The Sensitivity Analysis for Model One

Panel A: Bound Testing Results			
Model	$FP_t = f(IPI_t, EXC_t, CO_t, PO_t^{(USD)})$		
Optimal Lag Length (AIC)	(11, 12, 11, 7, 1)		
F-Statistics (Bound Test)	7.9947***		
Panel B: Long-run Relationship Results			
Variables	Coefficient	t-Statistic	Probability
CO_t	0.1953***	4.8441	0.0000
$REER_t$	-1.5748***	-7.0524	0.0000
IPI_t	0.3302***	5.1156	0.0000
$PO_t^{(USD)}$	0.0168**	2.4834	0.0162
R-squared		0.9987	
Adjusted R-squared		0.9977	
Durbin-Watson statistics		2.3109	
F-Statistics		931.7481***	
ECT_{t-1}		-0.2059***	
Panel C: Diagnostic Testing Results			
Serial correlation		1.2543 (0.2808)	
Model specification		0.2300 (0.6335)	
Normality		0.5001 (0.7787)	
Heteroskedasticity		1.0904 (0.3804)	

Source: Author's calculations using EViews 12.
Note: Critical values are obtained from Pesaran *et al.* (2001), Table CI (iii) Case III: Unrestricted intercept and no trend, p. 300. (***) and (**) represent significance at 1% and 5%. The lag length is auto-selected based on the Akaike info criterion (AIC), and the maximum lag (K) is set at 12. The LM, ARCH and Ramsey RESET test statistics are based on F-statistics.

Figure 4.2: CUSUM and CUSUM of Squares Analysis Result for Sensitivity Analysis of Model One.



Source: Illustration by EViews 12.

The long-run relationship results in Panel B align with the outcomes of the primary analysis (model 1). Notably, crude oil prices, industrial growth, and USD-denominated palm oil prices exert positive influences on food prices in

Malaysia. Conversely, the exchange rate exhibits a negative influence. All variables exhibit significance at the one per cent level, except for palm oil, which is significant at the five per cent level. Examining the coefficient of $ECT(t-1)$ for the sensitivity model reveals a value of -0.2077, significant at the one per cent level. This indicates that approximately 20.77 per cent of the shock from the previous period converges back to the long-run equilibrium in the current period. The negative sign suggests a return to equilibrium, taking about five months. Diagnostic tests in panel c and CUSUM and CUSUM of Squares analysis (Figure 4.2) indicate the model's goodness of fit, further supporting its interpretability.

These findings reconfirm the robustness of the primary analysis results. Whether considering local or denominated palm oil prices, the influence on food prices in Malaysia remains consistently robust, underscoring the reliability and stability of the reported outcomes. To further validate the resilience of the findings, the model is further analysed using the DOLS method. This approach serves as an alternative methodological perspective, offering a different lens through which to assess the relationship between our variables of interest. The detailed results of this analysis are comprehensively presented in Table 4.10.

Intriguingly, the outcomes of the DOLS analysis are closely parallel to the primary findings (model one). The variables consistently exhibit positive associations with food prices in Malaysia, except for the exchange rate, which demonstrates a contrasting negative influence. Significantly, all variables maintain their impact at the one per cent level, underscoring their substantive influence on food prices. While palm oil prices, in this case, show significance at the ten per cent level, the overall consistency in significance levels across variables further reinforces the robustness of our results.

In essence, the reliability of our findings is affirmed not only through the consistency of outcomes in the sensitivity analysis but also by the corroborating evidence provided by the DOLS approach. This dual validation enhances the confidence in the reliability and credibility of the relationships elucidated in model one, demonstrating the robustness of the analytical framework.

Table 4.10: Dynamic OLS (DOLS) Result for Model One

Variable	Coefficient	t-Statistic	Probability
CO_t	0.4081***	9.0094	0.0029
$REER_t$	-2.7186***	9.1165	0.0028
IPI_t	1.3954***	20.286	0.0003
PO_t	0.0272*	2.8963	0.0627
R-squared		0.9461	
Adjusted R-squared		0.9063	

Source: Author's calculations using EViews 12.
Note: (***) and (*) represent significance at 1% and 10%. The lag length is auto-selected based on the Akaike info criterion (AIC), and the maximum lag (K) is set at 10.

4.7.2 Robustness Checking for Model Two

The robustness checking for the asymmetric model will be conducted in this section. Again, the USD-denominated palm oil price value will be used in the model, replacing the local palm oil price. This variable will be disaggregated into positive and negative changes, checking for the sensitivity of the primary analysis results. The results of the sensitivity analysis are reported in Table 4.11. Employing the NARDL method to assess co-integration, the F-statistic value of 7.6109 is observed, significant at the one percent level. This significant F-statistic indicates the presence of co-integration within the model, affirming the interconnectedness of the variables considered in the analysis.

The long-run relationship results in Panel B align consistently with the outcomes of the primary analysis (model 2). Notably, the impacts of positive and negative changes in exchange rates, crude oil prices, industrial growth, and USD-denominated palm oil prices on food prices in Malaysia mirror those observed in the primary analysis within model two. Particularly noteworthy is the USD-denominated palm oil price, demonstrating a similar impact on food prices, where both positive and negative changes in the denominated palm oil price contribute positively to food prices in Malaysia. An in-depth examination of the coefficient of $ECT(t-1)$ for the sensitivity model reveals a value of -0.5291, significant at the one per cent level. This suggests that approximately 52.91 per cent of the shock from the previous period converges back to the long-run equilibrium in the current period. The negative sign indicates a return to equilibrium, and this process takes about two months.

Furthermore, the diagnostic tests presented in Panel C, along with the CUSUM and CUSUM of Squares analysis depicted in Figure 4.3, affirm the model's goodness of fit. These analyses provide additional support for the interpretability and reliability of the model, reinforcing the robustness of the findings in Panel B. The detailed examination of the sensitivity model within Panel B not only reinforces the primary analysis results (model 2) but also provides a nuanced understanding of the adjustment dynamics and the system's responsiveness to shocks. This multi-faceted approach to analysis ensures a comprehensive evaluation of the relationships under consideration, further solidifying the credibility of the reported outcomes.

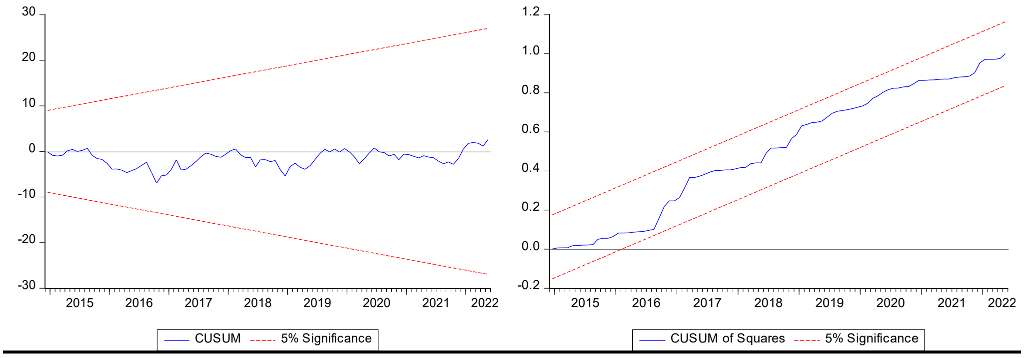
Table 4.11: The Sensitivity Analysis for Model Two

Panel A: Bound Testing Results			
Model	$FP_t = f(IPI_t^{(+)}, IPI_t^{(-)}, EXC_t^{(+)}, EXC_t^{(-)}, CO_t^{(+)}, CO_t^{(-)}, PO_t^{(USD)(+)}, PO_t^{(USD)(-)})$		
Optimal Lag Length (AIC)	(11, 12, 11, 7, 1)		
F-Statistics (Bound Test)	7.6109***		
Panel B: Long-run Relationship Results			
Variables	Coefficient	t-Statistic	Probability
CO_Pos_t	0.0180*	3.0874	0.0797
CO_Neg_t	-0.0233**	-2.4939	0.0145
$REER\_Pos_t$	-0.0326	-0.4486	0.6548
$REER\_Neg_t$	-0.2100***	-4.3216	0.0000
IPI_Pos_t	0.0146	0.7584	0.4502
IPI_Neg_t	0.1018***	6.2883	0.0000
$PO^{(USD)}\_Pos_t$	0.0139***	3.9367	0.0002
$PO^{(USD)}\_Neg_t$	-0.0398***	-5.9622	0.0000
R-squared		0.9985	
Adjusted R-squared		0.9983	
Durbin-Watson statistics		2.1049	
F-Statistics		3638.11***	
ECT_{t-1}		-0.5291***	
Panel C: Diagnostic Testing Results			
Serial correlation		1.5725 (0.2131)	
Model specification		0.3305 (0.5668)	
Normality		0.4212 (0.8101)	
Heteroskedasticity		1.1495 (0.3223)	

Source: Author's calculations using EViews 12.
Note: Critical values are obtained from Pesaran *et al.* (2001), Table CI (iii) Case III: Unrestricted intercept and no trend, p. 300. (***) and (**) represent significance at 1% and 5%. The lag length is auto-selected based on the Akaike info criterion (AIC), and the maximum lag (K) is set at 12. The LM, ARCH and Ramsey RESET test statistics are based on F-statistics.

In the subsequent phase of the analysis, the short- and long-run dynamics using the sensitivity model will be conducted. The outcomes of this analysis strongly confirm the existence of an asymmetric relationship between the independent variables and food prices in Malaysia in the long run. This finding aligns with the conclusions drawn from the primary analysis. Specifically, in the short run, both exchange rate and industrial growth continue to exhibit an asymmetric effect on food prices, consistent with the observations in the primary analysis.

Figure 4.3: CUSUM and CUSUM of Squares Analysis Result for Sensitivity Analysis of Model Two.



Source: Illustration by EViews 12.

However, a noteworthy departure emerges concerning USD-denominated palm oil prices, where the sensitivity model reveals an asymmetric impact in the short run. This contrasts with the symmetric relationship identified in the primary analysis for this variable during the short run. Despite this divergence, it is crucial to note that the probability value associated with this finding is very close to the non-rejection threshold (0.0935). This proximity suggests that the difference between the results of the primary analysis and the sensitivity model is not substantial. As such, while a nuanced distinction is identified, it can be reasonably assumed that the overall impact of USD-denominated palm oil prices on food prices in the short run remains relatively consistent across both analyses. In essence, the short- and long-run asymmetric analyses based on the sensitivity model provide a nuanced perspective on the relationships between independent variables and food prices in Malaysia. The proximity of probability values underscores the overall similarity between the primary analysis and the sensitivity model, contributing to the robustness and reliability of the findings.

Table 4.12: Asymmetric and Symmetric Analysis Results in Short- and Long-run for Model Two

Variables	Wald Statistics (F-statistics)		Decision	
	Short-run	Long-run	Short-run	Long-run
Crude Oil Price	0.4045 (0.5267)	2.5048** (0.0494)	Symmetric	Asymmetric
Exchange Rate	2.6479** (0.0453)	9.8689** (0.0024)	Asymmetric	Asymmetric
Palm Oil Price	1.8338* (0.0935)	3.2852* (0.0740)	Asymmetric	Asymmetric
Industrial Growth	2.3742** (0.1472)	4.5933*** (0.0354)	Asymmetric	Asymmetric

Source: Author's calculations using EViews 12.
Notes: The significance at the 1, 5 and 10 per cent levels is denoted by the asterisks (***), (**) and (*). The value in ( ) represents the probability value.

4.7.3 Robustness Test for Model Three

In the final phase, a robustness check was performed for model three, an extended model that integrates biodiesel demand factors to assess their impact on food prices in Malaysia. Two alternative analyses, DOLS and FMOL, were employed to scrutinize the dynamic effects of the variables. The result is presented in Table 4.13. Both analyses yielded robust findings, consistently aligning with the outcomes of the primary analysis for model three. The variables incorporated into the extended model exhibited a clear and precise relationship with food prices in Malaysia, reinforcing the understanding of how biodiesel demand factors influence the economic landscape. While the parameter values and levels of significance may differ slightly, the overall findings replicate those of the primary analysis, further validating the robustness of the results.

This dual validation through alternative analyses not only strengthens the credibility of the extended model but also emphasizes the resilience of the reported outcomes. The replication of findings across diverse analytical approaches adds a layer of confidence in the understanding of the intricate relationships between biodiesel demand factors and food prices in the Malaysian context.

Table 4.13: Dynamic OLS (DOLS) and Fully Modified OLS (FMOL) Result

Variable	DOLS Test Results	FMOL Test Result
CO_t	0.0424 [2.5323]***	0.0550 [2.5185]***
$REER_t$	-0.3680 [-2.2724]**	-0.3274 [-2.6748]**
BP_t	-0.1503 [-4.2562]***	-0.0515 [-1.9289]*
$INVESTMENT_t$	0.1967 [4.4398]***	0.0153 [0.8567]
$VEHICLES_t$	0.3667 [17.970]***	0.2757 [13.185]***
$POLICY_t$	2.7663 [2.1805]**	1.6821 [2.2946]**
R-squared	0.9995	0.9830
Adjusted R-squared	0.9967	0.9820

Source: Author's calculations using EViews 12.
Note: (***), (**) and (*) represent significance at 1%, 5% and 10%. The lag length is auto-selected based on the Akaike info criterion (AIC), and the maximum lag (K) is set at 4. Value in [ ] represents the t-statistic.

Besides, to comprehensively capture the impact of biodiesel demand in model three, which incorporates a select set of independent variables, the Wald test (F-statistic) analysis is conducted. This test, performed using the OLS model, aims to confirm the cumulative effect of the four biodiesel demand variables on food prices. The results of this test are reported in Table 4.14.

The F-statistic findings present compelling evidence, rejecting the null hypothesis and confirming the significant cumulative effect of biodiesel price, vehicle population, biodiesel policy, and investment in the biodiesel industry on food prices in Malaysia. This outcome solidifies the conclusion that the demand factors, taken together, exert a substantial and statistically significant influence on food prices in the Malaysian context. In essence, these results underscore the importance of considering the collective impact of biodiesel demand factors when evaluating their influence on the economic dynamics of food prices in Malaysia. The significant cumulative effect identified through the Wald test further reinforces the understanding that these demand factors play a noteworthy role in shaping the food price landscape in the country. Next, findings of the causality relationship between the variables will be reported.

Table 4.14: The Cumulative Effect of Biodiesel Demand Factors on Food Price in Malaysia

Test Statistic	Value	Probability
F-statistic	495.2203***	0.0000

Source: Author's calculations using EViews 12.
Note: (***) represents significance at 1%.

4.8 Toda–Yamamoto Causality Test Result

These sections discussed the causality relationship between the variables understudied. Cointegration in the models indicates that a causality relationship exists at least in one direction (Granger, 1988). The causality relationship is essential to know whether the food price influences other independent variables or vice versa. This finding is essential for policy implementation. First, the value of the lag length is chosen using the lag length criterion under the VAR model. The AIC criterion suggested a lag of 17 for model one and 12 for model three. Then, the VAR (*k*+*d*) model is constructed to test the causality using the chi-squared value among the variables[41]. Accordingly, the causality test results are reported in Table 4.15.

For model one, a unidirectional relationship is found between crude oil, palm oil, and food prices. The null hypothesis of crude oil price, not granger caused food prices, will be rejected at a one per cent significance level. The same goes for the palm oil price, whereby the null hypothesis was rejected at a five per cent significance level. However, the null hypothesis of food price does not granger cause both crude oil and palm oil prices cannot be rejected since the significant value is more than ten per cent. Accordingly, a unidirectional relationship exists between crude oil prices and food prices. A similar relationship exists between palm oil prices and food prices. This result shows that price changes in crude and palm oil prices will affect Malaysia's food prices. Nevertheless, the food price changes in Malaysia will not impact the price of crude and palm oil.

Besides, exchange rate and industrial growth have bidirectional causality towards food prices in Malaysia. The null hypothesis for industrial growth and exchange rate in both directions is rejected at a one per cent significance level. This demonstrated that food price is interdependent with the exchange rate and industrial growth, whereby changes in both parties will impact each other.

[41] Since majority of the variables integrated in I(1), the *d* value is set at one.

On the other hand, for Model Three, the unidirectional relationship is found between crude oil price and food price, similar to model one. This result shows that price changes in the crude oil price will affect the food price in Malaysia. However, changes in the food price will not significantly impact the crude oil price since the null hypothesis cannot be rejected at a ten per cent significance level. This finding is justifiable since Malaysia is a crude oil price taker, and this country has no power to control the market price of crude oil (further discussed in Chapter 5). Besides, all the biodiesel demand factors have a bidirectional relationship with Malaysia's food prices.

This finding shows that biodiesel demand and food prices complement each other in growth. Vehicle population on the road, which represents the industrial growth in model three, has a bidirectional relationship similar to industrial growth. The relationship between biodiesel and food prices in Malaysia is bidirectional, which differs from the effect of palm oil prices on food prices. This may be because palm oil production is mandatory in Malaysia, while biodiesel production is optional and depends on market demand and the need to protect palm oil prices. In addition, palm oil has endogenous power to influence food prices in Malaysia, while economic factors mainly drive the decision to biodiesel production in Malaysia.

Table 4.15: Toda–Yamamoto Causality Test Results

Hypothesis	Model 1	Direction	Model 3	Direction
IPI does not Granger Cause FP	25.3183 (0.0014)***	Bidirectional	-	-
FP does not Granger Cause IPI	29.8696 (0.0000)***		-	
PO does not Granger Cause FP	7.9267 (0.0190)**	Unidirectional	-	-
FP does not Granger Cause PO	1.2571 (0.2650)		-	
REER does not Granger Cause FP	33.3699 (0.0008)***	Bidirectional	15.5073 (0.0084)***	Bidirectional
FP does not Granger Cause REER	29.9599 (0.0016)***		11.9180 (0.0380)**	
CO does not Granger Cause FP	34.2705 (0.0011)***	Unidirectional	4.0232 (0.0449)**	Unidirectional
FP does not Granger Cause CO	0.2476 (0.6188)		2.8744 (0.1900)	
BP does not Granger Cause FP	-	-	22.4850 (0.0001)***	Bidirectional
FP does not Granger Cause BP	-		11.0332 (0.0009)***	
INVESTMENT does not Granger Cause FP	-	-	26.7708 (0.0000)***	Bidirectional
FP does not Granger Cause INVESTMENT	-		23.5422 (0.0001)***	
VEHICLES do not Granger Cause FP	-	-	22.7481 (0.0000)***	Bidirectional
FP does not Granger Cause VEHICLES	-		29.9599 (0.0016)***	
POLICY does not Granger Cause FP	-	-	12.9413 (0.0239)**	Bidirectional
FP does not Granger Cause POLICY	-		10.3741 (0.0653)**	

Source: Author’s calculations using EViews 12.

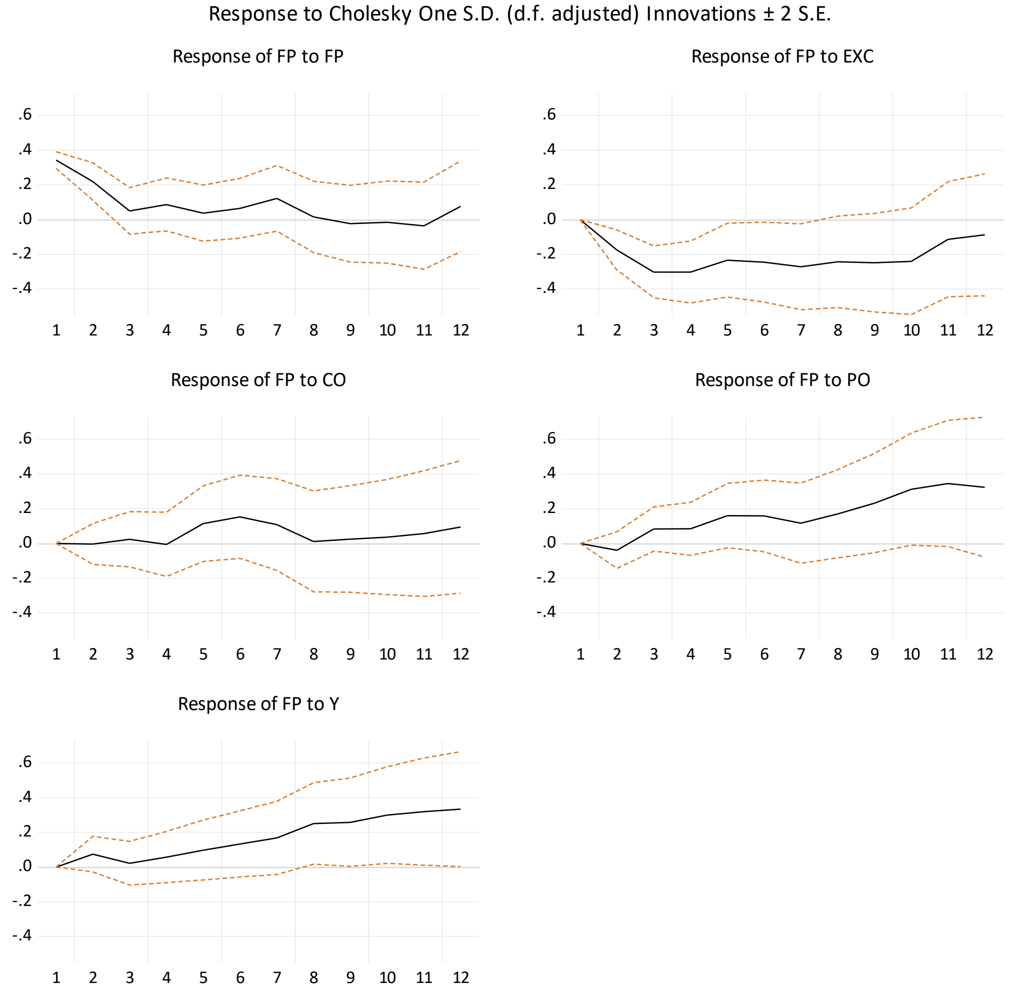
Notes: The significance at the 1, 5 and 10 per cent levels are denoted by the asterisks (***), (**) and (*). The optimum lag is fixed at 17 for model 1 and 12 for model 3 based on AIC.

4.9 Impulse Response Function and Variance Decomposition Analysis Result

Lastly, the impulse response function and the variance decomposition analysis results will be reported and discussed in this section. Figure 4.4 represents the impulse response function analysis in the graphical figure for model one. This analysis is a fundamental aspect of time series. The findings of this analysis provide insights into how one variable responds to a shock or change in another variable over time. After identifying these effects, analysts can use this information to predict the behaviour of the system's variables. Accordingly, this study tried to demonstrate the shock effect for the period of 12 using the VAR model framework.

Based on Figure 4.4, one SD shock on the food price in Malaysia initially decreases the own price in the short run. The decline trend stops in period three and shows no noticeable impact until period seven. After that, it started to decline again until it reached steady in period eight to eleven, then remained in the positive region. Thus, food price seems to have an asymmetric impact on its price in response to the shock. On the other hand, one SD shock on crude oil price does not immediately affect the food price in Malaysia. This can be viewed from Figure 4.4, whereby food prices do not react significantly to the shortfall until the fourth period. This could be due to the subsidy program implemented by the Malaysian government to protect food prices. Accordingly, the shock of crude oil prices transmitted to food prices after period four. After period four, food prices increase as a response to the shock and decrease from period six to eight before increasing back after the period. The responses remain in the positive region until period 12. This finding validates the short- and long-run relationship between crude oil prices and food prices generated using the ARDL model.

Figure 4.4: Impulse Response Function of Food Price for Model 1



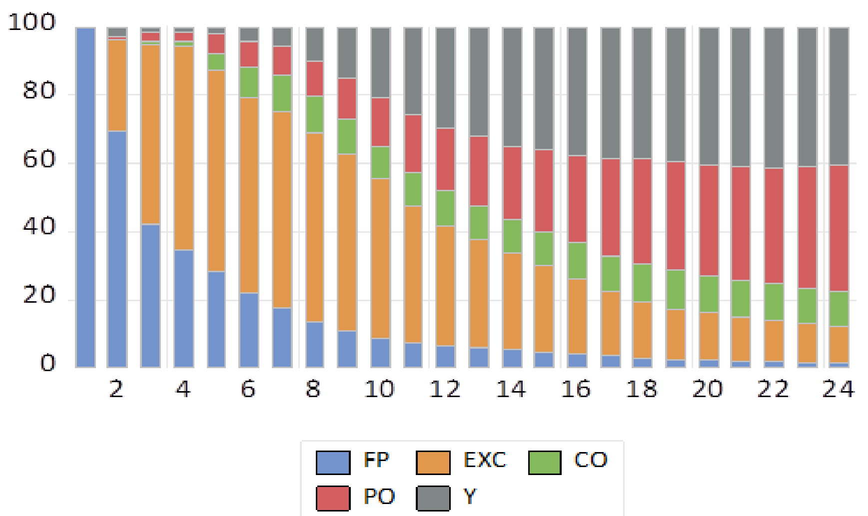
Source: Figure is generated using EViews 12.

Besides, food price decreases to the one SD shock of palm oil prices in the short run (until two periods). However, there was an immediate increase in the food price in response to the palm oil price shock from the second period onwards. Thus, it validates the positive long-run relationship presented in section 4.5. Thus, palm oil price seems to have an asymmetric impact on the food price in Malaysia. Furthermore, food prices increase consistently to one SD shock of industrial growth for the 12 periods. This indicates that industrial growth positively impacts the food price in Malaysia in the long run. In contradiction, food price responds negatively to the shock of the exchange rate in the 12-period period. The food price decreases until period four, then slowly increases until period 12. However, the shock remained negative for the exchange rate one SD shock. Overall, the impulse response function verified the short- and long-run relationship since the projection is very consistent with the findings of the ARDL model.

On the other hand, Figure 4.5 demonstrates the variance decomposition analysis results for model one. This analysis shows how much forecast error variance of the selected variables in the model can explain the exogenous shocks. Furthermore, these findings may extend the understanding of which independent variables influence the food price in Malaysia. Accordingly, to test the percentage of forecast error variance, 24 periods have been set, approximately two years into the future. The statistics have been generated graphically for a better view of the influences. Based on model one in Figure 4.5, the variables explain 100 per cent of the forecast error variance of food prices in Malaysia in period one. Thus, other variables in the model have a substantial exogenous effect in period one. However, the exchange rate in periods four to ten strongly forecasts food prices in Malaysia, reaching up to 60 per cent in periods four and five. The rest of the variables have a weak influence in predicting the food price in Malaysia up to period ten. Interestingly, crude and palm oil prices slowly gained the forecasting power from period six onwards.

However, in the long run, the food price shows low influence (less than 10 per cent from period ten onwards). Remarkably, the forecast error variance of palm oil price and industrial growth is moderately explaining the food price whereby the influences gradually up to 37 per cent and 40 per cent, respectively, in the period of 24. The crude oil price shows the same trend but has low influence, up to 10 per cent in the long run. This justifies the impulse response function whereby the shock on the crude oil price does not immediately transmit to the food price in Malaysia. Lastly, even though the forecasting power of the exchange rate is substantial in a short period, the influences seem to be dissolved in the long run, and this variable can predict about 11 per cent of the food price variance in the long run.

Figure 4.5: Variance Decomposition Analysis for Model 1



Source: Figure is generated using EViews 12.

Furthermore, Figure 4.6 illustrates the impulse response function of model three, including biodiesel demand factors. One SD shock of food price has no noticeable impact on the price in the short run (up to period two). However, after the second period, it shows a decreasing trend in the long run until period 12, moving towards the equilibrium. This shows that stabilising any food price shock will take more than one year. Interestingly, one SD shock of biofuel policy, crude oil prices and investment in the biodiesel industry reduce the food price in a short period. However, food prices increase to those variables' shocks in the long run and hit steady state value in periods two, four and seven, respectively. Thus, these three variables seem to have an asymmetric impact on the food price in Malaysia. This finding validates the short- and long-run relationship generated using the ARDL model.

However, one SD shock on the exchange rate, food prices decreasing until period six before increasing from period seven onwards, approaching steady-state value. Besides, one SD shock in biodiesel price and vehicle population increases the food price in Malaysia consistently from the initial point until the period of 12. These findings verified the short- and long-run relationship presented earlier since the impulse response function is very consistent with the findings of the ARDL model.

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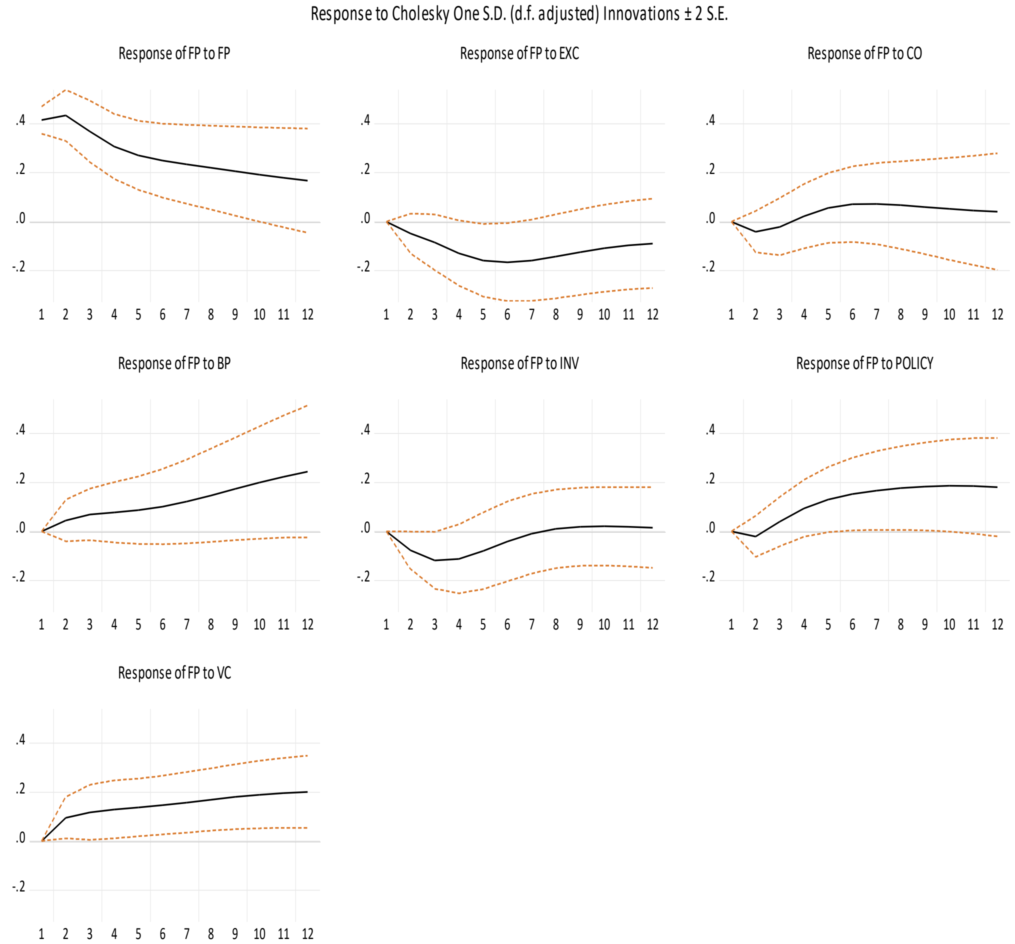
Figure 4.6: Impulse Response Function of Food Price for Model 3

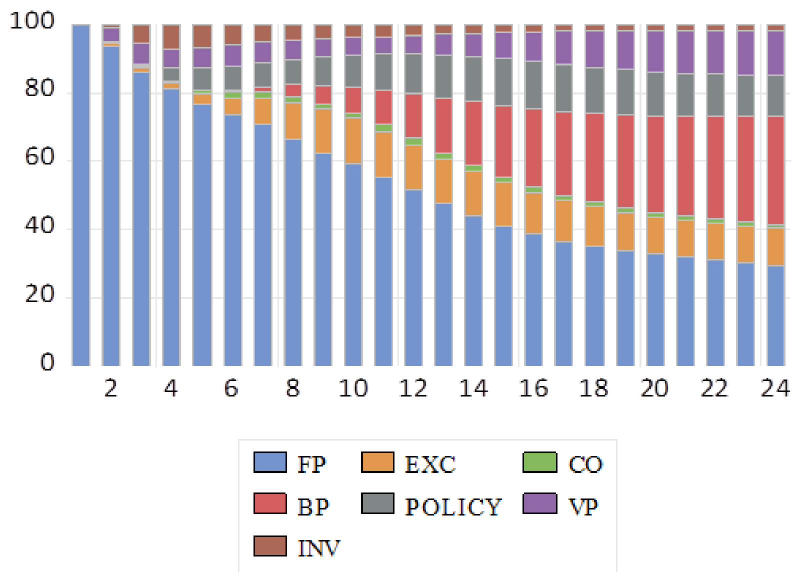


Source: Figure is generated using EViews 12.

Accordingly, Figure 4.7 demonstrates the variance decomposition information for model three. In period one, the variables explain 100 per cent of the forecast error variance of food prices in Malaysia. This influence slowly reduced to 30 per cent in two years. Thus, other variables in the model have a substantial exogenous effect in period one. Furthermore, in the short run, the variables have a weak influence in predicting the food price in Malaysia up to period ten, except for the exchange rate and biofuel policy, whereby very low forecast variance reported, i.e., about 13 per cent and 10 per cent, respectively. Exchange rates remain a critical component of forecasting the food price variable in Malaysia, based on variance decomposition analysis in models one and three.

In the long term, interestingly, the forecast error variance of biodiesel price, biofuel policy and vehicle population in explaining the food price increases gradually up to 32 per cent, 12 per cent, and 13 per cent in the periods of 24, respectively. The dominant forecasting role of palm oil in model one is ratified by the solid value of biodiesel price in model three. The exchange rate shows the same trend but has a low influence, up to 10 per cent in the long run. Similar to model one, crude oil prices remain exogenous in predicting Malaysia's food prices in the short- and long run. This variable can only predict the food price in Malaysia by about two per cent.

Figure 4.7: Variance Decomposition Analysis for Model 3



Source: Figure is generated using EViews 12.

4.10 Concluding Remarks

This section concludes the overall chapter on results and interpretation. Thus, the discussion presents descriptive statistics and the correlation analysis results. Even though the VIF values of certain variables show severe multicollinearity issues, it is still justifiable based on adopting the ARDL method to analyse the cointegration among the variables in the model. To ratify the issue of multicollinearity, some adjustments have been made in model three by removing the industrial growth from the model. Accordingly, three models are presented in this chapter to answer the research questions of this study. Before proceeding with the cointegration analysis, the unit root has been tested among the variables. Based on the ADF and PP unit root test, it is confirmed that variables understudied are integrated with *I(0)* or *I(1)*. No, *I(2)* variables have been used in the model, and the dependent variable, i.e., food price, is integrated in *I(1).* This validated one of the basic requirements of the ARDL model.

The analysis further progresses with the bound testing to identify the existing cointegration relationship among the variables using all three models. The results of the bound testing conclude that all three models have cointegration relationships. Remarkably, all the diagnostic tests are reasonable, and the models are stable based on CUSUM and CUSUM square tests. Thus, the analysis is further advanced to short- and long-run relationships using the ARDL model. The coefficient value of ECT_{t-1} for all the models are significant and have negative signs, as expected. The short- and long-run relationship between the variables in each model (models one and three) has been discussed in this chapter.

The analysis proceeds with the asymmetric effect investigation based on model two. Accordingly, crude oil prices, palm oil prices, exchange rate and industrial growth are asymmetric in long-run food prices in Malaysia. Subsequently, the study undergoes a robustness test to confirm the reliability and consistency of the ARDL findings. The robustness test confirmed that the primary findings are consistent and reliable. After presenting the short- and long-run results for models one and three, the causality test undergoes. For model one, a unidirectional relationship is found between crude oil, palm oil, and food prices. Besides, exchange rate and industrial growth have bidirectional causality towards food prices in Malaysia. For Model Three, the unidirectional relationship is found between crude oil prices and food prices in Malaysia, while exchange rate and biodiesel demand factors have bidirectional causality towards food prices in Malaysia.

Lastly, the impulse response function and the variance decomposition analysis results are reported and discussed. The impulse response function analysis is presented in the graphical figure for models one and three, validating the short- and long-run relationship that the ARDL model generates. Overall, the empirical findings presented in this chapter motivated to answer the study’s research questions. Accordingly, the next section will discuss the findings in detail, which the theories and relevant past studies will justify. Further discussion on how the findings explain the actual situation of food prices in

Malaysia will be presented in the next chapter. Hence, in the next chapter, each research question will be answered with the proper justification from the empirical findings from this chapter.

CHAPTER FIVE

FINDINGS DISCUSSION

5.1 Introduction

This study's motif is to investigate the relationship and the effect of palm oil prices, industrial growth and biodiesel demand factors on food prices in Malaysia. Hence, four research questions were raised in the earlier chapter. Furthermore, secondary data has been gathered, and selected econometric analysis has been conducted in the previous chapter to answer the research questions of this study. Finally, the significant findings have been tabulated in a presentable way and interpreted in chapter four.

This chapter will discuss how this study's results fit the existing empirical findings based on the literature. At the same time, the findings will be vindicated using theoretical/conceptual justification. This process is essential to ensure the current study's findings are well-admissible and valid for the context of Malaysia. Thus, the verified factual results of this study could help in the policy implication and making process later on. Thus, the current chapter is divided into six sections. The first section will be the introduction, followed by Section 5.2, which discusses the relationship between palm oil prices and industrial growth on the food price in Malaysia. This section is important to answer the first research question of this study.

Subsequently, the asymmetric relationship between palm oil prices and industrial growth on the food price will be discussed in Section 5.3. This discussion helps in answering the second research question of this study. The next section discussed the relationship between biodiesel demand factors on food prices in Malaysia. Each of the biodiesel demand factors and its relationship with food price will be discussed in detail using the theoretical justification. This section is important to answer the third research question of this study. To answer the last research question of this study, the dynamic effect of the variables will be discussed in Section 5.5. Lastly, the concluding remark section will take place.

5.2 The Nature of the Relationship between Palm Oil Price, Industrial Growth, Other Control Variables and Food Price in Malaysia.

This section will discuss the findings of the short- and long-run relationship and the causality relationship between palm oil prices, industrial growth, control variables and food prices in Malaysia. The short- and long-run relationship is analysed using the ARDL bound testing approach and the causality test using the Toda Yamamoto approach. The empirical findings are reported in Table 4.5, 4.6, 4.7 and Table 4.14, respectively, under the model one. Further discussion in this section helps in answering the first research question of this study.

5.2.1 The relationship between Crude oil price and food price in Malaysia.

Crude oil price is a fundamental determinant of the food price, reflecting the demand side. Thus, there is a strong argument in the literature on the impact of crude oil prices on food prices based on various countries (Sun et al., 2023; Dutta et al., 2021; Wong & Shamsudin, 2017; Timilsina et al., 2011). Accordingly, the crude oil price is added to Malaysia's food price model as a control variable, whereby past works of literature (Dutta et al., 2021; Wong & Shamsudin, 2017; Ibrahim, 2015), verify a strong influence of the crude oil price on the food price in Malaysia. Hence, the empirical findings of the current study endorse the arguments whereby a positive and significant impact of crude oil price on the linear model (models one and three) of food price in Malaysia is found in the long run. The findings show that a one-point increase in crude oil price will increase the food price of Malaysia by approximately 0.20 points (for model one) and 0.04 points (for model three) in the long run. The current study's finding stressed that crude oil price is an essential determinant of the food price in Malaysia.

The current study's finding is rational since crude oil is an essential input in the production process as raw materials and transportation. Various products are produced based on crude oil, such as gasoline, diesel fuel, lubricating oils, petrochemical feedstocks, and many more, mainly used in the industrial and transportation sectors. Hence, conceptually, an increase in the price of crude oil will increase the cost of production of products and services. This situation may increase the price of final goods and services, positively affecting the inflation rate and real interest rate (OECD Economic Outlook, 2023). This can be evidenced by the recent Russian invasion of Ukraine, whereby the crude oil price increased due to various types of economic restrictions imposed on Russia. This situation led to most of the countries' inflation rate jumping up. For instance, the US recorded a 9.1 per cent inflation rate on June 23, and the UK was about 9.4 per cent in the same period (World Bank, 2023). For Malaysia's case, Lily et al. (2019) confirmed that positive changes in the crude oil price have a positive significant impact on the consumer price index of Malaysia.

Interestingly, it is known that Malaysia is ranked second as a crude oil producer after Indonesia in Southeast Asia. Furthermore, according to the Central Intelligence Agency (CIA, 2020) report, Malaysia produced 647 thousand barrels of oil daily and ranked 27th most significant globally in 2018. Therefore, even though Malaysia is a significant global crude oil producer, this country is not immune to the oil price hike. This is mainly because the price of crude oil is determined based on the market forces of demand and supply, and the competition between the giant economies in consuming crude oil determines the market price of crude oil globally[42].

Since Malaysia is not immune to the crude oil hike, it will significantly impact Malaysia since crude oil prices have a significant positive effect on food prices in Malaysia. This statement is confirmed by this study's empirical findings

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[42] Organization of the Petroleum Exporting Countries (OPEC) is mainly in charged in influencing the crude oil price globally. This organisation is consisting of 13 members countries who managing the oil production, quotas, and reserves of the oil globally. OPEC is controlling about 71 per cent of the total global crude oil reserves. Notably, Malaysia is not a member of the OPEC.

in the previous chapter. However, it is notable that Malaysia's government implemented the Automatic Pricing Mechanism (APM) in 1983 to regulate domestic oil prices. Thus, this move is expected to help stabilise petroleum prices domestically. Furthermore, the implementation of the Automatic Pricing Mechanism will monitor the price of the petroleum products of the current month, and it will determine the price of the following month's petroleum products. This process could make implementing the fuel subsidies more effective from the government side. In this case, when the global crude oil price in higher in the current month, the Malaysian government will provide more subsidies by setting the retailing price below the actual international petroleum price.

For instance, with crude oil booming recently due to the war in Ukraine, the Malaysian government allocated fuel subsidies for petrol, diesel, and L.P. gas to about MYR 37.3 billion in 2022 to combat inflation in Malaysia (Ministry of Finance [MOF] 2022). Out of the total subsidies allocated by the Malaysian government, about 48 per cent covers the fuel subsidy itself. The formal financial minister, Tengku Datuk Seri Zafrul Tengku Abdul Aziz, added that the subsidy allocation for the year 2022 is the highest in the history of Malaysia, whereby the highest subsidy leads to the fuel price in Malaysia is relatively cheaper among the Association of Southeast Asian Nations (ASEAN) countries currently. The petrol price in Malaysia is somewhat lower than in Indonesia and Vietnam by 47.44 per cent and 54.24 per cent, respectively (Dermawan, 2022). This move may significantly help control the inflation rate in Malaysia, whereby in 2022, Malaysia is forecasted to have a second lower inflation rate in the

Southeast countries after Brunei. Malaysia's forecasted inflation rate in 2022 is 3.23 per cent, which is lower than Indonesia's and Vietnam's; the inflation rate of both countries recorded at 7.24 per cent and 4.4 per cent, respectively[43] (International Monetary Funds, IMF[a], 2023).

Furthermore, the current study's finding is in line with the theory of production cost of value, which indicates that food prices are determined by the resources used in production, such as labour, raw materials used, fuels for the types of machinery and transportation, and capital (Ruan, 2018). The usage of fuels in the kinds of machinery for activities such as farming and harvesting, as well as for the transportation sector, is expected to influence the value chain activities for food production. Thus, the effect is higher for food-importing countries such as Malaysia. This could be mainly due to extending the value chain activities by including the trading process. Even though the Malaysian government is giving subsidies on fuel prices to control inflation, crude oil prices affect the commodity prices, which are imported from other countries to Malaysia, and cannot be denied. This is because the fuel price effect is already transmitted in the commodity prices, as illustrated by the production cost of value theory.

For instance, studies such as Hung (2021) and Peersman et al. (2021) proved that crude oil price hike increases the price of crops such as corn, soybeans, and wheat. Accordingly, the import value of those commodities into

[43] However, the effect of the fuel subsidy by government on the food inflation is not explored in the current. Exploration of the role of subsidies in controlling the price of goods and services could be the future direction of this study.

the Malaysian market is already expensive, which will also increase the food price. Notably, Malaysia imported 2,050 and 3,800 thousand metric tonnes of wheat and corn in 2021, respectively (USDA, 2023). This creates an understanding that the subsidies on fuel and other relevant products could control domestic goods and services but not imported goods. In this case, the crude oil price influences the cost of production in the farm and production plants positively, and this will be reflected positively on the crops and food prices in the end. Thus, this argument is consistent with the bioenergy model proposed by Ciaian and Kancs (2011), whereby energy price increases the price of food crops by increasing the production cost of farm activities (Cao & Cheng, 2021).

On the other hand, the concept of "financialisation of commodity markets" further strengthens the current study's findings. Based on this concept, agriculture commodities are treated as another investable asset to overcome the heating and creating spillovers in the financial market (Wadud et al., 2023; Ordu-Akkaya & Soytas, 2020). As a result, agricultural commodities increased transmission stocks and commodities due to financialisation, increasing the integration between oil prices and agricultural commodities (Bossman et al., 2023; Ordu-Akkava & Soytas, 2020). With the increasing integration between the crude oil price and the agricultural commodities, the price of the crops is having strong co-movement with the price of crude oil globally. This is an alternative direction of the crude oil price effect on the commodity prices rather than the traditional theory of production cost of value. Overall, a solid theoretical and conceptual justification validates the current study's positive and significant findings between food prices and crude oil prices in Malaysia.

Based on the empirical findings, the current study's findings are similar to Majuca (2020), Lily et al. (2019) and Applanaidu et al., (2016). Those studies found a positive relationship between food prices and crude oil prices in Malaysia. The positive relationship in the current study indicates that crude oil price hike directly impacts transportation and other relevant food production costs positively. This led to the food products and services increase. Besides, the crude oil price raises Malaysia's food import bill, as Ibrahim (2015) argues. This argument justifies the previous claim that the international price of the commodities increases Malaysia's food price even though the Malaysian government subsidises the fuel price. Finally, the financialisation of the commodities leads to the price of agricultural commodities closely correlating with the crude oil price. Thus, crude oil prices will increase agrarian commodity prices used as the raw material in food production. Conceptually, this argument justifies the significant positive relationships between crude oil prices and food prices in Malaysia.

However, Norazman, Khalid and Ghani (2018) tell a different story whereby a negative relationship is found between crude oil prices and food prices in Malaysia. Even though Norazman et al. (2018) use monthly data similar to the current study, the sample period is only covered from 1991 to 2013, whereas this study's sample period is from 2013 to 2022. There are some advantages to the current study's sample period whereby it can cover the essential economic event which failed to be captured by Norazman et al., (2018). Those significant events are implementing the floating system for the fuel price, which started in 2014, and the Covid-19 pandemic affected Malaysia from March 2020. The effect of crude oil prices on food prices seems better reflected in these two economic events in Malaysia.

The Malaysian government policy to peg the MYR value to 3.80 towards USD was implemented from 1998 to July 2005. Implementation of the fixed exchange rate by the Malaysian government mainly to tackle the Asian Financial crisis and to promote economic stability in Malaysia during the crisis period. Accordingly, one of the advantages of the fixed exchange rate is promoting trade and boosting economic growth. Malaysia is an oil exporting country, and the peg of the exchange rate is beneficial in increasing the country's income[44]. Thus, this could drive down the price of non-traded goods in the domestic market (Butzer, 2015). On the other hand, due to the exchange rate being fixed for seven years, the actual effect of the crude oil price on the domestic food price may be dissolved (Norazman et al., 2018). Therefore, this fixed exchange rate policy could be the reason for the negative relationship in the long run between crude oil and food prices in Malaysia, based on the study of Norazman et al. (2018).

However, implementing the de-peg of the MYR value from July 2005 onwards and executing the floating fuel price in 2014 can bring the actual effect of the exchange value into the picture. In this case, the impact of the crude oil

[44] Malaysia is recorded the export of crude petroleum at USD 5.18 billion in 2020 which make Malaysia is 21st largest exporter of the crude oil in the world. In the same year Malaysia imported USD 4.75 billion of crude petroleum into Malaysia. As overall, it is recorded the net export of USD 0.43 billion.

price is better reflected in the food price captured by the current study. On the other hand, the COVID-19 pandemic negatively affects the crude oil industries due to the decrease in global industrial production. This event led to a negative financial bubble in most fuel-exporting countries (Gharib et al., 2021). Thus, a drop in the crude oil price also influences the commodity prices, which is not captured by the study of Norazman et al. (2018).

Besides, the causality test findings show that the crude oil price has the power to influence the food price in Malaysia. However, there is no reverse effect from food price to crude oil. This finding is similar to Norazman et al. (2018), which validates unidirectional causality from crude oil prices to food prices in Malaysia. This finding is justifiable because Malaysia is one of the oil-producing countries, earning solid income through oil trading. A report from the Federal Government revenue of Malaysia highlighted that Malaysia's petroleum income tax gain in 2022 is MYR 19,302 million, which is about 6.8 per cent of the overall revenue of Malaysia in 2022. However, Malaysia does not have the power to influence the international market price of crude oil, which is mainly controlled and monitored by OPEC member countries. Malaysia is known to be an energy price taker (Majuca, 2020). This argument validates the unidirectional causality of the current study, from crude oil prices to food prices in Malaysia.

Overall, it is clear that the crude oil price plays a crucial role in positively affecting Malaysia's food prices. At the same time, unidirectional causality from crude oil price to food price indicates the strong dependency of the food market on energy. The findings align with the theoretical justification and the previous studies. The effect of the exchange rate on the food price will be discussed in the coming section.

5.2.2 The Relationship between Exchange Rate and Food Prices in Malaysia

The effect of the exchange rate on the food price is highly complex since Malaysia is one of the net foods importing countries in the world. According to DOSM[c] (2021), Malaysia's import dependency on agricultural commodities increased from 7.3 per cent to 13.7 per cent from 1987 to 2015. The reliance on imported agricultural commodities increased by almost double in 28 years. Furthermore, the report highlighted that Malaysia's import of food products in 2020 was MYR 55.5 billion compared to its exports of MYR 33.8 billion[45]. Accordingly, due to Malaysia's higher dependency on food imports, the exchange rate fluctuation could affect the availability of domestic food supply and create instability in Malaysia's food prices. Thus, this argument can be explained using the law of one price, whereby the asset price will be the same across the market globally (Haskel & Wolf, 2001; Miljkovic, 1999). Thus, this ability can be achieved considering the currency exchange between the countries involved in the trading activities. So, arbitrage profitability can be ratified with the same value of the assets and commodities across the market. Thus, it is understood that solid currency value stabilises the prices and can reduce a country's import bill. Therefore, this minimises Malaysia's food inflation (Aliyu & Ismail, 2017).

[45] The trade deficit for the food products in Malaysia is recorded as MYR 21.7 billion in 2020, which is increased 24.9 per cent compared to 2019 (DOSM[c], 2021).

The weakened currency will negatively impact the open economy, such as Malaysia, by increasing imported food bills. Notably, Malaysia's dependency on imported foods is about 60 per cent due to industrial growth, whereby local agriculture production is being traded off (Business Today, 2022). Thus, the exchange rate is another crucial control variable that cannot be denied from the food price model in Malaysia. Accordingly, the exchange rate has been added to Malaysia's food price model to capture the effect of international trade on domestic food prices. The current study's finding shows that the exchange rate has a significant negative relationship with the food price in Malaysia, as expected. These findings are confirmed based on the linear models one and three. The results suggested that the appreciation of Malaysia's currency value by one per cent will decrease the food price by 1.64 per cent for model one and 0.24 per cent for model three in the long run. Based on the concept, theory, and past empirical findings, the findings are solid and well-justifiable.

Furthermore, most of the literature has similar findings in the case of Malaysia, for instance, Applanaidu et al. (2014), Norazman et al. (2018), and Hasan et al. (2018). Thus, the negative relationship indicates that the MYR depreciation will increase the domestic food price in Malaysia (Norazman et al., 2018). This is rational; for instance, the devaluation of the MYR could increase the import bills of the goods and services traded at international prices (Alotaibi, 2016; Kotil, 2019). This is because weakened currency value will lead to more budget allocated to import the same volume of commodities into Malaysia due to the food demand. This argument aligns with the law of one price whereby the trading activities use the USD for the commodities value standardisation. Thus, the devaluation of the MYR in Malaysia will create two consequences. The first consequence is that the price of raw materials in food production will increase due to the relatively higher import value. For example, Business Today (2022) reported that Malaysia depends on 88.8 per cent of mutton and 76.4 per cent of beef imported from India using the international currency value. This situation will increase Malaysia's food prices when the exchange value weakens.

The second consequence will be that the imported food supply will be reduced domestically due to higher import costs, which may increase the food price due to the demand and limited supply in the market. Thus, Ariff and Abubakar (1999) urged that Malaysia implement an expansionary fiscal policy to combat the Asian Financial Crisis in 1997/98. The import of luxury goods declined, mainly focusing on capital and intermediate goods[46]. Accordingly, based on the policy instrument, the effect of the exchange rate on the price of goods and services can be reduced by limiting the import quantities into Malaysia. This was practically done in 1997/98 when the Asian Financial Crisis impacted Malaysia. It is known that the Malaysian exchange rate plunged to a low of 4.88 in January 1988 against the USD in 1997 from 2.42 in April 1997 (IMF[b], 2023; Nambiar, 2009; Ariff & Abubakar, 1999). Due to the devaluation of the MYR, Malaysia undergoes various capital control strategies to reduce the import of goods and services into Malaysia to safeguard the MYR's value.

[46] The import of Malaysia drops from 27 per cent to 13 per cent and 16 per cent to 10 per cent for the period of 1995 to 2007, for Japan and US, respectively.

For instance, a ban on the offshore market trading of the local currency in September 1998 to curb speculation of the MYR, fixed the MYR exchange rate at 3.8 to the USD and introducing campaigns such as "*buy Malaysian products*" are policies that have been introduced to reduce the effect of the exchange rate on the imported products and services. Practically, these moves helped in the recovery process of Malaysia from the financial crisis during that period. However, these moves do not apply to importing food and food-related products into Malaysia. This is because food production in Malaysia is limited, and the majority of the food industry in Malaysia depends on raw materials from other countries. Thus, slacking the imports may negatively impact Malaysia's food processing industries. This will consequently lead to a food crisis in Malaysia. Therefore, it fixed the exchange rate to 3.8 against the US, minimising the effect in the crisis period in 1997/98. In this case, safeguarding the Malaysia MYR value is essential to control the food price in Malaysia since reducing food imports will not work for Malaysia in the current context.

Besides, Afolabi et al. (2022) and Baltagi and Wang (2023) argued that the exchange rates could explain the link between oil prices and agricultural commodity prices because oil trade is conducted mainly in USD. The report of World Economic Outlook, April 2023 from IMF stated that a 10 per cent depreciation in the U.S. dollar leads to an increase in crude oil prices by about 2-3 per cent and an increase in agricultural commodity prices of about 1-2 per cent (IMF[b], 2023). Accordingly, the devaluation of the MYR will reduce the import of petroleum products, fertiliser and other relevant products used in food production. This argument is supported by Butt et al. (2020), which shows that the exchange rate negatively impacts agricultural commodity prices such as palm oil, rubber and natural gas using monthly data similar to the current study. Accordingly, this will slow economic progress and lead to inflation in Malaysia. The finding is further strengthened by the recent decision by Indonesia to ban their export of palm oil in 2022 to alleviate the inflationary effect in that country due to the shortage of palm oil, which will increase the cost of vegetable oil (Business Today, 2022). Notably, with the solid international palm oil price (More than USD 6,653 per tonne), this decision was taken even though Indonesia lost about USD 3 billion a month in foreign revenues due to an unfavourable exchange rate in Indonesia. Thus, a firm currency value against the US will be very favourable towards trading activities. This justifies the negative relationship between Malaysia's exchange rate and food prices.

The causal relationship between Malaysia's exchange rate and food price indicates a bidirectional relationship between them in models one and three. This suggests that the exchange rate is vital to Malaysia's food prices. This is very rational, especially for Malaysia, which is known to be the net food importing country. The findings are supported by Samal et al., (2022), which found that India has a bidirectional relationship between exchange rate and food price. Overall, it is clear that the exchange rate plays a crucial role in negatively affecting Malaysia's food prices, which aligns with the theoretical justification and the previous studies. Accordingly, the effect of the experimental variable, i.e., palm oil price, on the food price will be discussed in the coming section.

5.2.3 The Relationship between Palm Oil Prices and Food Prices in Malaysia

Palm oil price is one of the essential experimental variables in this study. This study highlighted the assumption that palm oil prices will influence food prices in Malaysia since this commodity's oil is used in food production and as the primary cooking oil in Malaysia[47]. According to MPOC (2022), about 75.45 million metric tonnes of Malaysian palm oil were used for food production globally in 2020. This is higher than 2015/06, recorded as 59.5 million metric tonnes globally. Furthermore, the FAO Statistical Corporate Database (2022) report highlighted that palm oil is the world's most significantly consumed vegetable oil for 2020, followed by soybean oil. Thus, with the growing influence of palm oil on food production, the fluctuation in the palm oil price is hypothesised to impact the food price in Malaysia. Accordingly, this variable is vital in answering this study's first and second research questions.

The empirical findings of this study confirmed the hypothesis by indicating that palm oil price has a positive and significant impact on food prices in Malaysia in the long run. The findings suggested that a one-point increase in palm oil prices will increase the food price by approximately 0.06 points in the long run. Furthermore, the causality test findings indicate a unidirectional effect of palm oil prices towards Malaysia's food prices. Thus, this finding shows the palm oil price's significant role in Malaysia's food price hike.

[47] The palm oil produced in Malaysia is used globally as a cooking oil, margarine, vegetable ghee, ice cream, cheese analog, non-dairy products, and others (MPOC, 2022). Under the non-edible sector, palm oil used to produce products such as soaps, shampoos, detergents, pharmaceuticals and others (Abdullah, 2013).

The present study's significant positive relationship between palm oil prices and food prices in Malaysia is justifiable with the cost-of-production theory of value. The theory indicates that the cost of production of those goods determines the final value of the goods and services. In this case, the agriculture commodity prices are one of the factors of production which determine the final price of the food since it is used as the raw material for food production (Nigatu et al., 2020). Thus, this concept is founded by the supply-demand framework, widely used in energy-food studies (Kusz et al., 2021; Peersman et al., 2021; Taghizadah-Hesary et al., 2019).

Accordingly, various factors influence the price of palm oil in Malaysia. For instance, since palm oil is one of the highly tradeable commodities globally, supply and demand play a significant role in the price determined, which is agreed upon by both seller and buyer (Abdullah, 2013). In this case, the various factors affecting palm oil production will influence the availability of palm oil in the market. From the demand side, the higher the need for palm oil in the food and non-food industries, the higher the demand for this commodity from the national and international markets. For instance, Trading Economics (2023) reported that the local palm oil export increased by 27.7-33.1 per cent in February 2023 compared to the previous month. The increase in the export of Malaysian palm oil is mainly due to the export restrictions from Indonesia, which is known as the top producer of global palm oil (Tan & Lim, 2022).

Furthermore, increasing mandatory biofuel in Indonesia increases the demand for palm oil for blenders and reduces the global supply of cooking oil.

Lastly, the drop in the production level of palm oil in Malaysia recently due to tropical storms and floods increased the price of this commodity as well. Thus, various internal and external factors contribute to the fluctuations in Malaysia's palm oil prices.

Besides, the significant role of palm oil on the food price cannot be denied. This is because of the usage of palm oil in food production and preparation, i.e., as cooking and frying oil. Therefore, the cooking oil price is highly dependent on the price of local palm oil. This statement is further supported by Sarmidi et al., (2022), which found that palm oil prices strongly influence vegetable prices in Malaysia. Furthermore, the Malaysia Productivity Corporation (2022) indicates that Malaysian household spending on cooking oil is about 0.42 per cent of overall food expenditure. Thus, this is a small amount, but an increase in the cooking oil price may affect the "food away from home".

Interestingly, the chief statistician under the Department of Statistics Malaysia, Dr Uzir Mahidin, highlighted that the price index of "food at home" and "food away from home" increased by about 6.1 per cent and 6.6 per cent, respectively, in 2022[48]. Moreover, the Guardian (2022) highlighted that fast-food prices might increase globally due to the rise of cooking affected by the Russia-Ukraine invasion. The report indicates that the price of vegetable oil jumps to 22 per cent on average compared to last year. Based on this statement,

[48] According to Dr. Uzir Mahidin, the higher increase in the food away from home are roti canai (10.5%), economy rice (9.7%), cooked beef (7.8%), and noodles (7.0%).

it is notable that the effect of the global recession is higher on food away from home than food at home.

This is significant since most Malaysian working communities consume food away from home, such as stalls, restaurants, fast food centres, and morning and night markets, a trend and culture among Malaysians. Tan (2010) highlighted that about 91.2 per cent of Malaysian adolescents in the urban area preferred having family meals away from home at least once a week. Furthermore, Latimaah et al. (2018) highlighted that Malaysian income increases influence food intake away from home. The study found that an increased income of MYR 100 will increase the spending of Malaysians on food away from home by MYR 1. With Malaysia's focus on the industrial revolution and development, the population's income is increasing over time in Malaysia. For instance, implementing the minimum wage increase to MYR 1,500 in 2022. Thus, this will contribute to increasing spending on food away from home in Malaysia. Notably, food away from home covered the weightage of 9.6 per cent in the overall food price in Malaysia, representing a higher weightage than the other food components under the food at home category (DOSM, 2023)[49].

Thus, the effect of the cooking oil price on the food price cannot be denied here and is justifiable based on the current study's findings. To further strengthen the argument, Isa et al. (2020) found a significant positive relationship between palm oil prices and inflation in Malaysia. Even though Isa

[49] The overall food composition between food at home and food away from home is 27.3 per cent and 9.6 percent, respectively.

et al. (2021) use inflation overall, the current study explicitly uses the food price index. Food price is the most significant component of Malaysia's inflation rate, covering 33 per cent of overall inflation (DOSM, 2022). Interestingly, palm oil prices have a similar effect on both the inflation rate and the food price index in Malaysia, which is confirmed by Hameed et al. (2008), Peri and Baldi (2010), and Kang et al. (2019). These studies used vegetable oil as a proxy for food prices and inflation.

At the same time, the effect of crude oil prices on palm oil can also be denied (Hameed & Arshad, 2009). The concept of financialisation of the commodities could be another possible explanation for the positive relationship between palm oil prices and food prices in Malaysia. The financialisation of the commodities indicates that the co-movement of the agricultural commodities is highly correlated to the financial instruments such as crude oil price (Ordu-Akkaya & Soytas, 2020). Since palm oil price is highly integrated with the crude oil price, the effect of the palm oil price on the food price in Malaysia is similar to the impact of crude oil on food price. This is mainly due to the price effect of crude oil on the production cost of palm oil in Malaysia.

Accordingly, when the price of crude oil is higher, this will increase the production cost of palm oil, such as the price of fertiliser and diesel usage (Butt et al., 2020). This situation can lead to the palm oil price to increase, which has a similar impact on Malaysia's food prices. In addition, the Edge Market report highlighted that only about five to seven per cent of the crude palm oil is used to produce cooking oil in Malaysia. Thus, 70-80 per cent of the cooking oil cost structure statistically depends on Malaysia's crude palm oil price (Malaysia Productivity Corporation, 2022). Even though both crude oil and palm oil conceptually have a similar effect on food prices, the forecasting power of the palm oil price on the food price in Malaysia is higher which is 35 per cent, compared to the crude oil price, which can predict the food price variability about 10 per cent in two years. These findings proved that the direct effect of energy on the food price as a production cost is smaller than the agricultural commodity prices. Lastly, the impact of the industrial growth of Malaysia on food prices will be discussed in the following section.

5.2.4 The relationship between Industrial growth and Food Prices in Malaysia

Industrial production is the last experimental variable used in Malaysia's food price model. This variable is used as the proxy for income, which is the essential factor in the food demand in Malaysia. Income is added to Malaysia's food price model since it captures the people's purchasing power. Accordingly, aligned with 4IR, the National Policy on Industry 4.0 was launched in Malaysia in 2018. Thus, labour productivity growth and high-skilled jobs are some of the National goals under the 4IR, which focuses on improving the Malaysian standard of living and income. Accordingly, a positive relationship is hypothesised between industrial growth and food prices in Malaysia by confirming the hypothesis to answer this study's last research question.

The current study's linear model (model one) suggested a significant positive relationship between food prices and industrial production in Malaysia.

The finding indicates that a one-point increase in industrial production will increase the food price by approximately 0.33 points and 0.04 per cent for models one and three, respectively, in the long run. This finding aligns with the unified growth theory, whereby an increase in income will increase the demand for food and services (Madsen & Strulik, 2020; Rahman, 2017). Thus, with the limited availability of food and growing demand, the price is expected to go up.

Furthermore, Engel's Law illustrates that food demand increases with income increases in the initial stage. However, the proportion of food spending will be reduced at some point, whereby higher demand will be transferred to services such as better healthcare and education. Thus, the situation will be more practical for the developed nations, whereas in developing countries such as Malaysia, more priority will be on food accessibility, which is the basic need of citizens. Based on DOSM (2020), the average income of Malaysians in 2019 was MYR 7,901, whereby about 80 per cent of the Malaysian population is trapped under middle-income (M40) and low-income (B40) categories. The absolute poverty rate is recorded as 5.6 per cent, and the hardcore poverty was 0.4 per cent in 2019 (DOSM,2020). This survey shows that Malaysia is still ensnared under middle-income nations and that basic needs, such as food availability, are being prioritised.

On the other hand, the growth model stressed that population growth leads to an economic transformation whereby industrial development will be focused on (Gocoglu & Goksu, 2023). Accordingly, the country's industrial growth leads to the population's income increase. Moreover, conceptually, industrial growth may help develop a country's industrial base by creating more skilled job opportunities for citizens. For instance, Malaysia was known as an agriculture-based economy in the early stages of the 1950s and 1960s, the pillar of the Malaysian economy. However, Malaysia slowly progressed towards becoming an industrial nation from the 1970s onwards with the help of favourable industrial policy.

With industrially oriented policies such as Import Substitute industrialisation, Look East Policy and heavy industrialisation introduction, Malaysia's industrial contribution to the GDP overtook the agriculture sector's contribution in the 1980s'. Accordingly, with more emphasis shifted from social equity to wealth creation, the industrial base of Malaysia started to expand due to more pro-market and outward-oriented measures from the 1980s. All these progressive moves significantly contributed to the outstanding absorption of FDI into Malaysia, leading it to become one of the world's major electronics exporters. In addition, the Industrial Master Plan 1 (IMP1, 1986-95), Industrial Master Plan 2 (IMP2, 1996-05), and Industrial Master Plan 3 (IMP3, 2006-20) created a proper direction for the industrial growth in Malaysia until the current stage of 4IR.

Thus, the critical point here is the role of industrial growth in creating wealth among Malaysians. Expanding the industrial base in Malaysia from the 1980s until now creates more job opportunities for Malaysians and helps increase the standard of living (Rahman, 2017). For instance, the recent increase in the minimum wage in Malaysia under the Wages Councils Act 1947 will increase the price of goods and services in Malaysia. The minimum wage in Malaysia in 2013 was MYR 900 and MYR 800 per month in Peninsular and East Malaysia, respectively. Subsequently, the minimum wage increased to MYR 1,100 monthly in 2019 and MYR 1,500 in 2022. DOSM (2022)[b] stated the recent minimum wage increase in the manufacturing sector's productivity by 6.8 per cent in 2022.

Furthermore, Yeoh and Wen (2022) urged that an increase in the minimum wage may lead to Malaysia losing international competitiveness compared to neighbouring countries, resulting in a high cost of living and inflation. This is basically due to the labour cost of Malaysia being relatively higher than the neighbouring countries such as Thailand and Indonesia, which could lead to more FDI being shifted to neighbouring countries. Consequently, the lack of FDI affects business and market performance, leading to Malaysia's inflation, as Yeoh and Wen (2022) urged. Furthermore, studies such as Mustafa (2019) and Fama and Gibbons (1982) supported the argument by indicating that investment negatively affects the inflation rate. Thus, this argument justifies the present study's positive relationship between industrial production and food prices in Malaysia.

Besides, Malaysia focuses more on industrial than agricultural production in line with Malaysia's objective to become a high-performing industrial nation by 2050. Agricultural production could make the food price less expensive due to the higher availability of the crops in the market and less import. However, Malaysia is a net food importing country focusing on industrial growth, which may increase the population's income and living standards over time. Furthermore, agricultural production is limited by land, whereby industrial production is not subject to land availability. Thus, Malaysia is ranked 76 in agricultural land availability globally and 172 in the crop production index in 2020 (The World Bank, 2022; FAO, 2022). However, in the innovations index, Malaysia is ranked 36 and 37 globally in the economic globalisation index (WIPO, 2022; The Swiss Institute of Technology in Zurich, 2022). This ranking clearly shows the economic interest of Malaysia. With limited food production in Malaysia and increasing demand for food due to industrial growth, the price will increase, as argued by Mahmood et al. (2022). Thus, this could be another rational explanation for Malaysia's positive and significant relationship between income and food prices.

In addition, another model that can be used to validate the positive impact of industrial production on the food price in Malaysia is using the bioenergy model (Dutta et al., 2021). The alternative direction of Malaysia's industrial growth hypothesised to influence the food price directly is due to the energy demand (Fais et al., 2016; Marouane et al., 2021). Thus, the bioenergy model illustrated that integrating industrial growth and food prices could be a channel through the fuel market. This is due to fuel usage, and the increasing use of blended biofuel in industrial production increases the integration of the fuel market and industrial growth (Dutta et al., 2021; Ciaian & Kancs, 2011). Accordingly, both food industries and non-food industries are competing for fuel. At the same time, additional demand created in the biofuel market, which comes from industrial growth, could influence the food market by increasing the price pressure on the food market's raw material, i.e., agricultural commodities. Thus, these phenomena explain the positive impact of industrial growth on food prices in Malaysia.

In terms of empirical evidence, the study of Samal et al., (2022) has similar findings to models one and three of the current study. The study used monthly data for India and found that income has a significant and positive relationship with food prices. Samal et al., (2022) and Zimmermann and Rapsomanikis (2023) supported the argument that income increases the citizen's purchasing power, increasing food demand. Thus, increasing food demand will also increase the price of food. This explanation is reasonably fit for Malaysia as well. Even though India is a food exporter country compared to Malaysia, which is a food importer, the income effect seems similar to the food price in both countries. Besides, studies such as Carrasco and Mukhopadhyay (2012), Agrawal and Kumarasamy (2014), and Joiya and Shahzad (2014) have similar findings by using the sample countries such as India and Pakistan, which have industrial growth as a common objective as Malaysia.

Interestingly, most food price studies in Malaysia, for instance, Applanaidu et al. (2014) and Wong and Shamsudin (2017), show that income negatively affects the food price in Malaysia. Those findings align with Zimmermann & Rapsomaniki's (2023) argument, which indicates that economic growth will positively influence the food price in net food exporting countries and negatively influence the net food importing countries such as Malaysia. This is because better economic performance could affect the aggregate supply positively by improving the supply chain performance (Gillman et al., 2023; Goel et al., 2021). Thus, more supply could control food price inflation in Malaysia. However, this argument is debatable in the case of Malaysia, and further validation is needed since studies in Malaysia suggest that GDP growth positively impacts the inflation rate (for instance, Munir, Mansur & Furuoka, 2009; Munir & Mansur, 2009; Akter & Smith, 2021). In this case, GDP growth should increase inflation to increase the food price in Malaysia.

However, the disproving findings in the current study could be due to the proxy usage in the model whereby Applanaidu et al. (2014) and Wong and Shamsudin (2017) use GDP growth as the proxy for income. However, the current study using the industrial production index as a proxy for income follows Noviyanti and Beik (2014), Hasan et al. (2018) and Kapusuzoglu et al. (2018). Notably, GDP captures the income effect overall, whereby industrial production is a more specific component of the production effect covering industrial growth. So, the impact of industrial growth on the food price is not similar to Malaysia's GDP growth. Interestingly, industrial production theoretically could better reflect the income effect on the food price justifiable by theory.

Besides, the current study's causality test findings suggested a bidirectional effect between industrial growth and food prices in Malaysia. This finding illustrates that food price and industrial production are interdependent. This finding is well accepted since income growth and demand are highly integrated. Thus, the demand could influence the price of services and goods. At the same time, biodiesel production, which interlinks the palm oil industry and the fuel market, leads to industrial growth, and food prices depend more on each other. This argument is further strengthened by the finding of Akter and Smith (2021), whereby the study found a bidirectional causality between income and the inflation rate in Malaysia. Furthermore, the results are similar to the study of Samal et al. (2022), which found a bidirectional relationship between income and food price and income in India. Notably, there is no evidence of the causality effect between income and food price in the case of Malaysia that can be compared due to insufficient exploration in past empirical studies.

Overall, it is clear that industrial production and palm oil prices play a crucial role in positively affecting Malaysia's food prices, which is in line with the theoretical justification. Even though the empirical findings of some previous studies in Malaysia contradict the current study's findings, proper explanations and arguments are provided in the discussion to justify the findings. Besides, the results and arguments confirm the hypothesis that industrial growth and palm oil prices positively influence Malaysia's food prices. Accordingly, the study's first research question has also been answered.

5.3 The Asymmetric Relationship between Palm Oil Price, Industrial Growth, Other Control Variables and Food Price in Malaysia.

This section will discuss the findings of the asymmetric relationship between palm oil prices, industrial growth, control variables and the food price in Malaysia. The asymmetric effect is analysed using the non-linear ARDL bound testing approach. The empirical findings are reported in Table 4.5, 4.6, 4.7 and Table 4.8, respectively, under the model two. Further discussion in this section helps in answering the second research question of this study.

5.3.1 Asymmetric Relationship between Crude Oil Price and Food Price in Malaysia.

The asymmetric analysis confirmed that crude oil prices have an asymmetric effect on the food price in the long run and are symmetric in the short run. The NARDL findings suggest that when the price of crude oil increases by one point, the food price in Malaysia will increase by 0.04 points in the long run. On the other hand, a one-point reduction in crude oil increased Malaysia's food price by 0.02 points. The current study's findings supported the study of Ibrahim (2015), whereby crude oil's asymmetric effect on food prices was on hold in Malaysia. However, the study of Ibrahim (2015) revealed that only the positive changes in the crude oil price significantly influenced the food price in Malaysia, whereby the negative changes were not significant towards the food price in Malaysia. However, the current study shows that both positive and negative changes significantly impact food prices positively in Malaysia, similar to the study of Wong and Shamsudin (2017).

Thus, the variation in the findings between the current study and the study of Ibrahim (2015) could be due to two justifications. The first justification is the difference between the sample period usage in both studies, whereby the current research covers a more recent time frame. Thus, the COVID-19 pandemic effect is surrounded by the current study's time frame contributes to positive and negative changes in the crude oil price, more responding to the food price in Malaysia due to supply and demand disruptions, and speculation (Kumeka et al., 2022). Another justification is the high-frequency data usage in the current study, which is monthly frequency data compared to Wong and Shamsudin (2017) and Ibrahim (2015), which uses the quarterly and annual data frequency. Notably, high-frequency data can capture the impact of precisely timed shocks compared to low-frequency data (Dalia & Smith, 2021). On the other hand, the asymmetric model findings of this study are more relevant to the study of Wong and Shamsudin (2017), whereby both positive and negative changes in the oil price impact the food price in Malaysia positively.

It makes sense that when crude oil prices increase, food prices rise in Malaysia due to the increase in the cost of production, as discussed earlier. However, the decrease in the crude oil price positively impacts the food price in Malaysia, which is an interesting finding in the current study. The *ratchet effect* can be used to explain the asymmetric positive effect in this context (Jaen-Garcia, 2021; David, 2018). In Malaysia, food prices are often more sensitive to commodity price increases than price decreases. Consequently, businesses are more likely to pass on increases in costs to consumers than to pass on decreases in costs to consumers since profit-making is the priority for businesses. The ratchet effect can have a significant impact on consumers. For example, if the price of oil increases, this can lead to increases in transportation, food, and other goods. However, when oil prices decrease, consumers may not see the same level of decreases in the prices of goods and services. As a result, food prices can slowly decline even when there is downward pressure on prices. This justifies the positive asymmetric effect of the crude oil price on the food price in Malaysia.

Furthermore, the subsidy effect from the government on the fuel price in Malaysia compromised the crude oil price effect on the food price. The floating fuel price system and the pricing cap set at MYR 2.05 per litre for petrol and MYR 2.15 per litre for diesel are mainly expected to control inflation in Malaysia (Hussain et al., 2018). Conceptually, this effort maintains the domestic retailing of petrol and diesel prices, which led to the influence of the crude oil fluctuation being minimized in the food price of Malaysia. This statement further strengthens the study of Hussain et al. (2018), whereby the study attempts to investigate the effect of petrol and diesel retail prices on food prices in Malaysia. The findings show no significant impact of the retail price of petrol and diesel on the food price in Malaysia. Thus, the study of Hussain et al. (2018) indicates that due to the subsidy effect, petrol and diesel do not strongly influence the food price in Malaysia, which contradicts this study.

Due to the *ratchet effect* and fuel subsidy program by the Malaysian government, the global crude oil price increase and decline does not immediately transmit to Malaysia's domestic food price. Due to this, the negative changes in the crude oil price positively impact the food price in Malaysia, even though the effect is not as massive as the positive impact of crude oil on food prices. Further exploration of this issue could be another future direction of this research in creating better insight into the fuel subsidy effect on food prices in Malaysia.

5.3.2 Asymmetric Relationship between Exchange Rate and Food Price in Malaysia.

The asymmetric model (model two) of food prices in Malaysia suggested that the exchange rate is asymmetric on the food price in the short run and long run. The finding is similar to the study of Hong et al. (2022) and Hasan et al. (2018). The results illustrated that positive and negative exchange rate changes do not have similar effects on Malaysia's food prices in the short and long run. In detail, the current study's asymmetric linear model indicates that MYR's appreciation will decrease the food price in Malaysia.

The empirical findings of the present study suggested that a one-point appreciation in the exchange rate will reduce the food price of Malaysia by 0.21 points in the long run. However, the exchange rate depreciation does not significantly influence the food price in the long run, even though a negative impact is found, which indicates that a weakened MYR increases the food price in Malaysia. Nevertheless, the model suggested that the effects of the appreciation of the MYR value are higher on the food price than the depreciation of the MYR value, similar to Gohar et al. (2023). This asymmetric relationship can be further explained by the "*cost-push inflation*" theory whereby appreciation of currency value will reduce the import bill for food commodities. Thus, consumers are able to fell less pressure on the food price.

Thus, this finding strengthens the findings of linear models (model one), and a similar explanation is held. However, the current study's finding contradicts the analysis of Wong and Shamsudin (2017), whereby the authors identify that the appreciation of the MYR will increase food prices in Malaysia using the quarterly data. Thus, no proper theoretical justification can be used to support the evidence of this positive effect of the exchange rate on the food price in the asymmetric linear model of Wong and Shamsudin (2017). Conceptually, the cost of imported goods should not be favourable for the MYR value appreciation. In this case, the current study's findings are more convincing.

5.3.3 Asymmetric Relationship between Palm Oil Price and Food Price in Malaysia.

Model two was developed to understand the asymmetric impact of palm oil prices on Malaysia's food prices. Thus, it is hypothesised that palm oil price asymmetry affects Malaysia's food prices. Besides, the findings of the asymmetric linear model are essential to answer the second research question of this study. Accordingly, the empirical result confirms that palm oil price has an asymmetric effect on food prices in the long run and is symmetrical in the short run, similar to the crude oil price on food prices. Furthermore, NARDL results show that both positive and negative changes in palm oil prices significantly impact food prices in Malaysia. Empirically, a one-point increase in the palm oil price will increase the food price by 0.07 points in the long run. Therefore, it makes sense that when the price of palm oil increases, the food price increases in Malaysia. The justifications are provided in the earlier discussion. On the other hand, a one-point decrease in the palm oil price will increase Malaysia's food price by 0.15 per cent in the long run. Therefore, the reduction in the palm oil price positively impacts Malaysia's food price, which is an exciting finding in the current study.

Thus, the asymmetric linear model's finding of palm oil on food prices is similar to the impact of crude oil on the food price in Malaysia. It justifies the concept of financialisation of the commodities since there is a higher integration between the crude oil price and cooking oil. Thus, the similar effect of palm oil prices on the food price could be due to the cooking oil subsidy in Malaysia. MOF (2022) announced that a subsidy of MYR 4 billion had been allocated for the one kg packets of cooking oil in 2022, which is expected to subsidise 60 thousand metric tonnes per month. Thus, this subsidy will help control the one kg packets of cooking oil price to MYR 2.50 each, whereby the initial price of the cooking oil without subsidy will be MYR 9 each. Furthermore, based on the report from the MOF (2022), it is notable that the subsidy value is increasing by the year. In 2020, the subsidy allocated by the Malaysian government for cooking oil was MYR 500 million only, whereby MYR 2.2 billion was spent in the year 2021.

The cooking oil subsidy allocation in Malaysia is following the growing vegetable oil price trend globally, which is expected to control inflation in Malaysia. Yahoo et al. (2017) confirmed that the subsidy removal on cooking oil would increase the price of cooking oil and the consumer price index (CPI) by 0.04 per cent in the short-run and 0.02 per cent in the long-run, respectively, in Malaysia. Thus, the growing subsidy allocation is expected to minimise or liquefy the actual effect of the palm oil price on cooking oil in Malaysia. Due to this, the drop in the palm oil price seems to be not immediately transmitted into the domestic food price in Malaysia since the subsidies cooking oil price is set at MYR 2.50 per packet and not floating based on the market price of palm oil. Thus, this cooking oil subsidy effect could justify the positive impact of both positive and negative changes in palm oil prices on food prices in Malaysia. Besides, further exploration of this area as future research could create better insight and understanding of the impact of the cooking oil subsidy on the food price in Malaysia.

5.3.4 Asymmetric Relationship between Industrial Growth and Food Price in Malaysia.

For the asymmetric linear relationship, this study shows that industrial growth has an asymmetric effect on the food price in the short- and long-run. The findings indicate that negative changes in industrial development affect

Malaysia's food prices positively in the long-run. There is no significant impact of positive changes in industrial growth on food prices. Empirically, a one-point increase in industrial growth will decrease the food price by 0.09 points in the long run. The results are similar to the study of Wong and Shamsudin (2017), whereby using the quarterly data from 2000Q1 to 2016Q2, the authors found that an asymmetric effect exists between income and food prices in the long run. The current study revealed that in the long run, the negative growth in industrial production is decreasing the food price in Malaysia. Even though this finding aligns with the theoretical justification, reducing income will decrease purchasing power and lead the food price to drop due to the limited demand for food. The findings contradict Wong and Shamsudin's (2017) findings, whereby the authors found the opposite effect between income and food prices in Malaysia. This could be mainly due to the different proxy usage between the studies, as argued earlier.

Overall, this study's theoretical and empirical evidence can justify the significant role of palm oil prices and industrial growth in Malaysia's food prices. Accordingly, the hypothesis of the significant asymmetric impact of palm oil prices and industrial growth on the food price in Malaysia is accepted. Thus, this study's second research question has been answered. The effect of biodiesel demand factors on the food price will be discussed further in the next section.

5.4 The Relationship between Biodiesel Demand Factors on Food Prices in Malaysia.

Since the first and second hypotheses of the significant relationship between palm oil prices on Malaysia's food prices are confirmed, biodiesel demand will also come into the picture. This is mainly due to the downstream activities of the palm oil industry in producing biodiesel for industrial and transportation sector usage. Thus, theoretically, additional demand created by the biodiesel industry could make the palm oil price more competitive, which will lead to some spillover effect to other elements related to the palm oil industry, for instance, cooking oil. This study focuses on biodiesel demand rather than current production or price levels, recognizing that while biodiesel's scale in Malaysia is modest today, the growing structural demand, which is driven by vehicle growth, investment, and policy mandates, presents potential long-term pressure points on the food sector. Therefore, the findings provide anticipatory insights rather than immediate impact assessments.

Hence, former financial minister Lim Guan Eng indicates that implementing B20 biodiesel in Malaysia is expected to increase the palm oil demand by 500 thousand tonnes per annum (Ying, 2019). Furthermore, the international export demand for biodiesel from countries such as Canada, India, Vietnam, and the European Union is increasing over time due to the upward trend of petroleum (USDA, 2022). Accordingly, this study hypothesised that biodiesel demand could impact the food price positively. The empirical findings are reported in Tables 4.5, 4.6, 4.7 and Table 4.14, respectively, under the model three. Further discussion in this section helps in answering the third research question of this study.

The idea to incorporate the biodiesel demand in the food price model is founded on the supply and demand framework, further illustrated by the bioenergy model by Kalogiannidis et al. (2023) and Ciaian and Kanc (2011). The additional demand created by the alternative energy market on crops increases the price of the crops. This is expected to be reflected in the food price in the end due to the usage of crops in food processing and production. This phenomenon can also be explained by the concept of financialisation of the commodity, as argued by Ordu-Akkaya and Soytas (2020), whereby the close co-movement between the international price of crude oil and palm oil expected to influence the biodiesel demand as well. Accordingly, four different biodiesel demand factors have been included in the food price model to capture the biodiesel demand's effect and confirm the hypothesis of the positive impact of biodiesel demand on Malaysia's food price. The effect of each factor has been discussed in the sub-section below.

5.4.1 The Relationship of Biodiesel Price on the Food Price in Malaysia

The first biodiesel demand factor used in this study is the biodiesel price. According to the law of demand, price plays an essential role in the need for the product in a perfectly competitive market. The decision to consume a product or service depends on the competitiveness of the products and services compared to the competitive products. On the other hand, the product's price determines the producers' decision on the production level. This decision is significant since it reflects the producers' profit margin. Thus, biodiesel is an alternative energy replacing crude oil usage in industry and transportation. The higher price of biodiesel will make the demand for it drop, whereby the producer has to stick with the traditional fuel for production. In this case, the price factor will determine the energy demand. Accordingly, the law of demand stresses that there is a negative relationship between demand and the price of products and services.

Accordingly, this study's empirical findings align with the law of demand, whereby a significant negative relationship has been identified between biodiesel prices and food prices in Malaysia in the long run. The findings suggested that a one-point increase in biodiesel price will reduce the food price in Malaysia by approximately 0.18 points in the long run. Thus, from the biodiesel demand perspective, the increases in the price of biodiesel are expected to reduce the demand for biodiesel in the industry. A higher energy price will increase the production cost and minimise the firms' profit margin. In this case, reducing the demand for biodiesel will increase the availability of crops in the market since limited crops will be demanded in the biodiesel industry. Consequently, the high availability of the crops in the market will push down the palm oil price because the price pressure is compromised, leading to reduced food prices, as argued by Murshed (2021).

It is well acknowledged that agricultural commodities positively correlate to food prices (for instance, Adammer, Bohl, & Stephan, 2012; Ordu-

Akkaya & Soytas, 2020). The justification is rational since the palm oil price has a significant positive relationship with food prices in the long run, which has been proved by the empirical findings of the current study and discussed earlier. Furthermore, Uddin et al. (2021) found that uncertainty in the Malaysian palm oil price negatively affects the biodiesel price. Thus, the argument of Uddin et al. (2021) supports the significant negative relationship between biodiesel prices and food prices in Malaysia. Thus, the current finding confirms the hypothesis that biodiesel demand positively affects Malaysia's food prices.

Interestingly, with the global awareness of environmental sustainability and favourable global policies towards renewable and alternative energies, the use of alternative energies in industries and transportation is growing slowly. According to the report USDA (2021), biodiesel usage in Malaysian industries started in 2019, whereby 120 million litres were used in that particular year and is forecasted to grow to 143 million litres in 2021. On the other hand, biodiesel usage in the transportation sector started in 2008. With the blended mandate requirement, the use slowly increased by 665 million litres in 2020 and was forecasted to increase to 720 million litres in 2021. Based on the report, biodiesel usage in the transportation sector is six times higher than in the Malaysian industries. This situation is occurring even though the market price of alternative energies is relatively higher than traditional fuel due to global awareness and focus on reducing the dependency on crude oil.

This can be viewed in Table 5.1, whereby the average price of diesel in the market from January to August 2021 is 0.51 USD/barrel. On the other hand, biodiesel is much more expensive than diesel, recorded as 0.56 USD/litre on average from January 2021 to August 2021. This evidence is supported by the report of IEA (2022) and Energy Efficiency and Renewable Energy (2022) by indicating that the biodiesel price is 70 – 130 per cent higher than the diesel price globally, depending on the crop used. Theoretically, this is not favourable towards biodiesel usage and production. However, due to the implementation of the APM system in Malaysia, the B10 biodiesel price is subsidised by the government and sold at the subsidised price of 0.52-0.54 USD/litre in the local petrol station. Thus, the subsidies for biodiesel prices make the B10 biodiesel price more stable and competitive compared to the international diesel price, which is highly fluctuated.

Table 5.1: The Market Price of Diesel and Biodiesel in Malaysia for the Year 2021

Period	Estimated Diesel Price (USD/Barrel)	Estimated B10 Biodiesel Price (USD/Liter)	B10 Biodiesel price (*Sold at local Petrol Station*) (USD/Liter)
January	0.42	0.47	0.52
February	0.48	0.52	0.52
March	0.50	0.55	0.52
April	0.50	0.54	0.52
May	0.52	0.58	0.54
June	0.56	0.60	0.54
July	0.57	0.61	0.54
August	0.56	0.60	0.52

Source: United States Department of Agriculture (2021)

Hanafi et al. (2011) highlighted that in 2010, about MYR 4 billion needed to be allocated as a subsidy for biodiesel to ensure the price remained competitive. However, in the current situation, with the increasing usage of biodiesel in industries and transportation, the subsidy amount could be much higher[50]. Thus, this subsidy is essential to ensure biodiesel prices are competitive in the fuel market so that biodiesel usage will increase in the industry and transportation sector. Furthermore, this aligns with Malaysia's National Biofuel Policy, which aims to reduce Malaysia's dependency on non-renewable fossil fuels. Thus, without the subsidy, the biodiesel price will be relatively high compared to diesel, leading to higher demand for diesel in transportation and industry. Furthermore, based on the USDA (2021) report, the Malaysian government have capped the maximum price of blended biofuel at a fixed rate of MYR 2.18 per litre. Accordingly, competitive prices are essential to ensure Malaysia's biofuel policy is booming.

Besides, the causality finding shows a bidirectional relationship between biodiesel prices and food prices in Malaysia. The results indicate that both biodiesel and food prices are interdependent. This evidence is well justified by the bioenergy model, whereby agricultural commodities are interconnected to the food and energy markets (Kalogiannidis et al., 2023). In Malaysia's case, palm oil interconnects the biodiesel industry and the food industry. The findings stressed the integration of the energy market into the food industry. The price-setting mechanism plays a significant role in determining the growth of Malaysia's bioenergy market and food. Accordingly, the price setting of the commodities is decided based on the demand and supply of the commodities in the local and international markets. Thus, the higher palm oil price will negatively impact Malaysia's food and bioenergy industries, which is confirmed by the empirical findings of the present study.

[50] The current subsidy value is not able to be gathered due to the limitation for the data provider.

Growing demand for essential commodities such as crude oil and palm oil in Malaysia increases the price and leads to inflation and food price hikes (Isa et al., 2021). Thus, to control inflation, the government implements various policy instruments such as tax preference, spending subsidies and environmental regulation. For instance, under the Petroleum (Income Tax) Act 1967 ("PITA"), the income tax for the marginal oil field under the petroleum industry has been reduced to 25 per cent compared to 38 per cent previously[51]. These moves benefit Malaysian oil and gas industries and help increase petroleum production capacity in the future (MOF, 2015). Notably, petroleum-related revenue is MYR 77.8 million, with a share of 27.3 per cent of the overall revenue to Malaysia in 2022 (MOF, 2022).

Furthermore, formal finance minister Tengku Datuk Seri Zafrul highlighted that additional tax revenue of MYR 10 billion due to increases in the price of crude oil palm and crude oil would help cover the subsidy spent by the government in controlling the prices (Khalid, 2022). These type of policy instruments helps in maintaining the commodities demand, trade, and price. Thus, competitive palm oil prices benefit Malaysia's food and bioenergy industrial growth. Accordingly, this justifies the bidirectional relationship between food and biodiesel prices in Malaysia.

[51] Marginal oil field referring to the uneconomical and smaller oil field plants which is remain unexploited due to their limited reserves and productions.

5.4.2 The Relationship Between Biofuel Policy on the Food Prices in Malaysia

The biofuel policy is the second biodiesel demand factor used in Malaysia's food price model. The effect of the biofuel policy is captured using the blended mandate requirement set by the government in the transportation sector in Malaysia, following Shri Dewi and Alias (2014) and Zulqarnain et al. (2020). The blended mandate requirement indicates how much the government is favourable to alternative energy usage in the economic activities in Malaysia. Under the 12th Malaysia Plan (2021-2025), the Malaysian government indicates its commitment towards green fuel by implementing the B20 biofuel programme in Malaysia in stages. Furthermore, the government committed to introducing B30 at the end of the plan, i.e., by 2025. Thus, the higher blended requirement proposed by the government in the industrial and transportation sectors is expected to increase the demand for biodiesel in Malaysia. In this case, a positive relationship is hypothesised between biofuel policy and food prices in Malaysia. Accordingly, the empirical findings of the current study identified a significant positive relationship between biofuel policy and food prices in Malaysia in the long run. The empirical results suggested that a one-point increase in blended mandate requirement will increase the food price in Malaysia by approximately 1.15 points in the long run.

The findings align with the microeconomic theory illustrated that derived demand for crops influences the good intermediate quantity. Hence, the increased demand for fuel (traditional and biofuel/biodiesel) translates into an associated higher price, directly impacting crops' prices, as explained by the bioenergy model. Thus, it is reflected in the food prices at the end, as it increases the food production cost (Janda et al., 2022; Malode et al., 2021). In the case of Malaysia, implementing the biofuel blended mandate requirement mainly depends on the palm oil price, as urged by Shri Dewi and Alias (2014). Thus, biodiesel was introduced in Malaysia to reduce the impact of subsidy spending and the high impact of petroleum prices and reduce the import of diesel into Malaysia. A piece of news reported in The Malaysian Reserve highlighted that Indonesia could reduce diesel imports by MYR 16.3 billion annually by adopting the B30 blended mandate from B20 (Azman, 2022). Even though biodiesel is known as the "*Golden Egg*" of palm oil downstream activity, Malaysia's government is highly conscious of the sudden increase in the blended mandate requirements since it may negatively impact the inflation rate in Malaysia.

The high consciousness of environmental sustainability will increase the blended mandate requirement, increasing biodiesel production in Malaysia. This is because more biodiesel will be required in the energy sector to fulfil the demand of Malaysia's industry and transportation sector. In addition, there is ongoing discussion and assessments from the government and stakeholders to address issues regarding the acceptance of B30 biodiesel in manufacturing plants in Malaysia (Azman, 2022). Thus, the evaluation covers the gaps and the costs required for the B30 implementation to ensure the program is cost-efficient. According to the biofuel report, with various blended mandate requirements, biodiesel production in Malaysia is increasing from 0.51 million litres in 2013 to 1.150 million litres in 2022, whereby the number of biorefineries increases from 13 to 18 in this particular period[52] (USDA, 2022).

Accordingly, increasing biodiesel production required more palm oil as the raw material. This situation will increase the demand for palm oil in the market, which has a significant role in food and non-food products. USDA (2022) further indicates that the usage of palm oil feedstock for biodiesel production increased from 469,000 metric tonnes in 2013 to 1,059,000 metric tonnes in 2022. The increased use of palm oil feedstock on biodiesel has doubled in less than ten years in Malaysia. Even though a talk on electric vehicles for heavy vehicles is ongoing, it may take about 8-10 years to become mainstream in Malaysia, as urged by Sharan Raj, the infrastructure policy analyst and environmentalist (Azman, 2022). This is mainly because such technology in the current stage will not be cost-efficient in Malaysia. In this case, biodiesel is still relevant to the economic activities of Malaysia in the short term. The growth trend is expected to remain with the increased blended requirement mandate planned to follow Malaysia's biodiesel policy.

Thus, following the ideology of the bioenergy model, the additional demand created by the biodiesel industry could increase the food price in Malaysia. However, this argument remained undiscovered in Malaysia's case until now, whereby the present study provided empirical proof to confirm the effect. This statement is supported by Janda and Kristoufek (2019) by indicating

[52] The highest biodiesel production is recorded in 2019 with the production amount of 1.778 million liters.

that biofuel policies have significant roles in the price transmission between the food and fuel markets. In addition, the positive relationship between the implementation of biofuel policy and vegetable oil prices is validated by some previous studies, such as Cui and Martin (2017), indicating that the imported palm oil demand increases with the biofuel production in the US.

This situation increases the global vegetable oil price due to the additional demand created by biofuel production, supported by the current study's empirical evidence. In the case of Malaysia's study, Shri Dewi and Alias (2014) confirmed the arguments by identifying that the blended biofuel mandate requirement will increase the domestic consumption of palm oil by 23.31 per cent and its price by 0.07 per cent, which strongly validates this study's findings. Interestingly, the present study advances understanding by regressing the palm oil/biodiesel price and biofuel policy to the food price. A positive relationship was found between palm oil prices and food prices in the earlier section, justifying the role of palm oil prices and the biofuel policy on the food price in Malaysia.

Besides, the biofuel policy not only positively affects the palm oil price, as argued by Shri Dewi and Alias (2014), but it also has a spillover effect on the food market and prices in Malaysia. In reality, based on the report from USDA (2022), after the full reopening of the economic activity and business sectors in 2022, the usage of B10 blended biofuel increased by 11 per cent in the transportation sector. Furthermore, in the industrial sector, with the implementation of B7 blended mandate requirements from July 2019, biodiesel usage will increase by 10 per cent in 2022. Accordingly, biodiesel use favours Malaysia's economic activities and industrial progress. This rationalises the positive relationship between industrial production and food price, confirmed by the present study. Thus, this supported the positive relationship between the biofuel policy and food prices in Malaysia, whereby an increase in the blended mandate requirement increases the demand for biodiesel usage in Malaysia. Accordingly, the biodiesel demand positively affects Malaysia's food prices, as confirmed by the empirical evidence of the current study.

Due to the awareness of the possible impact of the biofuel blended mandate on the prices, the intention to roll out the B20 mandate in Malaysia is still pending, even though it is already proposed for implementation in 2020. Varies factors are linked to the delay in implementing the B20 blended mandate requirement in transportation, such as the COVID-19 pandemic, the government's fiscal budget constraints and the political instability in Malaysia during that period. Further exploration into this matter will give better insight into the delay in Malaysia's biofuel blended mandate requirement, whereby Indonesia seems more advanced in biofuel policy effectiveness. Interestingly, data supplied by USDA (2022) indicates that the capacity usage of the biorefineries in Malaysia reaches the maximum use in the 40-76 per cent range only. This shows that in terms of capacity, Malaysia can still increase biodiesel production in the future. The high level of biodiesel acceptance in industries and the transportation sector will soon change Malaysia's biodiesel scenario (Malaysian Investment Development Authority, MIDA[a], 2021).

The annual biofuel report suggested that the palm oil price will decrease further in 2023, so the Malaysian government may consider launching the B20 mandate this year (USDA, 2022). This statement stressed the price factor's role in implementing Malaysia's biofuel policy. This statement is justifiable based on the causality test results of the current study as well. The causality test shows that the biofuel policy is interdependent with food prices in Malaysia since a bidirectional relationship is identified. In this case, the development of blended mandate requirements and food price considerations will complement each other. The critical matter here is the price of palm oil, the raw material for biodiesel and the food industry. The success of the biofuel policy in Malaysia is mainly determined by the competitive price of biodiesel in the market and minimising inflation. The biofuel policy confirms the hypothesis that biodiesel demand positively affects Malaysia's food prices.

5.4.3 The relationship between Biodiesel Investment on the Food Price in Malaysia.

Investment in the biodiesel industry is the third biodiesel demand factor used in Malaysia's food price model. Biodiesel production has been used as a proxy for investment in the biodiesel industry, following Liu et al. (2018), Noriega and Narvaez (2020) and Zulqarnain et al. (2020). Conceptually, the demand curve for agricultural commodities is inelastic to price change (Koizumi, 2015). In this case, the demand for agricultural commodities is consistent mainly, even if the price fluctuates over time. It is understood that the agricultural commodities' price fluctuation is due to various factors, as discussed earlier. The consistent demand for crops is mainly due to food consumption, which is the basic need of humans.

Accordingly, with the limited alternative for food, the additional demand in the energy market for biofuel/biodiesel production could double the crop demand and, consequently, the price of the crops (Janda et al., 2022). The price increases benefit the producers, who will be motivated to improve their crop production to maximise profit. It could indirectly influence the plantation areas and agricultural investment positively. Subsequently, the supply curve's elasticity is critical in determining the agricultural commodity price and the increase in supply resulting from the price change resulting from an increase in biodiesel demand.

At the same time, the relationship is channelled through biofuel production and the global oil price, which is highly correlated with the agriculture commodity prices due to the financialisation of the commodities. The phenomena lead towards integrating palm oil supply and demand into the food price. Thus, the empirical finding of the current study suggested that biodiesel investments have a similar effect as biofuel policy on the food price in Malaysia. This could be mainly because both demand factors will positively influence biodiesel demand. The empirical findings suggested that a one-point increase in biodiesel industry investment will increase Malaysia's food price by approximately 0.05 points in the long run. Thus, the positive effect of the biodiesel investment is not huge towards Malaysia's food price; it is still significant. The current finding is well justifiable, whereby increasing investment in the biodiesel industry will expand the sector, whereby more biodiesel-producing firms will be set up, or more refineries will be added to the existing industries.

In Malaysia, with the Malaysian Biofuel Industry Act 2007 regulating and licensing biofuel firms, more than 20 active biodiesel companies are currently operating (MIDA, 2021). Those companies could produce biodiesel with a capacity of 2.1 million tonnes annually in Malaysia[53]. Thus, the number of current active biodiesel firms in Malaysia has recorded growth compared to 2012, which reported only 13 active biodiesel industries with an overall production capacity of 1.5 million tonnes (USDA, 2013). Interestingly, the recorded growth of the biodiesel industries in Malaysia is in line with the Biofuel Industry Act 2007 and is very favourable as a potential investment portfolio for investors looking for investment opportunities in Malaysia. This argument is supported by the MIDA[b] (2021), whereby more and more companies are interested in new projects in Malaysia's biodiesel industry as they view it as a potential investment destination. In addition, MIDA[b] (2021) expected heavily pour-in investments in the biodiesel industry from 2022 to 2025[54].

Accordingly, the significant development in the biodiesel industry in Malaysia is favourable to the government's role and policy, which attached more investors to Malaysia. For instance, investors are eligible for consideration in the Pioneer Status and Investment Tax Allowance under the Promotion of

[53] The biofuel annual report of USDA (2022) reported the biodiesel production capacity of Malaysia’s firm is 2.54 million tonnes with reported processing plants of 18. There is a small variation in the data supplied by both agencies.
[54] The official data on the investment under the biodiesel industries are not available publicly.

Investment Act (PIA) 1986 if they invest in a product or activities related to the biodiesel industry (MIDA[b], 2021). These policies re-energised Malaysia's biodiesel industries and contributed to increasing more active biodiesel firms in Malaysia. Interestingly, this led to an increase in the production level of biodiesel domestically, even though total capacity in the production is not achieved in Malaysia. Based on the report of USDA (2013; 2022), biodiesel production in Malaysia increased from 0.35 million litres in 2013 to 1.150 million litres in 2022. Furthermore, based on overall biodiesel production in Malaysia in 2023, 36 per cent of biodiesel is exported to other countries, and the rest is used domestically.

Notably, biodiesel in Malaysia is produced using vegetable oil, animal fat, algae, and recycled cooking oil (MIDA[b], 2021). In this case, biodiesel production is increasing due to the rise in investment in using palm oil feedstock in biodiesel production in Malaysia. However, the growth of the biodiesel industries in Malaysia still depends on the price of palm oil as well. Therefore, the high price of palm oil may make biodiesel expensive compared to traditional diesel fuel. This may lead to the market demand for biodiesel shifting to diesel fuel. In this case, the biodiesel industry in Malaysia is interdependent with the palm oil price and also the food price. This justifies the bidirectional relationship between biodiesel investment and food prices in Malaysia. The palm oil feedstock used in the biodiesel industry increased by 125.80 per cent from 2013 to 2023 (USDA, 2023). Thus, with the significant role of palm oil in the food and non-food industries, additional demand for palm oil creates price pressure for this commodity. This argument is supported by the study of Jafari and

Othman (2016), whereby the authors indicate that biodiesel development increases the demand and price of palm oil in Malaysia. Thus, this led to the reverse effect on the outputs of competing products such as food and biochemicals.

Furthermore, Jafari and Othman (2016) argued that the higher price of palm oil would reduce the production of the goods related to palm oil due to the relatively higher costs of inputs. With the significant positive relationship between the palm oil price and food prices in Malaysia, this situation could also have a similar impact on the food prices in Malaysia. Accordingly, this argument is supported by Subramaniam et al. (2019; 2020), indicating that biodiesel production worsens food security in developing countries, including Malaysia. The authors suggest that biodiesel production will negatively affect crops' availability. Thus, the reverse effect of the findings from biodiesel production to food production strengthens the positive relationship of the current study between biodiesel production and the food price in Malaysia. This reverse effect can be explained by the microeconomic theory whereby food production negatively affects the food price. In this case, with biodiesel production, more palm oil has been used for biodiesel production, and the price of palm oil will increase due to the demand. Accordingly, the positive impact of biodiesel investment on the food price is well justified in this case.

The empirical finding of the current study is further strengthened by Brikman et al., (2020) study indicating that biodiesel production shares the land resources with food production and energy, positively affecting food prices.

Other than that, various studies confirm the current study's findings, such as Martinez-Jaramillo et al. (2019), Paris (2018) and Koizumi (2015). These arguments validate the significant positive long-run relationship between biodiesel investment and food prices in Malaysia. The biodiesel investment confirms the hypothesis that biodiesel demand positively affects Malaysia's food prices.

5.4.4 The Relationship between vehicle population and the food price in Malaysia

Lastly, vehicle population on the road has been used in Malaysia's food price model to capture the population effect on the food price, an essential component of the demand model (United Nations, 2021; Dijk et al., 2021). Interestingly, since the study covers the scope of biodiesel and palm oil price effect on the food price, vehicle population has been used as the operationalised variable to capture the impact of the population in the model. Furthermore, based on the Malthusian growth theory, the population is urged to grow much faster than food production and availability. Thus, the rising global population and urbanisation increase the demand for cereals, putting pressure on the world supply's downward trend (United Nations, 2021). United Nations reported that the global population reached eight billion in mid-November 2022; about 690 million people (8.9 per cent of the overall population) were undernourished in 2019. These phenomena justify the Malthusian and neo-Malthusian models and the demand-supply framework on food availability.

In addition, the crops for feed and food are directed to food production and supply (supported by a study such as Mitchell, 2008; Subramaniam et al., 2019; 2020). However, crops for fuel are directed to the biodiesel/biofuel producers who supply biodiesels for transportation and industrial usage by blending with crude oil. In Malaysia, biodiesel is used in various industries such as automotive, power generation, marine and machinery. Thus, biodiesel usage in transportation is relatively higher than in Malaysia's industrial use. USDA (2022) report forecasted that biodiesel usage in the transportation sector would be 798 million litres compared to industrial usage of 157 million litres in 2022. In this case, biodiesel usage in the transportation sector is about five times higher than industrial usage in Malaysia. In other words, the agricultural industry, which has supplied food and feed for livestock, is now providing biodiesel for transportation and industrial production purposes. Due to the significant role of biodiesel in transportation, the vehicle population has been used as an indicator to capture biodiesel demand in Malaysia's food prices. Accordingly, a positive relationship was hypothesised between the registered vehicles on the road and Malaysia's biodiesel demand. At the same time, this will also positively impact the food prices in Malaysia.

The current study's findings provided sufficient evidence to show that the vehicle population is positive and significantly impacts Malaysia's food prices. The empirical results suggested that a one-point increase in the registered vehicles on the road will increase the food price in Malaysia by approximately 0.27 points in the long run. Furthermore, a bidirectional relationship was found between the vehicle population and the food price in Malaysia. The bidirectional relationship between registered vehicle population and food price stresses that both are interdependent in Malaysia. This is rational since more diesel vehicles on the road will increase biodiesel usage in Malaysia. Thus, this will increase the demand for palm oil. On the other hand, increasing diesel vehicles on the road indicates that industrial growth may impact food prices by increasing income levels (Yang et al., 2023). Furthermore, the finding is in line with the Malthusian growth theory, which indicates that population positively impacts the demand for food, whereby the growing demand for the crops for food and biofuel/biodiesel productions with limited supply will increase the price of the crops which will contribute to the increase of the food price.

The current study's findings show that increasing the number of vehicles on the road will demand more fuel[55]. In Malaysia, diesel fuel on-road transportation usage is expanding, recorded at 7.6 billion litres in 2022. This amount is 0.4 billion litres higher than in 2021 (Statista, 2023). At the same time, with the government's consent on environmental sustainability, the usage and blended requirement mandates looked more favourable in Malaysia, which has been discussed in the earlier sub-section in detail. Accordingly, with the increasing trend in the blended requirement from B5 up to B15 and the potential of B20 soon, the biodiesel demand will also increase over time. Thus, biodiesel demand will boost Malaysia's food prices by increasing the price of local palm oil. This argument is justifiable based on the positive relationship identified between crude oil and palm oil prices towards the food price in Malaysia.

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[55] For current study, due to the data limitation, the overall new registered vehicles have been used the capture the population effect of the vehicles on the road. This covered the gasoline-powered vehicles and diesel-powered vehicles in Malaysia. The data on only diesel-powered vehicles population able to give more accurate findings in the context of current study.

Furthermore, the positive relationship between registered vehicle population and food price justifies the effect of income on the food price. Therefore, income growth in Malaysia directly affects food prices positively in the long run (will be discussed in detail in the next section). At the same time, studies such as Lescaroux (2010) and Dargay (1999; 2001) have confirmed that increasing income will increase vehicle ownership. Thus, these studies indicate that more people prefer to purchase cars when income rises. Therefore, this could be an alternative view of the positive relationship between the vehicle population and food prices in Malaysia. This is supported by a study by Azhar and Zahari (2022), which found that income significantly influences car ownership in Malaysia. Furthermore, the study used the sample from Kuala Lumpur and found that automobiles are ordinary consumer goods people will get when their income increases.

The causality test results further strengthen the above arguments by indicating a bidirectional relationship between the vehicle population and food prices in Malaysia. In this case, food prices and the number of vehicles on the road complement each other in growth, in line with the Malthusian growth theory. Thus, favourable GDP growth due to industrial activities contributes to Malaysia's economic and social activity growth. Increasing income in Malaysia increases the demand for food, increasing the food price in Malaysia (Shamsudin, 2022).

At the same time, using the blended mandate requirement of biodiesel in the transportation sector further strengthens the vehicle's two-way causal effect from vehicle population to food price in Malaysia. Accordingly, increasing the number of cars on the road increases the demand for fuel and biodiesel, thus increasing food prices (Yusoff et al., 2021). Overall, the vehicle population confirms the hypothesis that biodiesel demand positively affects Malaysia's food prices. However, even though the initial idea has been statistically proven, due to data limitations, the actual effect of vehicle ownership on the food price in Malaysia is still not strong. Therefore, more work needs to be done to measure better the actual impact of the vehicle's population on the biodiesel industry and food-related outcomes.

On the other hand, Malaysia is looking into green and sustainable mobility in the transportation sector as an agenda of environmental sustainability. For instance, introducing electric vehicles for personal and commercial use in Malaysia can reduce the country's dependency on crude oil. The favourable policy move encourages the utilisation of electric vehicles in the economy undertaken by the Malaysian government. For instance, Malaysia excises the import duty exemption for electric vehicles, which can last until 2025 (Hiew, 2023). The current tablet budget of 2023 proposed to extend the import duty exemption to encourage more electrical vehicles into Malaysia.

However, the news for TheStar highlighted that electric vehicles could not become mainstream in Malaysia for timing due to electric vehicles are not cost-efficient and lack of infrastructure (Hiew, 2023). Due to this, Malaysia's take-up rate remains low; only 274 EVs were sold in 2021 out of 508,911 units. Furthermore, until May 2023, only 390 electric vehicles were sold in Malaysia

(MITI, 2021). Even though it shows an increasing trend, the take-up rate is still about 0.05 per cent. In this case, the role of electric vehicles as the mainstream in the transportation sector is not significant for the near future. Thus, biodiesel adoption is more relevant in Malaysia since most commercial vehicles are diesel-engine-based. Hence, it shows the significance of the current study.

Overall, this study's theoretical and empirical evidence justifies the significant role of biodiesel demand in Malaysia's food prices. Accordingly, the hypothesis of biodiesel demand's significant relationship with Malaysia's food prices is accepted. Thus, based on the overall demand factors used in this study, the third research question of this study has also been answered.

5.5 The Dynamic Effect of Variables Understudied on Food Prices in Malaysia

This section will discuss the findings of the dynamic effect of palm oil prices, industrial growth, biodiesel demand and control variables on the food price in Malaysia. The dynamic effect is explored using the impulse response function and variance decomposition using the VAR model. The empirical findings are reported in Figures 4.4, 4.5, 4.6 and 4.7, respectively. Further discussion in this section helps in answering the fourth research question of this study.

5.5.1 The Dynamic Effect of Control Variables on Food Price in Malaysia

The impulse response function and variance decomposition analysis are conducted in the previous chapter to capture the emotional shock of the food price in Malaysia. The current study's finding illustrated that the crude oil price very moderately influences the food price in the long run, whereby this variable can predict the food price of about 10 per cent in two years from the current period. The finding strengthens the findings of Norazman et al. (2018), which indicates that crude oil prices recorded a more negligible impact on food prices in Malaysia. These supportive findings could be due to the fuel subsidy program from the Malaysia government, whereby the effect of crude oil on the food price was compromised by controlling the cost of production. On the other hand, the recent study by Taghizadeh-Hesary et al. (2019) indicates that crude oil prices can explain the food prices in ASEAN countries by about 64 per cent using the panel data, which contradicts based on the individual country-based study due to various subsidy programs by ASEAN countries.

Interestingly, the variance decomposition analysis proves that the exchange rate strongly forecasts short-run influence on the food price, whereby it can forecast nearly 60 per cent of food prices in Malaysia. However, the effect slowly dissolved after ten months, which can predict about 15 per cent in a two-year forecasting time. This is mainly due to the significant influence on the exchange rate in the trading activities whereby Malaysia is a net food importing country. Thus, fluctuation in the exchange value will immediately affect the food price. However, the effect slowly dissolves over time due to the subsidies on the food price the Malaysian government gives to control food inflation. Thus, this possibly reduces the influence of international food trade on local food prices in the long run. Taghizadah-Hesary et al. (2019) validate the current study findings whereby the panel study using Asian economies such as Thailand and Vietnam found that the long-run exchange rate furcating effect is statically small on the food price.

5.5.2 The Dynamic Effect of palm oil price on food price in Malaysia

The impulse response function analysis provides valuable insights into the dynamic relationship between palm oil prices and food prices. The positive impact revealed by this function signifies that any sudden change or shock in palm oil prices leads to a subsequent positive response in food prices within the Malaysian context. This suggests a direct and significant connection between the two variables, where fluctuations in palm oil prices play a crucial role in influencing the overall food price dynamics. The theoretical underpinning of this observed phenomenon finds resonance in the context of commodity price transmission theory. According to this theory, changes in the prices of key commodities, such as palm oil, can transmit across related markets, influencing the pricing dynamics of interconnected goods like food (Goodwin, 2021; Rose & Paparas, 2023).

This finding is strengthened by the study of Solaymani (2022), whereby palm oil prices were positively response to the food price crisis in Malaysia using the IRF. The author sub-grouped the data into before food prices (before

April 2006) and after the food crisis (after April 2006) and found that palm oil prices were very responsive to the food prices after the food crisis, which is supportive towards the findings of this study.

Additionally, the examination of forecast error variance sheds light on the predictive power of local palm oil prices in relation to food prices. In the short run, the influence appears to be relatively weak, indicating that short-term variations in local palm oil prices may not strongly predict immediate changes in food prices. However, the scenario shifts when considering the long run. Over an extended period, the impact gradually strengthens, reaching a substantial 35% within two years. This implies that, while short-term predictions may be less pronounced, the influence of local palm oil prices on food prices becomes more prominent and enduring over time.

In summary, the empirical findings underscore the significance of palm oil prices as a key determinant of food prices in Malaysia, showcasing both the immediate response to shocks and the evolving impact over an extended timeframe.

5.5.3 The Dynamic Effect of Industrial Growth on Food Prices in Malaysia

The observed positive response of food prices to industrial growth shocks in Malaysia aligns with the findings of Kapusuzoglu et al. (2018), who conducted a study on Turkey using monthly data and identified a similar positive reaction of food prices to income shocks. This consistency provides robust support for the existence of a positive long-term relationship between food prices and industrial production in the Malaysian context.

While industrial growth demonstrates a reasonably impactful role in predicting food prices in Malaysia, these findings find resonance in previous research. Hasan et al. (2018) and Applanaidu et al. (2014) have explored similar dynamics. Hasan et al. (2018) revealed that industrial production can account for approximately 12.57% of Malaysia's food prices over 24 months. Although this prediction effect is somewhat smaller compared to the model one finding of this study, where industrial production contributes about a quarter of the overall effect over 24 months, it emphasizes the increasing influence of industrial production on food prices as time progresses in Malaysia. Moreover, the study by Applanaidu et al. (2014) adds another layer of insight. Their findings indicate that income alone explained approximately 4.95% of food prices in Malaysia over a decade, a longer timeframe than the current study and Hasan et al. (2018). This highlights the evolving importance of industrial production in shaping food prices over time in Malaysia, surpassing the explanatory power of income alone.

In conclusion, the study provides robust evidence for a positive long-term relationship between industrial growth and food prices in Malaysia. The nuanced exploration of time frames and predictive effects emphasizes the growing significance of industrial production in influencing the dynamics of food prices over extended periods in the Malaysian context.

5.5.4 The Dynamic Effect of Biodiesel Demand on Food Prices in Malaysia

This section particularly explores the intricate dynamic effects of biodiesel demand factors on food prices in Malaysia, drawing upon theoretical foundations to provide a comprehensive understanding by employing the IRF methodology to illuminate the connection between biodiesel market dynamics and the fluctuations in food prices. From a theoretical standpoint, the responsiveness observed in Malaysia's food prices to shocks in biodiesel price, vehicle population, and biofuel policy aligns with the bioenergy model. This model suggests that energy and food markets are fundamentally interconnected, with changes in one sector cascading into the other. The IRF analysis substantiates this theoretical framework, revealing a positive response in food prices to fluctuations in biodiesel-related factors. This coherence with the bioenergy model lends robust theoretical support to the empirical findings. The findings resonate with the arguments put forth by Rashidi et al. (2022) and Tan and Yap (2019), underscoring the significance of the energy market in influencing the food market in Malaysia.

Investigating deeper into the Variance Decomposition analysis, the prominent role played by biodiesel prices in explaining approximately 25% of the forecast error variance in food prices over a two-year horizon finds resonance in the energy-price transmission theory. According to this theory, changes in energy prices can significantly influence the prices of related commodities, such as food (Zhang et al., 2021). The empirical evidence, mirroring the theoretical expectations, underscores the considerable impact of biodiesel prices on shaping food prices in the Malaysian market. Moreover, the gradual rise in the explanatory power of biofuel policy and vehicle population, collectively explaining about 12% and 13% of the variance in food prices, aligns with the assumptions of energy policy theory (David, 2021). This theory suggests that government policies in the energy sector can have far-reaching implications on related markets, including food. In the Malaysian context, the findings suggest that biofuel policies and the proliferation of vehicles powered by biodiesel contribute progressively to the dynamics of food prices, offering empirical support to energy policy theory.

The synthesized empirical and theoretical insights not only contribute to the scholarly discourse but also enrich our understanding of the food-energy market dynamics in Malaysia. The bioenergy model, energy-price transmission theory, and energy policy theory collectively provide a robust theoretical framework that aligns seamlessly with the observed empirical patterns. This alignment fortifies the hypothesis that biodiesel demand factors exert a positive influence on Malaysia's food prices, emphasizing the multifaceted relationship between the energy and food markets in the country.

5.6 Concluding Remarks

In this chapter, the study's empirical findings have been discussed in detail. In addition, the detailed discussion of each independent variable used in Malaysia's food price model has been addressed with proper theoretical and conceptual justification. Past empirical studies were also used to strengthen the arguments for the study's findings. Accordingly, the present chapter and empirical evidence from the earlier chapter have answered all four research questions. Besides, the coming chapter will discuss the policy implications and suggestions which can improve and lead Malaysia to more sustainable progressive economics in future.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.0 Introduction

In this concluding chapter, the focus turns towards the future, directing attention to outlining a roadmap for future research and drawing overarching conclusions. Throughout the preceding chapters, the research embarked on a journey to interpret the complex relationships that underpin Malaysia's energy, economic, and food security landscape. Food price dynamics hold paramount significance for a nation's populace and the stability of its economy. This is especially pertinent in the context of Malaysia, a country where a diverse array of factors influences food price fluctuations.

The empirical analyses have shed light on the significant impacts these variables have on each other and, by extension, on the well-being of the nation's populace. As the multifaceted relationships between palm oil prices, biodiesel demand, industrial growth, and food prices in Malaysia are navigated, this chapter will synthesize the findings and offer comprehensive recommendations for future research endeavours. These recommendations are crafted to guide scholars, policymakers, and stakeholders in further unravelling the complexities of this critical nexus and devising strategies that foster sustainable development, resilience, and equitable prosperity in the case of Malaysia.

6.1 Summary of the Major Findings of the Study Based on Research Questions

This research explores the relationships between palm oil prices, biodiesel demand, industrial growth, and food prices in Malaysia. Furthermore, the dynamic effect of the variables on the food price in explored as well. Using a rigorous empirical approach and considering the unique dynamics of the Malaysian economy, this study sheds light on the key findings regarding these factors' impacts on food prices. The demand for biodiesel production grows and its notable influence on palm oil prices becomes apparent, this issue gains prominence in Malaysia. The research landscape concerning bioenergy and food prices in Malaysia remains underexplored, with minimal studies dedicated to this intersection.

This observation underscores the relatively recent and emerging nature of studies examining the relationship between biodiesels and food in the Malaysian context. This serves as a motivation for conducting the present study within Malaysia. Through an in-depth analysis of economic variables and their interactions, the study provides valuable insights into the mechanisms driving food price fluctuations in the country based on the bioenergy model. These insights are intended to provide policymakers and stakeholders with invaluable knowledge. Accordingly, this section delves into the discussion of the major findings of this study based on the research questions.

RQ1: How do palm oil prices and industrial growth affect food prices in Malaysia?

The first research question of this study centres on the relationship between palm oil prices, industrial growth, and food prices in Malaysia. The ARDL analysis indicates a statistically significant positive relationship between palm oil prices, industrial growth, and food prices in Malaysia. Furthermore, the causality test findings indicate a unidirectional effect of palm oil prices towards Malaysia's food prices. This result aligns with the notion that palm oil is a crucial commodity in the Malaysian food industry, and variations in its price can have cascading effects on food prices throughout the country. The positive correlation and cointegration between palm oil and food prices highlight the interdependence of these variables and underscore the importance of monitoring palm oil price fluctuations for policymakers concerned with food affordability and inflation.

The estimated relationship also underscores the vulnerability of Malaysia's food security to fluctuations in palm oil prices, given the country's dependence on palm oil as a primary cooking oil and ingredient in numerous food products. Furthermore, the increased use of palm oil as a feedstock for biodiesel production has driven up the price of this commodity. This price pressure can have a cascading effect on food prices, given the significant role of palm oil in the food and non-food industries. Thus, this study provided some significant fresh findings on this relationship in Malaysia. This study convincingly establishes that the demand for agricultural commodities remains relatively inelastic due to price fluctuations, primarily due to the fundamental necessity of food consumption. These findings are consistent with Kalogiannidis et al. (2023) and Ciaian and Kanc's (2011) argument that increased demand for biodiesel feedstocks, such as palm oil, can lead to speculative behaviour and export restrictions, affecting food prices.

Besides, industrial production serves as a proxy for income, reflecting the growth of high-skilled jobs and increased labour productivity associated with industrial growth. Malaysia's industrial growth efforts, aligned with the 4IR, drive economic development and improved income levels, which should not ignored in the food price model. The overall empirical analysis provides a statistically significant positive relationship between industrial growth and food prices in Malaysia.

This result highlights a novel insight into the interplay between industrial growth and food affordability, suggesting that as industrial growth in Malaysia expands, it exerts upward pressure on food prices. This finding aligns with the unified growth theory, suggesting that rising income levels increase demand for food and services, resulting in higher prices due to limited supply. This relationship is attributed to several factors. Industrial growth, which often leads to increased urbanization and higher incomes, drives greater demand for food products. Additionally, industrial development can compete with the agricultural sector for resources, such as land and labour, limiting agricultural production and increasing food prices. The income effect of industrial growth, leading to higher wages and disposable incomes, can also stimulate food consumption, further influencing food prices.

The research acknowledges Malaysia's income growth, population dynamics, and industrial growth complexities. While some studies have suggested a negative relationship between income and food prices in net food-exporting countries, Malaysia's status as a net food importer necessitates a different perspective. With limited food production and a growing population, the increasing demand for food driven by industrial growth can lead to higher food prices. The study highlights the bidirectional causality between industrial production and food prices, underscoring their interdependence. The demand created by industrial growth can influence food prices by exerting price pressure on agricultural commodities, leading to a positive feedback loop.

These findings underscore the need for comprehensive and integrated policies that balance palm oil prices, industrial growth and food security objectives. Policymakers must consider the potential inflationary effects of palm oil prices and industrial growth on food prices and implement measures to ensure food affordability for the population.

RQ2: Do changes in palm oil prices and industrial growth have asymmetric effects on food prices in Malaysia?

The second research question introduces an element of asymmetry in the relationship between palm oil prices, industrial growth, and food prices in

Malaysia. The empirical results reveal an asymmetric effect of palm oil prices and industrial growth on food prices in Malaysia in the long run. This finding suggests that positive and negative changes in palm oil prices impact the food price positively. The asymmetric linear model's finding of palm oil on food prices is similar to the impact of crude oil on the food price in Malaysia. It justifies the concept of financialisation of commodities since there is a higher integration between the crude oil price and cooking oil.

For industrial growth, the empirical analysis revealed that in the long run, the negative growth in industrial production is decreasing the food price in Malaysia, whereas positive changes do not significantly influence the food price. This finding aligns with the theoretical justification, reducing income will decrease purchasing power and lead the food price to drop due to the limited demand for food. The asymmetry in this relationship between palm oil prices and industrial growth holds significant implications for policymakers and market participants. It implies that measures to stabilize palm oil prices and reduce its influence in the food market are important in mitigating the inflationary pressures on food prices. Furthermore, it underscores the need for adaptive and responsive policy strategies to address the differentiated impacts of palm oil price fluctuations and industrial growth on food affordability in Malaysia, further discussed in the upcoming section.

RQ3: What is the impact of biodiesel demand on food prices in Malaysia?

The third research question delves into the relationship between biodiesel demand and food prices in Malaysia. The summary of the empirical analysis provides evidence of a statistically significant positive relationship between biodiesel demand factors and food prices in Malaysia. This finding underscores the significant influence of biodiesel production and consumption on food affordability within the country. As Malaysia continues to promote biodiesel and advance its biofuel policy, the demand for biodiesel has increased, leading to substantial implications for the food market. This influence is complexly linked to the expansion of biodiesel production, often accompanied by investments and blended biofuel mandate requirements in the biodiesel industry.

The research thoroughly analysed factors contributing to domestic biodiesel demand in Malaysia, shedding light on the intricate web of influences that affect food prices in Malaysia. The estimated results align with the global consensus that biodiesel demand, often derived from agricultural feedstocks like palm oil, can directly and positively impact food prices. This relationship is characterized by increased competition for agricultural resources, such as land and labour, and the potential for higher production costs, which are eventually passed on to consumers.

One of the pivotal factors examined is the impact of biodiesel industry investment, a basis of the domestic biodiesel demand framework. The empirical findings demonstrate a noteworthy relationship between investment in the biodiesel industry and food prices in Malaysia. Even though the magnitude of this relationship may not be immense, it assumes great significance within the broader economic context. This relationship signifies that investment in the biodiesel sector directly contributes to food price inflation positively in Malaysia. As the biodiesel sector expands, more firms emerge, and existing refineries undergo expansion, exerting pressure on the demand for local palm oil for biodiesel production. The research underscores the conducive environment for biodiesel investment in Malaysia, with government regulations like the Malaysian Biofuel Industry Act 2007 and incentives like Pioneer Status and Investment Tax Allowance driving an increase in active biodiesel companies. Interestingly, based on empirical evidence from this study, biofuel policy positively impacted the food price as well. Consequently, biodiesel production has experienced substantial growth, resulting in increased production capacity and exports.

Additionally, the study delves into another critical facet of domestic biodiesel demand: the impact of vehicle population on food prices in Malaysia. The vehicle population serves as a proxy for population growth and economic development (industrial growth), reflecting the evolving mobility landscape of the country. Empirical results confirm a significant and positive relationship between the number of registered vehicles on the road and food prices in Malaysia. In addition, the bidirectional relationship underscores the influence of vehicle population on food prices, mirroring established economic theories like the Malthusian growth theory, which posits that population growth places upward pressure on food demand.

To provide a deeper understanding of this relationship, the study highlights the nexus between rising income levels, increased vehicle ownership, and heightened demand for food. As income levels increase, more individuals opt for car ownership, amplifying the demand for fuel and biodiesels and, in turn, impacting food prices through the elevated demand for palm oil. These findings harmonize with Malaysia's governmental efforts to encourage sustainable mobility and diminish dependence on crude oil. While the country has introduced policies to promote electric vehicle adoption, the research underscores that biodiesel adoption remains more substantial, particularly in the commercial vehicle sector.

The positive impact of biodiesel demand on food prices highlights the importance of a balanced approach to biofuel policy, considering both environmental sustainability and food security concerns. Moreover, the findings reinforce the notion that energy and food markets are intricately connected, and changes in energy demand, such as the growth in biodiesel consumption, can have far-reaching consequences on food markets. Policymakers need to consider these interdependencies when crafting energy and agricultural policies.

RQ4: How do dynamic fluctuations in palm oil prices, industrial growth, and biodiesel demand impact food prices in Malaysia?

Understanding the dynamic impact of independent variables on food prices is crucial for sustainable policymaking in Malaysia. Empirical evidence gleaned from IRF analysis affirms that abrupt changes or shocks in palm oil prices lead to subsequent positive responses in food prices within the Malaysian context. These findings underscore the pivotal role of palm oil price fluctuations in influencing the overall dynamics of food prices. Similarly, a positive response of food prices to shocks in industrial growth in Malaysia is observed. This highlights the growing influence of industrial production on food prices as time progresses in the Malaysian context.

Conversely, biodiesel demand factors reveal a positive response of food prices to fluctuations in biodiesel-related elements. The observed responsiveness of Malaysia's food prices to shocks in biodiesel prices, vehicle population, and biofuel policy aligns with the bioenergy model. According to this model, energy and food markets are fundamentally interconnected, with changes in one sector cascading into the other. This consistency with the bioenergy model provides robust theoretical support to the empirical findings.

In addition to the four primary research questions, control variables such as crude oil prices and exchange rates were included in the analysis. Crude oil prices are pivotal in shaping food prices, impacting production and transportation costs. The estimated results support the notion that fluctuations in crude oil prices can significantly and positively impact food prices in Malaysia, emphasizing the importance of monitoring global oil market dynamics. Exchange rates, which affect international trade and the cost of imported goods, were also examined. The analysis demonstrates that exchange rates exert a statistically significant influence on food prices in Malaysia, further highlighting the country's vulnerability to external economic factors. Hence, the empirical analysis provides robust support for the four research questions explored in this study:

1. The linear relationship between palm oil prices, industrial growth and food prices is statistically significant and positive, highlighting the importance of monitoring palm oil price fluctuations and industrial growth to address food affordability concerns.

2. An asymmetric effect is observed in the relationship between palm oil prices, industrial growth, and food prices, with both positive and negative changes in palm oil prices having a positive impact on food prices in Malaysia.

3. Biodiesel demand factors positively impact food prices in Malaysia, emphasizing the need for a balanced approach to biofuel policy that considers environmental, economic sustainability and food security in Malaysia.

4. The dynamic effect of the shock in palm oil price, industrial growth and biodiesel demand led to the food price response, positively

enriching our understanding of the food-energy market dynamics in Malaysia based on the bioenergy model.

In summary, this study effectively integrates the elements of domestic biodiesel demand, considering the price of biodiesel, the number of registered diesel vehicles, investment in the biodiesel industry, and biofuel policies. Furthermore, the significant gap between the palm oil price to food price has been fulfilled. They underscore the importance of evidence-based policymaking that accounts for the multifaceted relationships in this complex system. These findings have important implications for policymakers and stakeholders in Malaysia, emphasizing the need for a comprehensive approach to address food price dynamics. Sustainable policies that balance economic development with food security are essential to ensure the population's well-being and economic stability. Accordingly, policy implementation will be further discussed in the next section.

6.2 Theoretical Implications of the Study

This study advances and contextualizes several established economic theories by offering new insights into how the interactions between palm oil prices, biodiesel demand, and industrial development shape food prices in Malaysia. While this study does not propose a new theory, it contributes to the theoretical literature by expanding the bioenergy–food price model to include palm oil and biodiesel demand dynamics in Malaysia. This refinement reflects the unique economic structure of Malaysia, where palm oil serves both the energy and food sectors. By applying established economic theories, such as price transmission, cost of production, and the food–fuel nexus, within a Malaysia-specific framework, the study offers a contextually grounded extension that enhances the applicability of these theories in biofuel-producing countries. This section consolidates the key theoretical implications of the findings.

First, the findings of this study support *Ricardo's Cost of Production Theory of Value* by showing that increased demand for biodiesel-related inputs, particularly palm oil, will raise input costs, which in turn inflates food prices. Since palm oil is used in both food and fuel markets, a cost increase in one sector inevitably affects the other. This finding extends Ricardo's classical theory into the context of the modern bioeconomy/bioenergy, illustrating how the diversion of resources toward biodiesel production can trigger indirect inflation in food prices in a biodiesel-producing country like Malaysia.

Secondly, the study validates the *Price Transmission Theory* by demonstrating that price shocks in energy and agricultural input markets, such as crude oil and palm oil, ripple through to food prices via interconnected commodity supply chains. This is well supported by the concept of "*Financialization of the Commodities*" as well. The presence of both linear and asymmetric transmission effects reveals that these linkages are not only direct but can also be amplified under specific structural or policy conditions. This enhances the relevance of the theory in emerging economies where energy and food markets are increasingly interdependent.

Next, the research builds on the *Food–Fuel Nexus Framework* by shifting focus from the conventional emphasis on biodiesel prices or output to a more comprehensive view of demand-side dynamics. By incorporating factors such as diesel vehicle population, blending mandates, investment in biodiesel infrastructure, and biodiesel pricing, the study captures structural demand pressures that shape long-term food price trends. This approach broadens the traditional model of the *Food-Fuel Nexus Framework*, highlighting how non-price variables can drive sustained effects on food markets.

Finally, the integration of industrial activity, which is measured via the IPI, provides empirical support for *Unified Growth Theory*. This theory suggests that as economies develop and undergo structural transformation, imbalances can arise that affect basic commodity markets. In Malaysia's case, industrial expansion contributes to higher demand for both energy and agricultural inputs, indirectly fueling food price inflation. This connection underscores the trade-offs that may emerge between industrial growth and food affordability. Importantly, this study moves beyond using broad indicators such as GDP to represent income or development effects. By adopting a disaggregated indicator (IPI), the model captures sector-specific dynamics that are more closely tied to resource use and demand pressures. This refinement allows for a more nuanced theoretical interpretation and supports targeted policy formulation, especially in contexts where industrial policies intersect with food and energy markets.

In summary, this study not only confirms the validity of multiple economic theories but also extends their applicability by embedding them within a Malaysian context. Through the use of linear, nonlinear, and dynamic modelling approaches, the research delivers a deeper understanding of food price determinants in economies that produce biofuels.

6.3 Policy Implications of the Research Findings

The findings of this research have significant policy implications for Malaysia, offering guidance on navigating the intricate relationships between critical factors such as the palm oil industry, biodiesel industry, industrial growth, and food prices. These implications are essential for sustaining food security, ensuring economic growth, and promoting energy security. In this section, this research will present three key policy areas with in-depth discussions, addressing the strengths and weaknesses of current policies and offering a path forward.

6.3.1 Palm Oil Industry and Its Impact on Food Prices

The palm oil industry is pivotal in Malaysia's economy, contributing significantly to export earnings. However, it also exerts pressure on food prices due to its influence on cooking oil costs, indirectly affecting the prices of various food items. While current policies such as The Malaysian Palm Oil Industry Transformation Plan (MPIT2030) and The Malaysian Sustainable Palm Oil

(MSPO) certification scheme aimed to promote efficiency and sustainability within the palm oil sector, challenges remain, particularly concerning land use and deforestation. To tackle these challenges, world organisations such as the EU introduced various regulations, such as the EU Deforestation-Free Regulation (EUDR), to promote good agricultural practices (GAPs) under the commodity markets. Thus, policies such as MPIT2030 and MSPO have succeeded in elevating Malaysia's image as a responsible palm oil producer but fall short in addressing its impact on food prices. The empirical finding of this study confirms the significant positive role of palm oil prices on the food price in Malaysia. A revised policy framework should emphasize a balance between palm oil industry growth and food price stability. The palm oil pricing strategy is the key measurement here. The framework should include the following measures:

1. Encourage sustainable practices in palm oil cultivation and production level by compliance with the GAPs. This is fundamental for the palm oil pricing strategy to stabilize the market ensuring affordability for consumers and supporting long-term market resilience. As the World Bank (2023)[b] report highlighted, higher volatility in the palm oil price is mainly due to the supply-demand imbalance, changes in weather patterns, biofuel policy and speculation. To mitigate these fluctuations, continuous monitoring of oversupply and undersupply conditions is necessary. This can be strategically complemented by aligning biodiesel production levels with palm oil inventory trends. Such integration would allow

Malaysia to use biodiesel production as a buffer mechanism, helping to absorb excess supply during periods of surplus and reduce pressure during shortages, thereby regulating price swings more effectively.

Interestingly, the EU Deforestation-Free Regulation may create some challenges to the palm oil industry. Regulation will require palm oil producers to prove that their products are deforestation-free before selling to the European Union's 27 member states (Reuters, 2022). This may create some issues for the Malaysian palm oil industry, such as increased cost of compliance, reduced market access and reputation risks. However, the Malaysian palm oil industry's move towards preparing the industry for the regulation is noticed as a positive signal. For instance, forming a joint task force with the EU to implement the regulation and providing financial assistance (RM 100 million) to small farmers to help them comply with the regulation by adopting sustainable practices and improving their traceability systems are well-deserved steps forward under the palm oil industry. Furthermore, the Malaysian government’s intention to promote sustainable palm oil production by introducing a mandatory Malaysian Sustainable Palm Oil (MSPO) certification scheme and increasing the forest cover by 50 per cent by 2023 is the value added to the EUDR (Tan, 2023).

Another critical policy implication is the need to improve the transparency and efficiency of the palm oil market. This can be done by improving the collection and dissemination of market data and promoting fair trade and ethical practices throughout the supply chain. Even though the Malaysian government is taking the initiative to make some of the palm oil industry-related data such as production, market price and exports available publicly, land ownership, supply chains, and labour practices remain far from transparent in Malaysia. This may complicate the intention of addressing the sustainability challenges in this industry. In this regard, the government's commitment under the Malaysian Palm Oil Industry Transformation 2030 (MPIT2030) to establish a public palm oil traceability system is a welcome initiative. Such a system would promote greater accountability, transparency, and compliance with environmental and social standards, ultimately encouraging producers to adopt responsible and sustainable practices across the value chain.

Furthermore, stabilising palm oil prices can be achieved by minimising the market power of a monopolistic producer by forming a producer cartel or through international commodity agreements between buyers and sellers. The issue of cartels in the Malaysian palm oil industry is complex and sensitive. While the formation of producer cartels or coordinated pricing mechanisms may offer short-term price stability, they also raise concerns related to market fairness and consumer welfare. Malaysian Competition Commission (MyCC) was launched in Malaysia in 2011 under the Ministry of Domestic Trade and Consumer Affairs to protect consumers and businesses from anti-competitive practices. This agency, in 2019, fined a few palm oil companies for engaging in price-fixing (Gimino, 2022). The MyCC's action against the palm oil companies is a positive step towards improving transparency and competition in the Malaysian palm oil industry. However, for such efforts to be effective and sustained, greater enforcement authority and independence should be granted to MyCC. Empowering the Commission with enhanced investigative tools, legal authority, and inter-agency cooperation can strengthen its ability to detect, prevent, and penalize anti-competitive behaviours, thereby contributing to a more transparent and competitive palm oil market.

Besides, an alliance between Indonesia and Malaysia (over 85% of the palm oil producers globally) could boost the bargaining power of both countries in setting the CPO price and control output, thereby reducing the volatility of all palm oil products in the future. This is mainly due to both countries having the market power and bilateral understanding and agreement between these two countries able to use their combined weight to influence the market and promote their interests. For instance, the Council of Palm Oil Producing Countries (CPOPC) was formed in 2019 to promote palm oil producers' interests and address the industry's challenges in both countries. Under CPOPC, the two countries have agreed to cooperate on developing palm oil biodiesel and promoting certified sustainable palm oil. This is a welcoming move towards the sustainability of this industry. This kind of bilateral agreement between both countries is essential in the current situation.

Malaysia's biodiesel industry has grown significantly, driven by government support and incentives. However, as highlighted in this study, biodiesel prices, investments, and policies can impact food prices, necessitating careful management. While current policies on the blended mandate requirements in the transportation and industry have successfully stimulated biodiesel production, contributing to energy diversification, there is a need to address the potential inflationary effects on food prices. A more integrated policy framework is required, one that balances the goals of energy security and environmental sustainability with food price stability and consumer welfare. To this end, future policy measures should incorporate regular impact assessments, stakeholder consultations, and market-based adjustment mechanisms that ensure biodiesel expansion does not come at the expense of food affordability. This will strengthen the long-term resilience and inclusivity of Malaysia’s green energy transition.

This framework should include measures to implement mechanisms for monitoring and regulating biodiesel prices, investments and policies concerning their impact on food prices to promote research and innovation in sustainable biodiesel production practices that minimize the use of land and resources. Using waste and non-food feedstocks (for instance, waste cooking oil, animal fats, and algae), improving the efficiency of biodiesel production (for instance, higher production with minimum resources) and promoting sustainable farming practices such as agroforestry, precision agriculture, and intercropping, to enhance land-use efficiency and reduce environmental degradation.

Overall, there are several ways that the palm oil framework can be revised to benefit food prices. By taking these steps, the government can help to ensure that food is affordable for consumers. In addition to these specific measures, developing comprehensive policies promoting sustainable palm oil and biodiesel production in Malaysia is essential. These policies should be developed in consultation with all stakeholders, including farmers, biodiesel producers, and environmental groups. By implementing these policies, we can help to ensure that palm oil and biodiesel are truly sustainable commodities and fuels that can help to reduce greenhouse gas emissions and improve air quality without driving up food prices in Malaysia.

Other than focusing on enhancing the palm oil market framework, some other strategies can also be used to reduce the domination of palm oil in the food market in Malaysia. The proposed strategies are as follows:

1. Promote the diversification of cooking oil sources to reduce dependence on palm oil-based cooking oil in Malaysia. This could be ambiguous at this stage as palm oil remains the most affordable edible oil, and promoting diversification needs major structural changes in the agricultural sector. While this transformation may not be immediately feasible, it is not unrealistic. Rather, it should be viewed as a long-term strategic initiative aimed at strengthening the resilience and sustainability of Malaysia's food system. The close integration of palm oil in food prices is mainly due to the usage of this commodity in the food processing industry and as the leading cooking oil in Malaysia and most Asian countries. The cooking oil subsidies are a good move to control food prices, whereby Malaysia allocated about MYR 4 billion in 2023 for subsidizing cooking oil in 1kg packets. The Malaysian government introduced the subsidy in February 2022 to help Malaysians cope with the rising cost of living. The subsidy was initially set at MYR 2.50 per 1 kg of cooking oil but increased to RM4.00 per 1 kg in March 2022. This subsidy program should continue in Malaysia since Malaysia benefits from this program, especially the B40.

However, this move is not sustainable, and it is highly debatable. Some economists argue that the subsidy is not sustainable and could lead to cooking oil shortages in the future, and it also depends on the government's financial position. Therefore, promoting alternative cooking oil with a competitive price could be a long-term sustainable move to reduce the dependency on palm oil. Varies replacements of cooking oil available in the Malaysian market, i.e., corn, canola, sunflower, and many more. Among these, corn oil has potential due to Malaysia's ongoing efforts to expand corn production for feed and food security. With proper support, including R&D investment, agro-extension services, and oil processing infrastructure, corn could serve as a feasible alternative in the medium to long term in Malaysia.

Corn oil presents a viable long-term diversification pathway, supported by Malaysia’s current efforts to expand grain corn cultivation under the National Agrofood Policy 2.0 (2021-2030). Under this policy framework, grain corn is given priority to reduce the import dependency as Malaysia currently imports over 90 per cent of the grain corn. Although primarily focused on animal feed, increased domestic production of corn opens opportunities for downstream processing into food products such as corn oil. This provides a foundation for upstream investments, including local processing of corn, which may include edible oil extraction if economic feasibility supports it.

2. Encouragement of the diversification of crop plantations among the farmers in Malaysia could improve food availability and minimise the role of palm oil in the food industry. Countries such as Indonesia, Thailand, and Vietnam have initiated or expanded programs to

promote alternative oil crops like soybean, sunflower, and sesame alongside existing palm oil production. These initiatives aim to enhance edible oil security, diversify farmer income, and reduce market vulnerability from over-dependence on a single crop. For instance, Indonesia is seeking to reduce its reliance on imported cooking oils and increase local soybean production (Harsono et al., 2022).

In Malaysia, multiple pilot programs and state-level projects (e.g., in Perlis, Kedah, and Sabah) have been launched to promote grain corn farming using local cooperatives and contract farming models. These initiatives aim to expand corn cultivation from under 20,000 ha to over 80,000 ha by 2033 (The Star, 2022). This will be the key movement towards reducing the food import of Malaysia and is highly significant for food sustainability in Malaysia. This crop can be promoted as a new source of national wealth, as announced by the formal financial minister in the 2018 budget (Rosali et al., 2019). With its significant effect on the food industry, as grains, animal feeds and cooking oil, it helps in the diversification of crop plantations and reduces the dependency on palm oil as the main cooking oil in Malaysia. On the other hand, increasing the production of corn can reduce the import of corn and increase its SSR in Malaysia.

However, the major challenge of corn cultivation in Malaysia is the higher cost of production, low productivity and low return on investment (ROI) (Nazmi et al., 2021). Thus, the cooperation between government and private sectors could make this proposed initiative more successful. For instance, educate farmers about crop diversification's economic, environmental, and social benefits, support research and development into new diversified crops, help identify crops well-suited to Malaysia's climate and soil conditions, and develop value-added products from diversified crops. Promoting the food crop industry as a potentially profitable venture among farmers and youth entrepreneurs could help reduce the influence of palm oil crops in the food market and reduce its reliance on imported food in Malaysia. Subsidies to the farmers for producing other food crops and R&D implications for the new food crop production improve the situation as well. Statistics indicate a worrying situation whereby the average age of paddy farmers in Malaysia is 60 years old, and farmers below 40 years are only about 15 per cent (Azuar, 2021). This is a warning alarm towards food sustainability in Malaysia. A very holistic measure is needed to increase the young entrepreneurs' interest in the food production businesses.

While the proposal does not suggest an immediate replacement of palm oil, it aims to create pricing competition, enhance market resilience, and provide a buffer against supply-side shocks stemming from the biofuel or export markets. Over time, a more diversified cooking oil market will reduce the systemic risk associated with Malaysia’s current heavy reliance on palm oil, both for food and fuel.

6.3.2 Industrial Growth and Its Impact on Food Prices in Malaysia

On the other hand, Malaysia's industrial growth efforts have been a driving force behind economic development. However, the growth of industries can exert pressure on food prices, mainly due to increased energy demands and resource competition. The Malaysian government has implemented several industrial growth policies over the years. These policies have been designed to promote the development of the manufacturing sector, create jobs, and boost the economy. For instance, the most recent policy is the National Policy on Industry 4.0 (Industry4WRD), which focuses on promoting the use of advanced technologies, such as artificial intelligence, robotics, and the Internet of Things, in the manufacturing sector.

Current policies have been effective in attracting investments and fostering industrial growth. However, this policy paid limited attention to managing the impact on food prices. However, the National Agrofood Policy (NAP 2.0) was launched in 2021 to develop the agro-food sector by focusing on developing Malaysia's agriculture, livestock, fisheries, and food processing industries. Thus, it indicates that Malaysia's industrial policies are in the proper direction to help Malaysia become a more competitive and sustainable agro-food producer. Furthermore, a holistic policy framework should aim to harmonize industrial growth with food price stability. This framework should include measures to promote energy-efficient practices within industries to reduce pressure on biodiesel resources, monitor and address energy-related impacts on food production and prices, and encourage the diversification of energy sources, including renewable and sustainable options.

Interestingly, this study found that the effect of the crude oil price on food prices is minimal. This is mainly due to the subsidy allocation by the Malaysian government on petrol and diesel. The subsidy program looks pretty progressive in the short term since it can dissolve the effect of crude oil on food prices and help stabilise Malaysia's food prices. On the negative side, subsidies can discourage innovation where the industries invest in new technologies and practices that could improve efficiency and reduce costs. Furthermore, it can lead industries to depend highly on government support, making it difficult for them to become self-sufficient. Regarding sustainability, the subsidy program is not an effective long-term solution in Malaysia (Heuvelen, 2023). Instead of relying on subsidy programs, the focus should be on developing and investing in sustainable solutions such as producing alternative energy to reduce crude oil dependence. These solutions may be more expensive in the short term but will be more sustainable and beneficial in the long term.

In conclusion, Malaysia faces the critical challenge of balancing economic development, energy security, and food affordability. These three key policy areas: oil industry, biodiesel industry, and industrial growth—require thoughtful and coordinated policies that take into account their impacts on food prices. Strengthening and adapting these policies can ensure sustainable growth, energy security, and food access for the nation's citizens. It is essential to acknowledge that the success of these policy frameworks will depend on effective implementation, continuous monitoring, and a commitment to addressing emerging challenges. Policymakers must remain vigilant, open to adjustments, and responsive to changing circumstances to secure Malaysia's prosperous and food-secure future.

6.4 Limitations of the Research

While this study has made significant contributions to understanding the intricate interactions among palm oil prices, biodiesel demand, industrial growth trends, and food price dynamics in Malaysia, it is essential to acknowledge the limitations that affect the interpretation and generalization of the findings. This section comprehensively discusses these limitations to guide future research and policymaking.

One of the primary limitations of this research is the availability and quality of data. The study relies on existing datasets from various government agencies and organizations, which may have inconsistencies, gaps, or limitations in terms of coverage and accuracy. For instance, data on biodiesel is very limited in Malaysia since this industry is still young. One of the biodiesel demand indicators is the investment in the biodiesel industry. The lack of data on biodiesel investment hinders a comprehensive assessment of its impact on food prices in Malaysia. Furthermore, this study's reliance on historical data means it captures relationships and trends up to the data cutoff point. The dynamics between the variables may evolve, and the research does not account for potential changes or shocks that occurred after the last available data point. Theoretically, the usage of biodiesel production justifies the investment effect, yet the actual effect is still unascertainable. Enhancing the quality and availability of data is crucial for conducting more robust analyses in the future.

Furthermore, another limitation in this study relates to the use of newly registered diesel vehicles as a proxy for biodiesel-related transportation demand. While this dataset reflects annual vehicle additions, it does not capture deregistered or inactive vehicles, which may no longer be operational or present on the road. As such, the variable may overstate the actual number of active diesel vehicles, especially over a multi-year period where some vehicles would naturally exit the fleet. This limitation is due to the unavailability of comprehensive vehicle de-registration or retirement data in Malaysia's public data repositories. Nevertheless, newly registered vehicles are used in many empirical studies as a practical indicator of fuel-related transportation demand and sectoral growth trends.

Another standard limitation in economics studies is the simplification of complex interaction. This research simplifies the intricate interactions among palm oil price, biodiesel demand, industrial growth, and other control variables towards food prices into linear and asymmetric linear relationships. These relationships are multifaceted and subject to various external factors and feedback loops that the study does not fully capture. This may limit the overview of the food price framework of Malaysia and the policy implications proposed in this study. For instance, this study does not delve deeply into the social and cultural factors that can influence food consumption and preferences. These factors can significantly influence food price inflation and should not be overlooked (Landes et al., 2016). This effect is not explored in this study because this is not the primary consideration of the aim of this study. This can be the future direction which engages communities and stakeholders to develop culturally sensitive strategies.

Furthermore, this research does not explicitly account for the broader policy context and political considerations that can affect the implementation and effectiveness of policies related to palm oil prices, biodiesel demand, industrial growth, and food security. The policy implications and direction proposed in this study are guided by the empirical analysis conducted in this study based on the control of the environment. Thus, it is highlighted as a limitation in this study since a comprehensive policy analysis was not provided. Policymakers should conduct comprehensive policy assessments that incorporate political and contextual factors. Develop strategies for policy communication and stakeholder engagement to ensure successful policy implementation. This study's empirical findings offer policymakers a glimpse into the intricate connections between the variables examined. However, a more comprehensive understanding is crucial for implementing broad and effective policies.

Lastly, the study does not account for external factors or shocks that can influence the relationships examined. For instance, global economic crises, natural disasters, or sudden changes in global oil prices can significantly impact biodiesel investment, industrial growth, and food prices. In the time frame of this study, the COVID-19 pandemic also took part, significantly impacting Malaysia's economy. The exclusion of the effect in the model is justifiable based on the empirical statistics, whereby no significant structural breaks are found in the food price in Malaysia. However, including those impacts may create more complex and better insight into the understudied relationship. This may contribute to better policymaking by developing contingency plans to mitigate the effects of unforeseen events.

Overall, while offering valuable insights into the intricate interplay among palm oil price, biodiesel demand, industrial growth, and food price dynamics in Malaysia, this research is subject to several limitations that should be acknowledged and addressed in future studies and policymaking efforts. Understanding these limitations is crucial for accurately interpreting the research findings and designing policies that effectively navigate the complex challenges at the intersection of energy, industry, and food security. Policymakers should adopt a flexible and adaptive approach, considering the evolving nature of these relationships and the potential influence of external factors. Thus, the next section will give some recommendations for the future research direction of this study.

6.5 Future Recommendations for Research

While this study has made significant strides in unravelling the intricate relationships between palm oil price, biodiesel demand, industrial growth and food price dynamics in Malaysia, there remain ample opportunities for future research to expand upon and enhance understanding of these complex dynamics. This is because the biodiesel industry is still young, and the study relevant to the biodiesel industry in Malaysia is still at the pre-mature level.

First, biodiesel investment growth's sustainability dimension merits further exploration. Future research should assess the environmental impacts of biodiesel production and consumption, including greenhouse gas emissions and land-use changes, particularly in biodiesel-producing regions such as Malaysia, Indonesia, and Latin America. Understanding the trade-offs between biodiesel expansion and environmental sustainability is vital in the context of global climate change. Life cycle assessments and environmental impact assessments can be employed to quantify the environmental footprint of biodiesel production and its implications for sustainability. Researchers can also explore the potential for sustainable biodiesel production practices, such as emissions reduction, biodiversity conservation, and soil health. Additionally, comparative studies using spatial analysis and remote sensing data can help track land-use conversion over time, while policy scenario modelling (e.g., using CGE or system dynamics models) can explore alternative investment pathways that promote sustainable biodiesel production practices (e.g., use of waste oil feedstocks, agroforestry integration, or yield-enhancing technologies).

Furthermore, interdisciplinary research teams can offer diverse perspectives and expertise in energy, economics, and food security in Malaysia. Complex issues at the intersection of energy, industry, and food security require interdisciplinary collaboration across economics, environmental science, agricultural studies, and public policy. Future research in the biodiesel industry should encourage collaborations between economists, environmental scientists, social scientists, and policymakers to address these multifaceted challenges comprehensively. Specifically, researchers could integrate mixed-method approaches, such as combining econometric modelling (e.g., ARDL/NARDL) with qualitative case studies or stakeholder interviews to capture both macroeconomic patterns and on-the-ground realities. Tools like system dynamics modelling or multi-criteria decision analysis (MCDA) can help explore trade-offs and synergies across sectors. In the Malaysian context, collaboration between institutions such as Universiti Malaya, MPOB, SEDA Malaysia, and international partners could yield robust, policy-relevant insights. Funding agencies, including MOSTI, FRGS, or APEC, can further support such initiatives by earmarking grants for cross-disciplinary research on sustainable energy transitions.

Besides, food prices are a regional and global issue. Future research should extend beyond the confines of Malaysia to encompass a broader spectrum of countries, each with its unique socio-economic context, policies, and industrial structures. Future research may consider applying this study’s modelling framework in other biofuel-producing countries to explore the extent to which food–fuel–differing institutional and market settings shape industrial interactions. Comparative studies across different regions and nations can provide valuable insights into how the alternative energy sector and industrial growth may influence food prices in varying environments. For instance, studies could focus on Southeast Asia (e.g., Indonesia, Thailand, Vietnam) and extend to Latin America (e.g., Colombia, Brazil) regions where biodiesel industries are also expanding. Such research can help identify common trends, regional disparities, and best practices on the regional base. Researchers can employ panel data analysis (e.g., panel ARDL, dynamic panel GMM), meta-analytic techniques, or case studies that involve multiple countries to compare the relationships under investigation. Such approaches allow for robust generalizations while respecting country-specific heterogeneity, thus strengthening policy recommendations that are both context-aware and globally informed.

The current model can be further enhanced by involving mediation factors such as political influences, social and cultural factors and policy interventions. This entails identifying mediating factors and pathways through which these variables affect one another. Investigating how policies across these domains can be harmonized to achieve multiple objectives simultaneously is essential for sustainable development. Researchers can conduct policy analysis and scenario modelling to explore integrated policy frameworks. Besides, investigating the mechanisms can help policymakers develop more targeted and effective interventions. For instance, understanding how cultural preferences, dietary habits, and social norms intersect with food prices and availability can provide valuable insights for policymakers seeking to promote food security.

Engaging with communities and stakeholders can facilitate a comprehensive understanding of these factors. Qualitative research methods such as ethnographic studies, interviews, surveys, and case studies can be employed to uncover the intricate mechanisms and mediating factors rather than solely depending on the secondary data analysis.

Furthermore, given the practical implications of this research, future studies should focus on policy analysis and evaluation. Researchers can assess the effectiveness of existing policies, considering their impact on food prices. Investigating the potential trade-offs and synergies between policy objectives is crucial for informed decision-making. Researchers can employ policy evaluation techniques such as cost-benefit analysis, impact assessments, and scenario modelling to assess the outcomes of various policy interventions. In addition, researchers can utilize time series analysis and event studies to explore short-term variations in palm oil and biodiesel growth. Analyzing policy changes and their immediate consequences can be particularly informative. This can guide policymakers in designing more effective and balanced policies.

The complex relationships studied here call for advanced modelling and simulation techniques. Future research can leverage agent-based modelling, system dynamics, and other computational approaches to simulate the interactions among biodiesel prices, policies, investment, industrial growth, vehicle population, and food prices. These models can offer a dynamic and nuanced perspective on the dynamics at play. Researchers can collaborate with experts in computational modelling to develop and validate models that capture the system's complexity. Sensitivity analyses and scenario simulations can help identify critical tipping points and potential policy implications.

Overall, while this research has significantly advanced our understanding of the relationships between palm oil prices, biodiesel demand, industrial growth and food price dynamics in Malaysia, there are numerous avenues for future research to explore. These recommendations span various dimensions, from methodological enhancements to policy analysis, and emphasize the importance of interdisciplinary collaboration and a holistic approach to addressing the complex challenges at the nexus of energy, industry, and food security. Future research endeavours guided by these recommendations can contribute to more informed policymaking and sustainable development strategies not only in Malaysia but also in a global context.

6.6 Chapter Summary

In this chapter, this research presents a comprehensive analysis of the intricate relationships between palm oil prices, biodiesel demand factors, industrial growth, and food prices in the context of Malaysia. Our study tackles a critical concern rooted in the multifaceted relationships between these vital variables, offering valuable insights into the broader implications for Malaysia's energy sector, economic development, and food security landscape. Guided by research objectives focused on these critical elements, this chapter encapsulates key findings, hypothesis summaries, the central conclusion, policy implications, future research recommendations, and acknowledged limitations.

This study's main findings shed light on the significant impact of palm oil prices and biodiesel demand factors on food prices within the Malaysian landscape. Furthermore, this research elucidates the complex connections between these elements and industrial growth, highlighting their pivotal roles in shaping Malaysia's energy landscape, economic trajectory, and food security. This study systematically evaluated hypotheses centered around palm oil prices, biodiesel demand factors, industrial growth, and food prices. These hypotheses received empirical support, underscoring the intricate interdependencies among these variables. As Malaysia continues promoting biodiesel utilisation and fostering industrial expansion, vigilance regarding potential food price inflation remains paramount. These findings underscore these elements' fundamental role in influencing Malaysia's energy security, economic growth, and food affordability.

This chapter's conclusion reaffirms this research objectives and problem statement while summarizing the estimated results. This research emphasizes the need for a balanced approach to palm oil prices, biodiesel demand, industrial growth, and food security. This offers a holistic perspective on Malaysia's complex challenges in these vital domains. The policy implications section discusses how these research findings can inform policymaking in Malaysia. It underscores the importance of considering the ramifications of palm oil prices, biodiesel demand, and industrial growth on food prices. This study suggests the necessity for integrated policies that harmonize these critical sectors. Policymakers are encouraged to evaluate potential trade-offs and synergies among various policy objectives, prioritizing sustainability and affordability.

The future research recommendations emphasize the need for regional and cross-country comparative studies, a focus on temporal dynamics and short-term effects, and an exploration of causal mechanisms and mediating factors. This research also suggests analyzing policy effectiveness, considering environmental and sustainability aspects, examining social and cultural factors in food security, employing advanced modelling techniques, and promoting interdisciplinary collaboration. While this research constitutes a significant step in understanding these complex dynamics, it is essential to acknowledge its inherent limitations. Acknowledging this study's limitations, this chapter underscores the importance of addressing these gaps in future research. Limitations include data constraints, the intricacy of causal relationships, and the need for more nuanced analyses in specific areas. These limitations offer valuable insights for researchers seeking to build upon this foundational research.

This conclusion summarizes the main findings of the thesis, argues for the significance of the research, restates the thesis statement, and reflects on the research process. This research lays the foundation for addressing the multifaceted challenges at the intersection of energy, industry, and food security. It serves as a stepping stone for future investigations and evidence-based policymaking, offering a compelling basis for navigating the intricate terrain of

Malaysia's economic and energy landscape. It also makes a call to action by recommending that policymakers carefully consider bioenergy's potential benefits and drawbacks before developing and implementing bioenergy policies to protect the food price in Malaysia.

REFERENCING

Abdullah, R. (2013). An Analysis on Trends of Vegetable Oil Prices and Some Factors Affecting CPO Price. *Oil Palm Industry Economic Journal, 13*(2), 1-14.

Abdullah, R., Abas, R. & Ayatollah, K. (2007). Impact of Palm Oil-based Biofuel Demand on Palm Oil Price. *Oil Palm Industry Economic Journal, 7*(2), 7–16.

Abed, R. E., Amor, T. H., Nouira, R. R., & Raul, C. (2016). Asymmetric effect and dynamic relationships between oil prices shocks and exchange rate volatility: Evidence from some selected MENA countries. *Topics in Middle Eastern and North African Economies, 18*.

Afolabi, A. A., Adeoye, B. W., & Olayemi, K. O. (2022). Exchange rate volatility and economic growth in Nigeria: Evidence from ARDL bounds testing approach. *African Economic Review, 10*(2), 45-67.

Ahmad, T., & Zhang, D. (2020). A critical review of comparative global historical energy consumption and future demand: The story told so far. *Energy Reports, 6*, 1973–1991. https://doi.org/10.1016/j.egyr.2020.07.020

Akram, F. Q., (2009). Commodity Prices, Interest Rates and the Dollar. *Energy Economics, 31*, 838-851. https://doi.org/10.1016/j.eneco.2009.05.016

Akter, S., & Basher, S. A. (2014). The impacts of food price and income shocks on household food security and economic well-being: Evidence from rural Bangladesh. *Global Environmental Change, 25*, 150-162. https://doi.org/10.1016/j.gloenvcha.2014.02.003

Algieri, B., & Kanellopoulou, S., (2008). Determinants of Demand for Exports of Tourism: An Unobserved Component Model. *Tourism and Hospitality Research, 9*(1), 9-19. https://doi.org/10.1057/thr.2008.39

Aliyu, A. J., & Ismail, N. W., (2017). Food imports and exchange rate: the application of dynamic cointegration framework. *Malaysian Journal of Mathematical Sciences, 11,* 101-114.

Al-Maadid, A., Caporale, G. M., Spagnolo, F., & Spagnolo, N., (2017). Spillovers between food and energy prices and structural breaks. *International Economics, 150*, 1-18. https://doi.org/10.1016/j.inteco.2016.06.005

Alnour, M., Altintaş, H., & Rahman, M. N. (2023). Unveiling the asymmetric response of global food prices to the energy prices shocks and economic policy uncertainty. *World Development Sustainability, 3*, 100083. https://doi.org/10.1016/j.wds.2023.100083

Al-Rousan, N., AL-Najjar, H., & AL-Najjar, D. (2024). The impact of Russo-Ukrainian war, COVID-19, and oil prices on global food security. *Heliyon, 10*(8), e29279. https://doi.org/10.1016/j.heliyon.2024.e29279

Almalki, A. M., Hassan, M.-u., & Amin, M. F. B. (2022). The asymmetric relationship between structural oil shocks and food prices: evidence from Saudi Arabia. *Applied Economics, 54*(54), 6216-6233. https://doi.org/10.1080/00036846.2022.2083065

Alnour, M., Altintaş, H., & Rahman, M. N. (2023). Unveiling the asymmetric response of global food prices to the energy prices shocks and economic policy uncertainty. *World Development Sustainability, 3*, 100083. https://doi.org/10.1016/j.wds.2023.100083

Alotaibi, K. (2016), How exchange rate influences a country's import and export. *International Journal of Scientific and Engineering Research,7*(5), 131-139.

Applanaidu, S. D., & Aziz, M. I. (2016). Crude Oil Price and Food Security Related Variables in Malaysia. *Global Journal of Business and Social Science Review, 4*(2), 17-21.

Applanaidu, S. D., Arshad, M. F., Shamsudin, M. N., & Yusop, Z., (2009). The impact of biofuel demand on the Malaysian palm oil market. *Prosiding Perkem;1*, 566-76.

Applanaidu, S. D., Bakar, N. A. A., & Baharudin, A. H., (2014). An Econometric Analysis of Food Security and Related Macroeconomic Variables in Malaysia: A Vector Autoregressive Approach (VAR). *UMK Procedia, 1*, 93-102.

Applanaidu, S. D., Yusop, F. M. A. Z., Shamsudin, M. N., & Alias, M. H., (2011). Impact of Biofuel Demand on the Malaysian Palm Oil Industry: A Simultaneous Equations Approach. *International Journal of Management Studies, 18* (Special Issue), 73-90. 10.32890/ijms.18.2011.10214.

Ariff, M., & Abubakar, S. Y. (1999). The Malaysian financial crisis: Economic impact and recovery prospects. *The Developing Economies, 37*(4), 417-438. https://doi.org/10.1111/j.1746-1049.1999.tb00241.x.

Arshad, F. M., & Hameed, A. A. A., (2009). Global Food Prices: Implications for Food Security in Malaysia. *Journal of the Consumer Research and Resource Centre.*

Ashford, N. A., Hall, R. P., & Ashford, R. H., (2012). The Crisis in Employment and Consumer Demand: Reconciliation with Environmental Sustainability. *Environmental Innovation and Societal Transitions, 2*, 1-22. https://doi.org/10.1016/j.eist.2012.01.002.

Asian Development Bank. (2021, May). A Practical Guide to Disaggregation for the Sustainable Development Goals. Asian Development Bank. Retrieved from https://www.adb.org/sites/default/files/publication/698116/guidebook- data-disaggregation-sdgs.pdf.

Austin, K. G., Mosnier, A, Pirker, J., McCallum, I., Fritz, S., & Kasibhatla, P. S., (2017). Shifting patterns of oil palm driven deforestation in Indonesia and implications for zero-deforestation commitments. *Land Use Policy, 69*, 41-48. https://doi.org/10.1016/j.landusepol.2017.08.036.

Ayompe, L. M., Schaafsma, M., & Egoh, B. N., (2020). Towards sustainable palm oil production: The positive and negative impacts on ecosystem services and human wellbeing. *Journal of Cleaner Production, 278,* 123914. https://doi.org/10.1016/j.jclepro.2020.123914.

Aziz, A., (2021, October 06). *Nationwide B20 biodiesel plan is still on, says Zuraida*. The Edge Malaysia. https://theedgemalaysia.com/article/ nationwide-b20-biodiesel-plan-still-says-zuraida.

Azuar, A., (2021, June 23). *Make agriculture attractive among youths*. The Malaysian Reserve. https://themalaysianreserve.com/2021/06/23/ make-agriculture-attractive-among-youths/#:~:text=Statistics%20 from%20the %20Muda%20Agricultural,are%20in%20the%20ageing%20population.

Baharumshah, A. Z., Mohd, S. H., & Masih, A. M. M., (2009). The Stability of Money Demand in China: Evidence from the ARDL Model. *Economic Systems, 33*(3). https://doi.org/10.1016/j.ecosys.2009.06.001.

Bai, Y., Alemu, R., Block, S. A., Headey, D., & Masters, W. A. (2021). Cost and affordability of nutritious diets at retail prices: Evidence from 177 countries. *Food Policy, 99*, 101983. https://doi.org/10.1016/j.food pol.2020.101983

Baltagi, B. H., Li, D., & Wang, B. (2023). The impact of exchange rate volatility on oil prices and agricultural commodity prices. *Energy Economics, 119*, 106485.

Bangun, Y., Azkarama, F., & Adriel, R. (2023). Geospatial Visualization for Second-Generation Renewable Diesel Feedstock from Palm Oil Value Chain. *Indonesian Journal of Energy, 6*(2), 131-14. https://doi.org/10.33116/ije.v6i2.174

Banerjee, A., Marcellino, M. and Masten, I. (2008), "Chapter 4 Forecasting Macroeconomic Variables Using Diffusion Indexes in Short Samples with Structural Change", *Rapach, D.E. and Wohar, M.E. (Ed.) Forecasting in the Presence of Structural Breaks and Model Uncertainty (Frontiers of Economics and Globalization, 3*, Emerald Group Publishing Limited, Leeds, 149-194. https://doi.org/10.1016/S1574-8715(07)00204-7

Bani-Mustafa, A., Matawie, K. M., Finch, C. F., et al. (2019). Recursive residuals for linear mixed models. *Qualitative and Quantitative, 53*, 1263–1274. https://doi.org/10.1007/s11135-018-0814-6

Bank Negara Malaysia, (BNM, 2021). Annual Report, 2021. Available from: https://www.bnm.gov.my/documents/20124/6458991/ar2021_en_book.p df

Barker, L. E., & Shaw, K. M. (2015). Best (but oft-forgotten) practices: Checking assumptions concerning regression residuals. *The American Journal of Clinical Nutrition, 102*(3), 533-539. https://doi.org/10.3945/ajcn.115.113498

Belhaj, M., (2002). Vehicle and Fuel Demand in Morocco. *Energy Policy, 30*, 1163-1171. https://doi.org/10.1016/S0301-4215(02)00008-3

Benito, S., Lopez-Martín, C., & Navarro, M. A., (2023). Assessing the importance of the choice threshold in quantifying market risk under the POT approach (EVT). *Risk Management, 25*(1). https://doi.org/10.1057/s41283-022-00106-w

Bevilacqua, M., Duygun, M., & Vioto, D., (2023). The impact of COVID-19 related policy interventions on international systemic risk. *Journal of International Financial Markets, Institutions and Money, 89*, 101859. https://doi.org/10.1016/j.intfin.2023.101859

Bilgili, F., Kocak, E., Kuskaya, S., & Bulut, U., (2020). Estimation of the Co-movements between Biofuel Production and Food Prices: A Wavelet-Based Analysis. *Energy, 213*, 118777. https://doi.org/10.1016/j.energy.2020.118777

Borozan, D., & Lolic C. M., (2022). Asymmetric and nonlinear oil price pass-through to economic growth in Croatia: Do oil-related policy shocks matter? *Resources Policy, 76*, 102736. https://doi.org/10.1016/j.resourpol.2022.102736

Bossman, A., Gubareva, M., & Teplova, T. (2023). Asymmetric effects of market uncertainties on agricultural commodities. *Energy Economics, 127*, 107080. https://doi.org/10.1016/j.eneco.2023.107080

Brinkman, M., Levin-Koopman J., Wicke, B., Shutes, L., Kuiper, M., & Faaij, A., (2020). The distribution of food security impacts of biofuels, a Ghana case study. *Biomass Bioenergy, 141*, 105695. https://doi.org/10.1016/j.biombioe.2020.105695

Broadbent, G. H., Allen, C. I., Wiedmann, T., & Metternicht, G. I., (2022). Accelerating electric vehicle uptake: Modelling public policy options on prices and infrastructure. *Transportation Research Part A: Policy and Practice, 162*, 155-174. https://doi.org/10.1016/j.tra.2022.05.012

Bruce, A., (2017). Derek Byerlee, Walter P. Falcon and Rosamond L. Naylor: the tropical oil crop revolution: food, feed, fuel and forests. *Food Sec., 9*, 883-885. https://doi.org/10.1007/s12571-017-0698-7

Bryman, A. & Bell, E. (2007). Business Research Methods. *Oxford University Press,* USA.

Business Today (2022, May 21). Malaysia and Our Food Security Conundrum. https://www.businesstoday.com.my/2022/05/21/malaysia-and-our-food-securit y-conundrum/.

Busse, S., Brummer, B., & Ihle, R., (2011). Emerging linkages between price volatilities in energy and agricultural markets. In A. Prakash (Ed.), *Safeguarding Food Security in Volatile Global Markets* (pp. 107–121). Food and Agriculture Organization of the United Nations.

Byerlee, D., Falcon, W. P., & Naylor, R. L., (2016). The Tropical Oil Crop Revolution: Food, Feed, Fuel, and Forests. *Oxford University Press*.

Byun, J., Kwon, O., Park, H., & Han, J. (2021). Food waste valorization to green energy vehicles: sustainability assessment. *Energy & Environmental Science*, *14*(7), 3651-3663. 10.1039/D1EE00850A

Cabrera-Jiménez, R., Mateo-Sanz, J. M., Gavaldà, J., Jiménez, L., & Pozo, C. (2022). Comparing biofuels through the lens of sustainability: A data envelopment analysis approach. *Applied Energy, 307*, 118201. https://doi.org/10.1016/j.apenergy.2021.118201

Cachia, F. (2014). Regional food price inflation transmission. *FAO Statistics Division Working Papers*.

Cao, Y., & Cheng, S., (2021). Impact of COVID-19 outbreak on multi-scale asymmetric spillovers between food and oil prices. *Resources Policy, 74*, 102364. 10.1016/j.resourpol.2021.102364.

Carreiras, H., & Castro, C. (Eds.). (2012). Qualitative Methods in Military Studies: Research Experiences and Challenges (1st ed.). *Routledge.* 10.4324/9780203099223

Caudill, S. B., & Jackson, J. D. (1993). Heteroscedasticity and Grouped Data Regression. *Southern Economic Journal, 128*. https://doi.org/1059937

Central Intelligence Agency (CIA, 2020)[b]. The World Factbook, 2020. https://www.cia.gov/library/publications/the-worldfactbook/rankorder/2253ra nk.html

Chan, T. H., & Lau, E., (2004). Business cycles and the synchronization process: a bounds testing approach. *MPRA*.

Chanthawong, A., Dhakal, S., & Jongwanich, J. (2016). Supply and demand of biofuels in the fuel market of Thailand: Two stage least square and three least square approaches. *Energy*, *114*, 431-443. https://doi.org/10.1016/j.energy.2016.08.006

Chebbi, H. E., & Boujelbene, Y., (2008). Agricultural and non-agricultural outputs and energy consumption in Tunisia: empirical evidence from co-integration and causality. *12th Congress of the European Association of Agricultural Economists – EAAE 2008*. 10.22004/ag.econ.44055

Chen, D., Gummi, U., & Umar, A. (2019) The Review on the Link between Food and Oil Markets in the View of Price Dynamics. *American Journal of Industrial and Business Management, 9,* 1890-1900. 10.4236/ajibm.2019.99122

Chen, S. T., Kuo, H. I., & Chen, C. C., (2010). Modeling the relationship between oil price and global food prices. *Applied Energy, 87*, 2517-2525. 10.1016/j.apenergy.2010.02.020

Chen, X., & Khanna, M., (2012). Food vs. Fuel: The Effect of Biofuel Policies. *American Journal of Agricultural Economics, 95*(2), 289-295. 10.1093/ajae/aas039

Cheng, S., & Cao, Y. (2019). On the relation between global food and crude oil prices: An empirical investigation in a nonlinear framework. *Energy Economics, 81*, 422-432. https://doi.org/10.1016/j.eneco.2019.04.007

Cheng, D., Shi, X., Yu, J., & Zhang, D. (2019). How does the Chinese economy react to uncertainty in international crude oil prices? *International Review of Economics and Finance, 64*, 147–164. 10.1016/j.iref.2019.06.002

Chi, J. (2018). Asymmetric effects of exchange rate and income changes on maritime freight flows between Japan and the US. *Transport Policy, 69*, 158-169. https://doi.org/10.1016/j.tranpol.2018.05.019

Cho, Y., Lee, J., & Kim, T. Y., (2007). The Impact of ICT Investment and Energy Price on Industrial Electricity Demand: Dynamic Growth Model Approach. *Energy Policy, 35*, 4730-4738. 10.1016/j.enpol.2007.03.003

Chong, C. T., Loe, T. Y., Wong, K, Y., Ashokkumar, V., Lam, S. S., Chong, W. T., Borrion, A., Tian, B., & Ng, J. H., (2021). Biofuel sustainability: The global impact of potential biofuel production on the energy–water–food (EWF) nexus. *Environmental Technology & Innovation, 22,* 1-20. 10.1016 /j.eti.2021.101408

Ciaian, P., & Kancs, D., (2011). Interdependencies in the Energy–Bioenergy–Food Price Systems: A Cointegration Analysis. *Resource and Energy Economics, 33*, 326–348. 10.1016/j.reseneeco.2010.07.003

Cohen, J. E., (1995). Population growth and earth's human carrying capacity. *Science 269*(5222). 341–346. 10.1126/science.7618100

Collins, K., (2008). The Role of Biofuels and Other Factors in Increasing Farm and Food Prices – A Review of Recent Developments with a Focus on Feed Grain Markets and Market Prospects. Supporting material for a review conducted by Kraft Foods Global, Inc.

Commission, E., (2016). *Proposal for a Directive of the European Parliament and of the Council on the Promotion of the Use of Energy from Renewable Sources*. https://eur-lex.europa.eu/legal-content/EN/TXT/ ?uri=CELEX %3A52016PC0767

Costantini, V., & Martini, C., (2010). The causality between energy consumption and economic growth: A multi-sectoral analysis using non-stationary cointegration panel data. *Energy Economics, 32*, 591-603. 10.1 016/j.eneco.2009.09.013

Crafts, R. N. F. (1996). The First Industrial Revolution: A Guided Tour for Growth Economists. *The American Economic Review, 86*(2), 197-201.

Crowther, D. & Lancaster, G. (2008). Research Methods: A Concise Introduction to Research in Management and Business Consultancy. *Butterworth-Heinemann*.

Dalia, G., & Smith, A. (2021). What Are the Benefits of High-Frequency Data for Fixed Effects Panel Models? Journal of the *Association of Environmental and Resource Economists, 8*(2), 199-234. 10.1086/710968

Dash, S. R., & Maitra, D., (2021). Do Oil and Gas Prices Influence Economic Policy Uncertainty Differently: Multi-Country Evidence Using Time-frequency. *Quarterly Review of Economics and Finance*. 10.1016/ j.qref.2021.06.012

David B. D., (2021). Energy Policy, Energy Research, and Energy Politics: An Analytical Review of the Current Situation. *Energies, 15*(23), 8792. https://doi.org/10.3390/en15238792

Dawson, R. H., Robert, A., & Bob A., (2006). Doing Case Study Research: A Practical Guide for Beginning Researchers. *Teachers College Press, 2006.*

De Gorter, H., & Just, D. R., (2008). The Law of Unintended Consequences: How the U.S. Biofuel Tax Credit with a Mandate Subsidizes Oil Consumption and Has No Impact on Ethanol Consumption. *Cornell University Working Paper No. 2007-20.*

De Gorter, H., & Just, D. R., (2009). The Welfare Economics of a Biofuel Tax Credit and the Interaction Effects with Price Contingent Farm Subsidies. *American Journal of Agricultural Economics, 91*(2), 477- 488.10.1111 /j.1467-8276.2009.01251.x

Department of Statistic Malaysia (DOSM, 2021)[c]. *Supply and Utilization Accounts Selected Agricultural Commodities, Malaysia 2016-2020.* Department of Statistic Malaysia https://www.dosm.gov.my/v1/index.php?r=column/cthemeByCat&cat=164&bul_id=cHgwanhNdU4vWXRvc3pnZU9xSjZTUT09&menu_id=Z0VTZGU1UHBUT1VJMFlpaXRRR0xpdz09.

Department of Statistic Malaysia (DOSM, 2022)[a]. *Gross Domestic Product Income Approach 2021*. Department of Statistic Malaysia https://www.dosm.gov.my/v1/index.php?r=column/ctheme.ByCat&cat=266&bul_id=NDYzci9qQnJaZDlYelVaalpnRzhQQT09&menu_id=TE5CRUZCblh4ZTZMODZIbmk2aWRRQT09.

Department of Statistic Malaysia (DOSM, 2022)[b]. *Labour Productivity of First Quarter 2022*. Department of Statistic Malaysia https://www.dosm.gov.my/v1/index.php?r=column/cthemeByCat&cat=438&bul_id=RW92VGNPZUxOci9sWVErNVB0Q0o1dz09&menu_id=Tm8zcnRjdVRNWWlpWjRlbmtlaDk1UT09.

Dodder, R. S., Kaplan, P. O., Elobeid, A., Tokgoz, S., Secchi, S., & Kurkalova, L. A., (2015). Impact of Energy Price and Cellulosic Biomass Supply on Agriculture, Energy, and the Environment: An Integrated Modelling Approach. *Energy Economics, 51*, 77-87. 10.1016/j.eneco.2015.06.008

Dogru, T., Sirakaya-Turk, E., & Crouch, G. I. (2017). Remodeling international tourism demand: Old theory and new evidence. *Tourism Management, 60*, 47-55. https://doi.org/10.1016/j.tourman.2016.11.010

Dormann, C. F. (2007). Effects of incorporating spatial autocorrelation into the analysis of species distribution data. *Global Ecology and Biogeography, 16*(2), 129-138. https://doi.org/10.1111/j.1466-8238.2006.00279.x

Drabik, D., Ciaian, P., & Pokrivcak, J., (2014). Biofuels and Vertical Price Transmission: The Case of the U.S. Corn, Ethanol, and Food Markets. LICOS Discussion Papers 35114, LICOS - Centre for Institutions and Economic Performance, KU Leuven.

Dumortier, J., Carriquiry, M., & Elobeid, A., (2020). Where does all the biofuel go? Fuel efficiency gains and its effects on global agricultural production. *Energy Policy, 148*, 111909. 10.1016/j.enpol.2020.111909

Dutta, A., Bouri, E., & Noor, M. H., (2018). Return and volatility linkages between CO2 emission and clean energy stock prices. *Energy, 164*, 803-810. 10.1016/j.energy.2018.09.055

Dutta, A., Bouri, E., Saeed., T., & Vo. X. V., (2021). Crude oil volatility and the biofuel feedstock market in Malaysia during the 2014 oil price decline and the COVID-19 outbreak. *Fuel, 292*, 120221. 10.1016/j.fuel.2021.120221

Economics and Industry Development division (2017). *Malaysian Palm Oil Board*. http://bepi.mpob.gov.my/index.php/my/statistics/export/60 export-2010.ht

Ekanayake, E. M., & Dissanayake, A., (2022). Effects of Real Exchange Rate Volatility on Trade: Empirical Analysis of the United States Exports to BRICS. *Journal of Risk and Financial Management, 15*(2), 73. 10.3390/ jrfm15020073

Elder, J., & Kennedy, P. E., (2001). Testing for Unit Roots: What Should Students Be Taught? *Journal of Economic Education, 32*(2), 137–146. 10.1080/00220480109595179

Eltony, M. N., & Al-Awadi, M., (2001). Oil Price Fluctuations and Their Impact on the Macroeconomic Variables of Kuwait: A Case Study Using A VAR Model. *International Journal of Energy Research, 25*, 939-959. 10.1002/er.731

Esmaeili, A., & Shokoohi, Z. (2011). Assessing the effect of oil price on world food prices: Application of principal component analysis. Energy Policy, 39(2), 1022-1025. https://doi.org/10.1016/j.enpol.2010.11.004

Energy Institute Statistical Review of World Energy (2023). Biofuel production by region. Our World in Data. https://ourworldindata.org/grapher/biofuels-production-by-region.

Engle, R. F., & Granger, C. W. J., (1987). Cointegration and Error-correction: Representation, Estimation and Testing. *Econometrica, 55*, 251–276. 10.2307/1913236

European Union Delegation to Malaysia (2012). The Malaysian Palm Oil Sector – Overview.

Fan, S., (2007). Investment Priorities for Hunger and Poverty, Paper Presented in a Seminar Title "Agricultural and Rural Development for Reducing Poverty and Hunger in Asia: In Pursuit of Inclusive and Sustainable Growth". Organised by IFPRI and ADB, Manila, Aug 9-11.

FAO (2008). *Crop Prospects and Food Situation (Report).* Available from: http://www. Fao.org/docrep/010/ai465e04.htm.

Fathian, F., Fard, A. F., Ouarda, T. B., Dinpashoh, Y., & Nadoushani, S. M., (2019). Modelling streamflow time series using nonlinear SETAR-GARCH models. *Journal of Hydrology, 573*, 82-97. 10.1016/j.jhydrol.2019.03.072

Flug, K., & Hercowitz, Z. (2000). Equipment Investment and the Relative Demand for Skilled Labor: International Evidence. *Review of Economic Dynamics*, *3*, 461-485. 10.1006/redy.2000.0090

Fontana, A., & Frey, J. (1994). Interviewing: The Art of Science. In N. Denzin, & Y. Lincoln (Eds.), Handbook of Qualitative Research (361-376). Thousand Oaks, CA: Sage Publication, Inc.

Food and Agriculture Organization of the United Nations (FAO) (2014). *A regional rice strategy for sustainable food security in Asia and the Pacific (Report).*

Food and Agriculture Organization of the United Nations (FAO) (2024). *World Food Situation.* Available in *https://www.fao.org/worldfoodsituation/foodpricesindex/en*

Fox, J. (2016). Applied regression analysis and generalized linear models (3rd ed.). Sage.

Gao, J., Ma, S., Zou, H., & Du, H. (2023). How does population agglomeration influence the adoption of new energy vehicles? Evidence from 290 cities in China. *Technological Forecasting and Social Change, 196*, 122857. 10.1016/j.techfore.2023.122857

Gaspard, G., Kim, D., & Chun, Y. (2019). Residual spatial autocorrelation in macroecological and biogeographical modeling: a review. *Journal of Ecology and Environment, 43*, 19. https://doi.org/10.1186/s41610-019-0118-3

Ghani, W. A. W. Ab. K., Salleh, M. A. M., Adam, S. N., Shafri, H. Z. M., Shaharum, S. N., Lim, K. L., Rubinsin, N. J., Lam, H. L., Hasan, A., Samsatli, S., Tapia, J. F., Khezri, R., Jaye, I. F. M., & Martinez-Hernandez, E., (2019). Sustainable bio-economy that delivers the environment–food–energy–water nexus objectives: The current status in Malaysia. *Food and Bioproducts Processing, 118*, 167-186. 10.1016/j.fbp.2019.09.005

Gharib, C., Mefteh-Wali, S., Serret, V., & Ben J., S. (2021). Impact of COVID-19 pandemic on crude oil prices: Evidence from Econophysics approach. *Resources Policy, 74*, 102392. 10.1016/j.resourpol.2021.102392.

Ghasemi, A., & Zahediasl, S. (2011). Normality Tests for Statistical Analysis: A Guide for Non-Statisticians. *International Journal of Endocrinology and Metabolism, 10*(2), 486-489. https://doi.org/10.5812/ijem.3505

Ghatak, S., & Siddiki, J. U., (2001). The use of the ARDL approach in estimating virtual exchange rates in India. *Journal of Applied Statistics, 28*(5), 578-583. 10.1080/02664760120047906.

Gillman, M., Benk, S., & Csabafi, T. (2023). Supply-side economics with AS-AD in Ramsey dynamic general equilibrium. *Economic Analysis and Policy*, *80*, 505-531. 10.1016/j.eap.2023.08.020.

Gimino, G., (2022, August 06). MyCC: Findings on poultry feed price fixing provisional, five not yet guilty. *The Star Online.* https://www.thestar.com.my/news/nation/2022/08/06/mycc-findings-on-poultry-feed-price-fixing-provisional-five-not-yet-guilty.

Global Oil and Fats (2020). Palm Oil: A Strategic Economic Sector for Malaysia. Retrieved from: http://gofbonline.com/palm-oil-a-strategic-economic-sector-for-malaysia/.

Go, Y., & Lau, W. (2021). Extreme risk spillovers between crude palm oil prices and exchange rates. *The North American Journal of Economics and Finance*, *58*, 101513. https://doi.org/10.1016/j.najef.2021.101513

Go, Y., & Lau, W. (2024). Terms of trade or market power? Further evidence from dynamic spillovers in return and volatility between Malaysian crude palm oil and foreign exchange markets. *The North American Journal of Economics and Finance*, *73*, 102178. 10.1016/j.najef.2024.102178

Göçoğlu, V., & Göksu, S. (2023). How do industrialization and agricultural land use affect urban population in Turkey? Policy implications in the context of SDGs. *Journal of Policy Modeling*. 10.1016/j.jpolmod.2023.08.004.

Goel, R. K., Saunoris, J. W., & Goel, S. S., (2021). Supply chain performance and economic growth: The impact of COVID-19 disruptions. *Journal of Policy Modeling*, *43*(2), 298-316. 10.1016/j.jpolmod.2021.01.003.

Goh, B. H., (2005). The Dynamic Effects of the Asian Financial Crisis on Construction Demand and Tender Price Levels in Singapore. *Building and Environment, 40*, 267-276. 10.1016/j.buildenv.2004.07.012

Gohar, R., Chang, B. H., Uche, E., & Bhatty, K., (2023). The Asymmetric Effect of Exchange Rate on the Household Consumption Expenditures. *Etikonomi, 22*(1), 31–44. 10.15408/etk.v22i1.23428.

Goodwin, B. K. (2021). Price Transmission in Agricultural Markets. *Annual Review of Resource Economics*. https://doi.org/10.1146/annurev-resource-100518-093938

Gordon, D. F., (1959). What Was the Labor Theory of Value? *American Economic Association*, 462-472.

Gorter, H. D., & Drabik, D., (2015). Policy Update: The Effect of Biofuel Policies on Food Grain Commodity Prices. *Biofuel, 3*(1), 21-24.

Gorter, H. D., & Drabik, D., (2016). Biofuel policies and the impact of developing countries' policy responses to the 2007–2008 food price boom. *Global Food Security, 11,* 64-71. 10.1016/j.gfs.2016.07.008.

Gujarati, D. N., & Porter, D. C. (2009). *Basic econometrics*. Boston, Mass: McGraw-Hill.

Guler, M. G., Bilgic, T., & Gullu, R., (2015). Joint Pricing and Inventory Control for Additive Demand Models with Reference Effects. *Ann Oper Res, 226*, 255-276. 10.1007/s10479-014-1706-3.

Guo, J., & Tanaka, T. (2022). Do biofuel production and financial speculation in agricultural commodities influence African food prices? New evidence from a TVP-VAR extended joint connectedness approach. *Energy Economics, 116*, 106422. https://doi.org/10.1016/j.eneco.2022.106422

Guo, L., & Liu, Y. (2022). Urban-Industrial Development and Regional Economic Growth in a Developing Country: A Spatial Econometric Approach. *SAGE Open*. https://doi.org/10.1177/21582440221102425

Hamit-Haggar, M. (2011). Greenhouse gas emissions, energy consumption and economic growth: A panel cointegration analysis from Canadian industrial sector perspective. *Energy Economics, 34*(1), 358-364. https://doi.org/10.1016/j.eneco.2011.06.005

Hanaysha, J. R., (2018). An examination of the factors affecting consumer's purchase decision in the Malaysian retail market. *PSU Research Review, 2*(1), 7-23. 10.1108/PRR-08-2017-0034.

Harri, A., Nalley, L., & Hudson, D., (2023). The relationship between oil, exchange rates, and commodity prices. *Journal of Agricultural and Applied Economics, 41*(2), 501–510.

Harsono, A., Harnowo, D., Ginting, E., & Adi Anggraeni Elisabeth, D. (2022). Soybean in Indonesia: Current Status, Challenges and Opportunities to Achieve Self-Sufficiency. *Intech Open*. 10.5772/intechopen.101264.

Hartley, F., Seventer, D. V., Tostao, E., & Arndt, C., (2019). Economic impacts of developing a biofuel industry in Mozambique. *Development Southern Africa, 36*(2), 233-249. 10.1080/0376835X.2018.1548962.

Hasan, M., Abedin, M. Z., Amin, M. B., Nekmahmud, M., & Olah, J., (2023). Sustainable biofuel economy: A mapping through bibliometric research. *Journal of Environmental Management, 336*, 117644. 10.1016/j.jenvman.2023.117644.

Haskel, J., & Wolf, H. (2001). The Law of One Price: A Case Study. *The Scandinavian Journal of Economics, 545*. https://doi.org/3441004

Haug, A. A., & Baster, S. A., (2007). *Linear or Nonlinear cointegration in the purchasing power parity relationship?* (Economics Discussion Papers), 0712. http://www.business.otago.ac.nz/econ/research/discussionpapers/index.html.

Hendry, D. F., & Morgan, M. S., (1929). Statistical Laws of Demand and Supply. *Journal of the American Statistical Association, 24*, 225-232.

Herrmann, R., Jumbe, C., Bruentrup, M., & Osabuohien, E., (2018). Competition between biofuel feedstock and food production: Empirical evidence from sugarcane out grower settings in Malawi. *Biomass and bioenergy*, *114*, 77–86. 10.1016/j.biombioe.2017.09.002.

Heuvelen, E. V., (2023, June). Subsidy Wars, Cooperation and common understanding could dial back trade tensions. International Monetary Fund. https://www.imf.org/en /Publications/fandd/issues/2023/06/B2B-subsidy-wars-elizabeth-vanheuvelen#:~:text=What's%20wrong%20with20subsidies%3F,resources%20to%20less%20productive%20uses.

Hitchcock, G., & Hughes, D. P. (1989). *Research and the teacher: A qualitative introduction to school-based research*. Routledge.

Hong N. N., Kim L. V. T., Hoang A. P., & Khanh, C. T. Q., (2022) Understanding exchange rate pass-through in Vietnam. *Cogent Economics & Finance, 10*(1). 2139916. 10.1080/23322039.2022.2139916.

Hung N. T., (2021). Oil prices and agricultural commodity markets: Evidence from pre and during COVID-19 outbreak. *Resour Policy, 73*, 102236. 10.1016/j.resourpol.2021.102236.

Hussain N. E., Shaari, M. S., & Abdullah, D. N. C., (2018). Effects of Retailing Selling Prices of Petrol and Diesel on Food Prices. *International Journal of Energy Economics and Policy, 8*(4), 28-32.

Hussein, M. E., Siwar, C., & Adham, K. N. (2017). The Role of Malaysian Palm Oil Industry in the Malaysian Sustainable Economic Development. *International Journal of the Malay World and Civilisation (Iman), 5*(Special Issue 1), 11-18.

Ibrahim, M. H. (2015). Oil and Food Prices in Malaysia: A Non-linear ARDL Analysis. *Agricultural and Food Economics, 3*(2), 1-14. 10.1186/s40100-014-0020-3.

Ina, I., Nor, A. I., & Rahyla, S. S., (2022). The Effect of Agriculture, Manufacturing and Transportation on Environmental Quality in Indonesian Selected Provinces. *Journal of Sustainability Science and Management, 17*(2), 187-204. 10.46754/jssm.2022.02.014.

Indonesian Palm Oil Association. (2021, December 24). Palm Oil to Remain World's Most Important Vegetable Oil In 2022. https://gapki.id/en/news/2021/12/24/palm-oil-to-remain-worlds-most-important-vegetable-oil-in-2022/

International Monetary Fund (IMF, 2008). Food and Fuel Prices – Recent Developments, Macroeconomic Impact, and Policy Response. Washington, DC: IMF.

International Monetary Fund (IMF, 2023)[a]. Inflation rate, average consumer prices. https://www.imf.org/external/datamapper/PCPIPCH@WEO/MYS/KHM/PAK?year=2022.

International Monetary Fund (IMF, 2023)[b]. The outlook is uncertain again amid financial sector turmoil, high inflation, ongoing effects of Russia's invasion of Ukraine, and three years of COVID. https://www.imf.org/en/Publications/WEO/Issues/2023/04/11/world-economic-outlook-april-2023.

Jaen-Garcia, M. (2021). Displacement Effect and Ratchet Effect: Testing of Two Alternative Hypotheses. *SAGE Open*. *11*(4), 21582440211061409. 10.1177/21582440211003577.

Janda, K., & Krištoufek, L. (2018). *The relationship between fuel, biofuel and food prices: Methods and outcomes* (No. 32/2018). IES Working Paper.

Janda, K., & Kristoufek, L. (2019). The Relationship between Fuel and Food Prices: Methods, Outcomes, and Lessons for Commodity Price Risk Management. *Annual Review of Resource Economics, 11*(1), 195–216. 10.1146/annurev-resource-100518-094012.

Janda, K., Michalikova, E., Rocha, L. C., Rotella Junior, P., Schererova, B., & Zilberman, D. (2022). Review of the Impact of Biofuels on U.S. Retail Gasoline Prices. *Energies, 16*(1), 428. 10.3390/en16010428.

Jarantow, S. W., Pisors, E. D., & Chiu, M. L. (2023). Introduction to the Use of Linear and Nonlinear Regression Analysis in Quantitative Biological Assays. *Current Protocols, 3*(6), e801. https://doi.org/10.1002/cpz1.801

Ji, Q. & Fan, Y., (2012). How Does Oil Volatility Affect Non-Energy Commodity Markets? *Applied Energy, 89*, 273-280. 10.1016/j.apenergy .2011.09.018.

Johansen, S., & Juselius, K., (1990). Maximum Likelihood Estimation and Inference on Cointegration with Applications to Money Demand. *Oxford Bulletin of Economics and Statistics, 52*, 169–210. 10.1111/j.1468-0084.1990.mp52002003.x.

Johari, A., Nyakuma, B. B., Nor, S. H. M., Mat, R., Hashim, H., Ahmad, A., Zakaria, Z. Y., & Abdullah, T. A. T., (2015). The Challenges and Prospects of Palm Oil Based Biofuel in Malaysia. *Energy, 81*, 255-261. 10.1016/j.energy.2014.12.037.

Jones, E., (1997). Consumer Demand for Carbohydrates: A Look across Products and Income Classes. *Agrobusiness, 13*(6), 599-612. 10.1002/(SICI)1520-6297(199711/12)13:6<599::AID-AGR5>3.0.CO;2-Z.

Julnes, G. (2019). Evaluating Sustainability: Controversies, Challenges, and Opportunities. *New Directions for Evaluation, 2019*(162), 13-28. https://doi.org/10.1002/ev.20361

Kamalu, K., & Wan Ibrahim, W. H. B. (2021). Foreign Remittances, Good Governance and Human Development in Sub-Saharan Africa: Evidence from FMOLS and DOLS. *The Journal of Management Theory and Practice (JMTP), 2*(4), 38–48. 10.37231/jmtp.2021.2.4.151.

Karkowska, R., & Urjasz, S. (2024). Importance of geopolitical risk in volatility structure: New evidence from biofuels, crude oil, and grains commodity markets. *Journal of Commodity Markets, 36*, 100440. https://doi.org/10.1016/j.jcomm.2024.100440

Kakpo, A., Mills, B. F., & Brunelin, S. (2022). Weather shocks and food price seasonality in Sub-Saharan Africa: Evidence from Niger. *Food Policy, 112*, 102347. https://doi.org/10.1016/j.foodpol.2022.102347

Kalkuhl, M. (2016). How Strong Do Global Commodity Prices Influence Domestic Food Prices in Developing Countries? A Global Price Transmission and Vulnerability Mapping Analysis. In: Kalkuhl, M., von Braun, J., Torero, M. (eds) Food Price Volatility and Its Implications for Food Security and Policy. *Springer, Cham*. https://doi.org/10.1007/978-3-319-28201-5_12

Kalogiannidis, S., Chatzitheodoridis, F., Kontsas, S., & Syndoukas, D., (2023). Impact of bioenergy on economic growth and development: An European perspective. *International Journal of Energy Economics and Policy, 13*(3), 494-506. 10.32479/ijeep.14220.

Kapetanios, G., & Tzavalis, E. (2010). Modeling structural breaks in economic relationships using large shocks. *Journal of Economic Dynamics and Control, 34*(3), 417-436. https://doi.org/10.1016/j.jedc.2009.10.001

Kapusuzoglu, A. & Ulusoy, M. K., (2015). The interactions between agricultural commodity and oil prices: an empirical analysis. *Agricultural Economics (Czech), 61*(9), 410–421. 10.17221/231/2014-AGRICECON.

Kargbo, J. M., (2005). Exchange rate volatility and agricultural trade under policy reforms in South Africa. *Development Southern Africa, 23*(1), 147-170. 10.1080/03768350600556315.

Kerdan, I. G., Giarola, S., Skinner, E., Tuleu, M., & Hawkes, A. (2020). Modelling Future Agricultural Mechanisation of Major Crops in China: An Assessment of Energy Demand, Land Use and Emissions. *Energies, 13*(24), 6636. 10.3390/en13246636.

Khalid, S., (2022, July 19). Additional RM20b oil and tax revenue insufficient to cover over RM40 billion surge in subsidies, says Zafrul. The Edge Market. https://theedgemalaysia.com/article/additional-rm20b-oil-and-tax-revenue-insufficient-cover-over-rm40-billion-surge-subsidies.

Khan, M. A. M., (1995). Impact of Households Income on Demand for Means of Transportation and Communication: A Case Study of Karachi. *Pakistan Economic and Social Review, 33*(1/2), 117-136.

Khatun, R., Reza, M. I. H., Moniruzzaman, M., & Yaakob, Z., (2017). Sustainable oil palm industry: The possibilities. *Renewable and Sustainable Energy Reviews, 76* (C), 608-619. 10.1016/j.rser.2017.03.077.

Kirchgassner, G., & Wolters, J., (2007). Introduction to modern time series analysis. New York: Springer Berlin Heidelberg. 10.1007/978-3-540-73291-4.

Kochaphum, C., Gheewala, S. H., & Vinitnantharat, S., (2013). Does biofuel demand affect palm oil prices in Thailand? *Energy for Sustainable Development, 17*(6), 658–670. 10.1016/j.esd.2013.07.005.

Koizumi, T. (2015). Biofuels and food security. *Renewable and Sustainable Energy Reviews, 52*, 829-841. 10.1016/j.rser.2015.06.041.

Kotil, E. (2019). Exports, Imports, and the Exchange Rate: A Causality Analysis for Turkey (2004–2017). *Contemporary Issues in Behavioural Finance Contemporary Studies in Economic and Financial Analysis, 101*, 163-170. 10.1108/S1569-375920190000101011.

Kouris, G., (1976). The Determinants of Energy Demand in the EEC Area. *Energy Policy*, *4*(4), 343-355. 10.1016/0301-4215(76)90027-6.

Kretschmer, B, Bowyer, C & Buckwell, A (2012) EU Biofuel Use and Agricultural Commodity Prices: A Review of the Evidence Base. *Institute for European Environmental Policy (IEEP): London*.

Kristoufek, L., Janda, K., & Zilberman, D., (2012). Relationship between Prices of Food, Fuel, and Biofuel. [Seminar Paper]. 131st EAAE Seminar ‘Innovation for Agricultural Competitiveness and Sustainability of Rural Areas’, Prague, Czech Republic, September 18-19, 2012.

Kulshreshtha, M., & Parikh, J., (2000). Modelling demand for coal in India: Vector autoregressive models with cointegrated variables. *Energy, 25*(2), 149-168. 10.1016/S0360-5442(99)00059-6.

Kumeka, T. T., Uzoma-Nwosu, D. C., & David-Wayas, M. O. (2022). The effects of COVID-19 on the interrelationship among oil prices, stock prices and exchange rates in selected oil exporting economies. *Resources Policy, 77*, 102744. 10.1016/j.resourpol.2022.102744.

Kurowska, K., Marks-Bielska, R., Bielski, S., Kryszk, H., & Jasinskas, A. (2020). Food security in the context of liquid biofuels production. *Energies*, *13*(23), 6247. 10.3390/en13236247.

Kusz, D., Kusz, B., & Hydzik, P., (2021). Changes in the Price of Food and Agricultural Raw Materials in Poland in the Context of the European Union Accession. *Sustainability, 14*(8), 4582. https://doi.org/10.3390/su 14084582

Lanclos, D. K., Devadoss, S., & Guenthner, J., (1997). Impacts of Foreign Direct Investment and Advertising on the Export Demand for U.S. Frozen Potatoes. *Agrobusiness, 13*(3), 273-284.

Landes, M., Melton, A., & Edwards, S., (2016, July 05). *India Emerges as a Major Beef Exporter.* USDA, Economic Research Service. https://www.ers.usda. gov/amber-waves/2016/july/india-emerges-as-a-major-beef-exporter/.

Leung, D., & Yuen, T. (2005). Do Exchange Rates Affect the Capital-Labour Ratio? *Working Paper 2005-12 / Document de travail 2005-12*.

Li, Y., Miao, L., Chen, Y., & Hu, Y. (2019). Exploration of sustainable urban transportation development in China through the forecast of private vehicle ownership. *Sustainability*, *11*(16), 4259.

Lily, J., Kogid, M., Nipo, D. T., & Lajuni, N. (2023). Oil price pass-through into inflation revisited in Malaysia: The role of asymmetry. *Journal of Applied Economics, 28*(2), 387-412.

Lodico, M., Spaulding, D. & Voegtle, K. (2010). Methods in Educational Research: From Theory to Practice, 2nd Edition. *San Francisco, CA: Jossey-Bass.*

Lutz, W. R., & Qiang, (2002). Determinants of human population growth. *Biol. Sci. 357*(1425), 1197–1210. https://doi.org/10.1098/rstb.2002.1121.

Maaouane, M., Zouggar, S., Karjacic, G., & Zahboune, H. (2021). Modelling industry energy demand using multiple linear regression analysis based on consumed quantity of goods. *Energy, 225,* 120270. https://doi.org /10.1016/j.energy.2021.120270

Madsen, J., & Strulik, H., (2020). Technological change and inequality in the very long run. *European Economic Review*, *129*, 103532. https://doi. org/10.1016/j.euroecorev.2020.103532

Maeda, M., Tokimatsu, K., & Mori, S., (2015). A global supply-demand balance model to assess potential CO2 emissions and woody biofuel supply from increased crop production. *Energy Procedia, 75*, 2865-2870.

Mahmood, J., Rajaram, N. N., & Guinto, R. R. (2022). Addressing Food Insecurity and Climate Change in Malaysia: Current Evidence and Ways Forward. *The Malaysian Journal of Medical Sciences : MJMS*, *29*(6), 1-5. https://doi.org/10.21315/mjms2022.29.6.1

Majuca, R. P., (2020). Assessing the Impact of Oil Prices on the Malaysian Economy. *The ASEAN+3 Macroeconomic Research Office (AMRO)*, Working Paper, WP/20-02.

Malaysia Productivity Corporation (2022, July 15). The sudden price hike of cooking oil — what is the issue? The Edge Market. https://theedgemalaysia.com/article/sudden-price-hike-cooking-oil-%E2%80%94-what-issue.

Malaysian Investment Development Authority (MIDA)[a]. (2021, December 13). Malaysia has started production of second-generation biodiesel, biojet fuel. https://www.mida.gov.my/mida-news/malaysia-has-started-production-of-second-generation-biodiesel-biojet-fuel/

Ministry of International Trade and Industry. (2022)[b]. MITI report 2021. https://www.miti.gov.my

Malode, S. J., Prabhu, K. K., Mascarenhas, R. J., Shetti, N. P., & Aminabhavi, T. M. (2021). Recent advances and viability in biofuel production. *Energy Conversion and Management, 10*, 100070. https://doi.org/10.1016/j.ecmx.2020.100070

Mankiw, N. G., (2004). Aggregate Demand in the Open Economy (Chapter 12). Book: Macroeconomics, fifth edition. *Worth Publisher*.

Manogna R. L., M., & Kulkarni, N. (2024). Does the financialization of agricultural commodities impact food security? An empirical investigation. *Borsa Istanbul Review*. https://doi.org/10.1016/j.bir.2024.01.001

Martínez-Jaramillo, J. E., Arango-Aramburo, S., & Giraldo-Ramírez, D. P. (2019). The effects of biofuels on food security: A system dynamics approach for the Colombian case. *Sustainable Energy Technologies and Assessments*, *34*, 97-109. https://doi.org/10.1016/j.seta.2019.05.009

Markel, E., Sims, C., & English, B. C., (2018). Policy uncertainty and the optimal investment decisions of second-generation biofuel producers. *Energy Economics, 76*, 89-100. https://doi.org/10.1016/j.eneco.2018.09.017

Matsuo, T., & Schmidt, T. S. (2019). Managing tradeoffs in green industrial policies: The role of renewable energy policy design. *World Development*, *122*, 11-26. https://doi.org/10.1016/j.worlddev.2019.05.005.

McCarty, T., & Sesmero, J., (2014). Uncertainty, irreversibility, and investment in second generation biofuels. *BioEnergy Research, 8*(2), 675–687.

Mehic, A., (2018). Industrial employment and income inequality: Evidence from panel data. *Structural Change and Economic Dynamics, 45,* 84-93. https://doi.org/10.1016/j.strueco.2018.02.006.

Mele, F. D., Guillén-Gosálbez, G., & Jiménez, L. (2008). Optimal Planning of Supply Chains for Bioethanol and Sugar Production with Economic and Environmental Concerns. *Computer Aided Chemical Engineering, 26*, 997-1002. https://doi.org/10.1016/S1570-7946(09)70166-X

Merlin, M. L., & Chen, Y. (2021). Analysis of the factors affecting electricity consumption in DR Congo using fully modified ordinary least square (FMOLS), dynamic ordinary least square (DOLS) and canonical cointegrating regression (CCR) estimation approach. *Energy, 232*, 121025. https://doi.org/10.1016/j.energy.2021.121025

Merriam, S. B., (2009). Qualitative research: A guide to design and implementation. *San Francisco, CA: Jossey-Bass*.

Miljkovic, D. (1999). The Law of One Price in International Trade: A Critical Review. *Applied Economic Perspectives and Policy, 21*(1), 126-139. https://doi.org/10.2307/1349976

Miller, J. I., & Ratti, R. A., (2009). Crude oil and stock markets: Stability, instability, and bubbles. *Energy economics, 31*(4), 559-568. https://doi.org/10.1016/j.eneco.2009.01.009.

Ministry of Finance (MOF, 2022). *Economic Outlook 2023*. https://budget.mof.gov.my/pdf/2022/economy/economy-2022.pdf.

Ministry of International Trade and Industry. (2021). MITI Report 2021. Ministry of International Trade and Industry Malaysia. https://www.miti.gov.my

Mitchell D., (2018). Why Is There a Ratchet Effect? Evidence from Civil War Income Taxes. *Public Choice Analyses of American Economic History,* 69-86. https://doi.org/10.1007/978-3-319-77592-0_5.

Mitchell, D., (2008). *A Note on Rising Food Prices*. Policy Research (Working Paper, No. 4682), the World Bank Development Prospects Group. https://doi.org/10.1596/1813-9450-4682.

Mohd Amin, S. I., Abdul-Rahman, A., Janor, H., Mohd Asri, A. K., & Muchtar, D. (2019). Financial development and performance of palm oil industry in Malaysia. *Economic Journal of Emerging Markets*, *11*(2), 135–151. https://doi.org/10.20885/ejem.vol11. iss2.art2

Moore, H. L., (1919). Empirical Laws of Demand and Supply and the Flexibility of Prices. *Political Science Quarterly, 34*(4), 546-567.

Mosarof M.H. (2015). Implementation of palm biofuel based on economic aspects, performance, emission, and wear characteristics. *Energy Conversation. Management, 105*, 617–629. https://doi.org/10.1016/j.enconman.2015.08.027

Mueller, S. A., Anderson, J. E., & Wallington, T. J., (2011). Impact of biofuel production and other supply and demand factors on food price increases in 2008. *Biomass and Bioenergy, 35*(5), 1623-1632. https://doi.org/10.1016/j.biombioe.2011.01.030

Murphy, D. J., Goggin, K., & Paterson, R. R. M. (2021). Oil palm in the 2020s and beyond: challenges and solutions. *CABI Agric Biosci, 2*, 39. https://doi.org/10.1186/s43170-021-00058-3

Murshed, M., (2021). Modeling primary energy and electricity demands in Bangladesh: An Autoregressive distributed lag approach. *Sustainable Production and Consumption, 27*, 698-712. https://doi.org/10.1016/j.spc.2021.01.035

Nambiappan B., Ismail A., Hashim N., Ismail N., Nazrima D., Idris N A N., Omar N., Salleh K M., Hassan N A M., Kushairi A. (2018). Malaysia: 100 years of resilient palm oil economic performance. *Journal of Oil Research, 30*(1), 13-25. https://doi.org/10.21894/jopr.2018.0014

Nambiar, S. (2009). Revisiting Privatisation in Malaysia: The Importance of Institutional Process. *Asian Academy of Management Journal, 14*(2), 21–40.

Narayan, P. K., (2005). The saving and investment nexus for China: Evidence from cointegration tests. *Applied Economics, 37*(17), 1979–1990. https://doi.org/10.1080/00036840500278103

Natoli, F., (2021). Financialization of Commodities Before and After the Great Financial Crisis. *Journal of Economic Surveys, 35*(2), 488-511. https://doi.org/10.1111/joes.12408

Nazlioglu, S., & Soytas, U. (2011). World Oil Prices and Agricultural Commodity Prices: Evidence from an Emerging Market. *Energy Economics*, *33*, 488-496. https://doi.org/10.1016/j.eneco.2010.12.007

Nazmi, M. S., Dardak, R. A., Rani, R. A., & Rabu, M. R., (2021). Benchmarking Indonesia for the Development of the Grain Corn Industry in Malaysia. *Food and Fertilizer Technology Center for the Asian and Pacifit Region.* https://ap.fftc.org.tw/article/2782

Negash, M., & Swinnen, J., (2013). Biofuels and food security: Micro-evidence from Ethiopia. *Energy Policy, 61*, 963-976. https://doi.org/10.1016/j.enpol.2013.06.040

Neo, P., (2021). Turbulent Times Ahead? Malaysia Palm Oil Faces Uncertain 2021 With Price, Production and Policy Challenges. Food Safety Analysis. Retrieved from: https://www.foodnavigator-asia.com/Article/2021/01/19/

Turbulent-times-ahead-Malaysia- palm-oil-faces-uncertain-2021-with-price-production-and-policy-challenges.

New Straits Times (2022, December 02). Speed up implementation of targeted fuel subsidy: CAP.https://www.nst.com.my/news/nation/2022/12/856948/speed-implementation-targeted-fuel-subsidy-cap.

Nigatu, G., Badau, F., Seeley, R., & Hansen, J. (2020). Factors contributing to changes in agricultural commodity prices (ERR-272). U.S. Department of Agriculture, Economic Research Service.

Nkoro, E., & Uzoamaka, N., (2017). Robustness of Autoregressive Distributed Lag (ARDL) Model to Multicollinearity. *International Journal of Scientific Research and Management, 5*(12), 7303-7308.

Norazman, U. Z., Khalid, H., & Ghani, G. M. (2018). Food inflation: A study on key determinants and price transmission processes for Malaysia. *International Journal of Business and Society, 19*(1), 117-138.

Noriega, M., & Narváez, P. (2020). Scale-up and cost analysis of biodiesel production using liquid-liquid film reactors: Reduction in the methanol consumption and investment cost. *Energy, 211*, 118724. https://doi.org/10.1016/j.energy.2020.118724.

Nsor-Ambala, R. & Amewu, G. (2023). Linear and non-linear ARDL estimation of financial innovation and economic growth in Ghana. *Journal of Business and Socio-economic Development, 3*(1), 36-49. https://doi.org/10.1108/JBSED-09-2021-0128

Nurul Eza Maisara Mohd Mahayuddin, Sharifah Nur Afiqah Syed Mustaffa, Hafiza Shukor, Jennifer Patero Tamayo, Farizul Hafiz Kasim (2022). Biodiesel production in Malaysia: Current status and challenges. *AIP Conf. Proc. 18 November 2022; 2541 (1)*, 020005. https://doi.org/10.1063/5.0113176.

Olorogun, L.A. Modelling Financial Development in the Private Sector, FDI, and Sustainable Economic Growth in sub-Saharan Africa: ARDL Bound Test-FMOLS, DOLS Robust Analysis. *J Knowl Econ (2023)*. https://doi.org/10.1007/s13132-023-01224-w

Ordu-Akkaya, B. M., & Soytas, U. (2020). Unconventional monetary policy and financialization of commodities. *The North American Journal of Economics and Finance, 51*, 100902. https://doi.org/10.1016/j.najef.2018.12.014.

Organisation for Economic Co-operation and Development (OECD) Economic Outlook (2023, June). Chapter 2: The war in Ukraine and its impact on the global economy. https://www.oecd.org/economic-outlook/june-2023/.

Organisation for Economic Co-operation and Development (OECD, 2008). Rising food prices: causes and consequences. Paris: OECD.

Othman, A. N., & Masih, M. (2015). Do profit and loss sharing (PLS) deposits also affect PLS financing? Evidence from Malaysia based on DOLS, FMOLS and system GMM techniques. *Munich Personal RePEc Archive, 65224*, 1–23. https://mpra.ub.unimuenchen.de/65224/1/MPRA_paper_65224.pdf

Oztek, M. F., (2013). Financial Crises, Financialization of Commodity Markets and Correlation of Agricultural Commodity Index with Precious Metal Index and S&P500. *ERC Working Papers in Economics 13/02*.

Ozturk, I., & Acaravci, A., (2010)[a]. Testing the causal relationship between energy consumption, economic growth, and carbon emissions: ARDL bounds approach. *Environmental Science & Policy 13*(5), 310-315. https://doi.org/10.1016/j.envsci.2010.03.010.

Ozturk, I., & Acaravci, A., (2010)[b]. The causal relationship between energy consumption and GDP in Albania, Bulgaria, Hungary and Romania: Evidence from ARDL bound testing approach. *Applied Energy, 87*, 1938-1943. https://doi.org/10.1016/j.apenergy.2009.10.010.

Palacio-Ciro, S., & Vasco-Correa, C. A., (2020). Biofuels policy in Colombia: A reconfiguration to the sugar and palm sectors? *Renewable and Sustainable Energy Reviews, 134,* 110316.https://doi.org/10.1016 /j.rser.2020.110316

Parveez, G. K. A., Hishamuddin, E., Loh, S. K., Ong-Abdullah, M., Mohamed Salleh, K., Zanal Bidin, M. N. I., Sundram, S., Hasan, Z. A. A., & Idris, Z. (2020). Oil palm economic performance in Malaysia and R&D progress in 2019. *Journal of Oil Palm Research, 32*(2), 159-190. https://doi.org/10.21894/jopr.2020.0032.

Peersman, G., Rüth, S. K., & Van der Veken, W. (2021). The interplay between oil and food commodity prices: Has it changed over time? *Journal of International Economics, 133*, 103540. https://doi.org/10.1016/j.jinteco.2021.103540

Peri, M., & Baldi, L., (2013). The Effect of Biofuel Policies on Feedstock Market: Empirical Evidence for Rapeseed Oil Prices in E.U. *Resource and Energy Economics, 35*(1), 18-37. https://doi.org/10.1016/j.reseneeco.2012.11.002

Persson, U. M., (2015). The Impact of Biofuel Demand on Agricultural Commodity Prices: A Systematic Review. *WIREs Energy Environ, 4*, 410–428. https://doi.org/10.1002/wene.155

Pesaran, M. H, & Shin, Y., (1999). An autoregressive distributed lag modeling approach to cointegration analysis. Chapter 11 in econometrics and economic theory in the 20th century: *The Ragnar Frisch Centennial Symposium, Strom S (ed.). Cambridge University Press: Cambridge.* https://doi.org/10.1017/CBO9781139052279.011

Pesaran, M. H., Shin, Y., & Smith, R., (2001). Bounds Testing Approaches to the Analysis of Level Relationships. *Journal of Applied Econometrics, 16*, 289 – 326. https://doi.org/10.1002/jae.616

Petruzzi, N. C., & Dada, M., (1997). Pricing and the Newsvendor Problem: A Review with Extensions. *Operations Research, 47*(2), 183-194. https://doi.org/10.1287/opre.47.2.183

Pierru, A., (2007). Allocating the CO2 Emissions of An Oil Refinery with Aumann–Shapley Prices. *Energy Economics, 29*(3), 563-577. https://doi.org/10.1016/j.eneco.2006.10.007

Priyati, R. Y., & Tyers, R., (2016). Price Relationships in Vegetable Oil and Energy Markets. [Discussion Paper]. Annual Australasian Development Economics Workshop Deakin University, 9-10 June 2016.

Proost, S., & Van de Loo, S. V. D. (2010). Transport infrastructure investment and demand. *Transportation Research Part A: Policy and Practice, 44*(9), 779-790. https://doi.org/10.1016/j.tra.2010.07.001

Rahman, M. M., Deb, S., Strawderman, L., Burch, R., & Smith, B. (2019). How the older population perceives self-driving vehicles. *Transportation Research Part F: Traffic Psychology and Behaviour, 65*, 242-257. https://doi.org/10.1016/j.trf.2019.07.020

Rahman, S. A., (2017). Rise of the Machines Redux – Education, Technological Transition and Long-run Growth. Departmental Working Papers 61, *United States Naval Academy Department of Economics*.

Rajcaniova, M., Drabik, D., & Ciaian, P., (2013). How Policies Affect International Biofuel Price Linkages. *Energy Policy, 59*, 857-865. https://doi.org/10.1016/j.enpol.2013.04.010

Rambaldi, A., & Doran, H., (1996). Testing for Granger Non-Causality in Cointegrated Systems Made Easy. *Working Papers in Econometrics and Applied Statistics*, No.88. University of New England.

Rashidi, N. A., Chai, Y. H. & Yusup, S., (2022). Biomass Energy in Malaysia: Current Scenario, Policies, and Implementation Challenges. *Bioenergy Resources, 15*, 1371–1386.

Razak, M. I. M., Hamzah, A. S. M. A., Abas, N., Idras, R., Ibrahim, Z., (2013). Sustaining Food Production for Food Security in Malaysia. *Journal of Economics and Development Studies, 1* (2), 19-25.

Reuters. (2022, December 23). Malaysia slams EU deforestation-free law for blocking palm oil market access. https://www.reuters.com/business/sustainable-business/malaysia-slams-eu-deforestation-free-law-blocking-palm-oil-market-access-2022-12-23/

Robinson, M. A., (1973). Determinants of Demand for Fish and Their Effects upon Resources. *Journal Fisheries Research Board of Canada,30*(12), 2051-2058. https://doi.org/10.1139/f73-334

Rodionova, M., Poudyal, R., Tiwari, I., Voloshin, R., Zharmukhamedov, S., Nam, H., Zayadan, B., Bruce, B., Hou, H., & Allakhverdiev, S. (2017). Biofuel production: Challenges and opportunities. *International Journal of Hydrogen Energy, 42*(12), 8450-8461. https://doi.org/10.1016/j.ijhydene.2016.11.125

Rodrik, D., (2016). Premature deindustrialization. *Journal of Economic Growth, 21*(1), 1-33. https://doi.org/10.1007/s10887-015-9122-3

Rosali, M. H., Rabu, M. R., Nor, N. A., (2019). An Overview of the Grain Corn Industry in Malaysia. *FFTC Agricultural Policy Platform (FFTC-AP).*

Rose, R., & Paparas, D. (2023). Price Transmission: The Case of the UK Dairy Market. *Commodities, 2*(1), 73-93. https://doi.org/10.3390/commodities2010004

Rosegrant, M. W., (2008). Biofuels and Grain Prices: Impacts and Policy Responses. *International food Policy Research Institute*. Testimony for the U.S. Senate Committee on Homeland Security and Government Affairs, May 2008.

Royfaizal, R. C. (2009). Crude oil consumption and economic growth: empirical evidence from Japan. *Integration & Dissemination, 4*, 87-93.

Ruan, X. & Zhang, J. E., (2018). Equilibrium Variance Risk Premium in a Cost-free Production Economy. *Journal of Economic Dynamics and Control, 98*, 42-60. https://doi.org/10.1016/j.jedc.2018.08.011

Sachs, J. D., Lafortune, G., Fuller, G., & Drumm, E. (2023). Implementing the SDG Stimulus. *Sustainable Development Report 2023*. Paris: SDSN, Dublin: Dublin University Press. https://doi.org/10.25546/102924

Sadorsky, P., (2009). Renewable Energy Consumption, CO2 Emissions and Oil Prices in the G7 Countries. *Energy Economics, 31*, 456-462. https://doi.org/10.1016/j.eneco.2008.12.010

Safiullin, M. R., Elshin, L. A., & Prygunova, M. I. (2014). Assessment of the Sustainable Development Prospects and Competitiveness of Industrial Production of a Region under External Shock "Impulses": The Case of the Republic of Tatarstan. *Procedia Economics and Finance, 24*, 574-582. https://doi.org/10.1016/S2212-5671(15)00638-3

Said, E. S., & Dickey, A. D., (1984). Testing for Unit Roots in Autoregressive-Moving Average Model of Unknown Order. *Biometrika , 71*(3), 599-607. https://doi.org/10.1093/biomet/71.3.599

Samal, A., Ummalla, M., & Goyari, P. (2022). The impact of macroeconomic factors on food price inflation: An evidence from India. *Future Business Journal, 8*(1), 1-14. https://doi.org/10.1186/s43093-022-00127-7

Sarmidi, T., Azam, A. H. M., Nor, A. H. S. M., & Zakaria, K. (2022). The Role of Palm Oil in Stabilising the Price of Vegetable Oil Market: Empirical

Evidence Using MGARCH Approach. *Journal of Sustainability Science and Management, 17*(3), 19-31.

Sayyed Mahdi Ziaei & Issa Ali (2021). Commodity exports and macroeconomic performance: The case of palm oil in Malaysia, *Cogent Economics & Finance, 9*(1), DOI: 10.1080/23322039.2021.1901388

Schneider, U. A., (2011). Impacts of Population Growth, Economic Development, and Technical Change on Global Food Production and Consumption. *Agric. Syst. 104*(2), 204–215. https://doi.org/10.1016/j.agsy.2010.11.003

Scott Long, & Laurie H. Ervin. (2000). Using Heteroscedasticity Consistent Standard Errors in the Linear Regression Model. *The American Statistician, 54*(3), 217-224. DOI: 10.1080/00031305.2000.10474549

Serra, T., & Zilberman (2013). Biofuel-related price transmission literature: A review. *Energy Economics, 37*, 141-151. https://doi.org/10.1016/j.eneco.2013.02.014

Sek, S. K. (2017). Impact of oil price changes on domestic price inflation at disaggregated levels: Evidence from linear and nonlinear ARDL modeling. *Energy*, *130*, 204-217. https://doi.org/10.1016/j.energy.2017.03.152

Shahbaz, M., Awan, R. U., & Nasir, N. M., (2009). Producer & Consumer Prices Nexus: ARDL Bounds Testing Approach. *International Journal of Marketing Studies, 1*(2), 78-86.

Shamsudin, M. N. (2022). *Rising food prices: Why, who are affected, and how to cushion the impact?* The Malaysian Reserve. Retrieved from https://www.freemalaysiatoday.com/category/nation/2022/07/01/rising-food-prices-explained/

Sharimakin, A., (2021). Modelling asymmetric price responses of industrial energy demand with a dynamic hierarchical model. *Energy Economics, 98*, 105255. https://doi.org/10.1016/j.eneco.2021.105255

Sharma, Y. C., & Singh, V., (2017). Microalga biofuel: A possible solution for India's energy security. *Renewable and Sustainable Energy Reviews, 67*, 72–88. https://doi.org/10.1016/j.rser.2016.08.031

Sharma, S. S. (2020). The role of palm oil price in Indonesia’s aggregate demand. *Bulletin of Monetary Economics and Banking, 23*(2), Article 1. https://doi.org/10.21098/bemp.v23i2.1305

Sherif, M., & Shaairi, N. A., (2013). Determinants of Demand on Family Takaful in Malaysia. *Journal of Islamic Accounting and Business Research, 4*(1), 26-50. https://doi.org/10.1108/17590811311314276

Shiozawa, Y., (2016). The Revival of Classical Theory of Values. Nobuharu Yokokawa et als. (Eds.). *The Rejuvenation of Political Economy*, May 2016, Oxon and New York: Routledge. Chapter 8, 151-172.

Shrestha, D. S., Staab, B. D., & Duffield, J. A., (2019). Biofuel impact on food prices index and land use change. *Biomass and bioenergy, 124* (24), 43-53. https://doi.org/10.1016/j.biombioe.2019.03.015

Shrestha, M. B., & Chowdhury, K., (2005). ARDL modeling approach to testing the financial liberalization hypothesis. *University of Wollongong, Economics Working Paper Series 2005,* 05-15.

Soliman, A. M., Lau, C. K., Cai, Y., Sarker, P. K., & Dastgir, S. (2023). Asymmetric Effects of Energy Inflation, Agri-inflation and CPI on Agricultural Output: Evidence from NARDL and SVAR Models for the UK. *Energy Economics, 126*, 106920. https://doi.org/10.1016j.eneco .2023.106920

Strulik, H., & Weisdorf, J. (2008). Population, food, and knowledge: A simple unified growth theory. *Journal of Economic Growth, 13*(3), 195-216. https://doi.org/10.1007/s10887-008-9033-7

Subramaniam, Y., Masron, T. A., & Azman, N. H. N., (2019). The Impact of Biofuels on Food Security. *International Economics, 160,* 72-83. https://doi.org/10.1016/j.inteco.2019.10.003

Subramaniam, Y., Masron, T. A., & Azman, N. H. N., (2020). Biofuels, Environmental Sustainability, and Food Security: A Review of 51 Countries. *Energy Research & Social Science, 68,* 101549. https://doi.org/10.1016/j.erss.2020.101549

Sun, Y., Gao, P., Raza, S. A., Shah, N., & Sharif, A. (2023). The asymmetric effects of oil price shocks on the world food prices: Fresh evidence from quantile-on-quantile regression approach. *Energy, 270*, 126812. https://doi.org/10.1016/j.energy.2023.126812

Syafiuddin, A., Chong, J. H., Yuniarto, A., & Hadibarata, T. (2020). The current scenario and challenges of biodiesel production in Asian countries: A review. *Bioresource Technology Reports, 12*, 100608. https://doi.org/10.1016/j.biteb.2020.100608

Szulczyk, K. R., & Yap, C. S., & Ho, P. (2021). The Economic Feasibility and Environmental Ramifications of Biofuel, Bioelectricity, and Bioethanol in Malaysia. *Energy for Sustainable Development, 61*, 206–216. https://doi.org/10.1016/j.esd.2021.02.005

Tadesse, G., Algieri, B., Kalkuhl, M., & Braun, J., V. (2013). Drivers and Triggers of International Food Price Spikes and Volatility. *Food Policy, 47*, 117-128. https://doi.org/10.1016/j.foodpol.2013.08.014

Taghizadeh-Hesary, F., Rasoulinezhad, E., & Yoshino, N. (2019). Energy and Food Security: Linkages through Price Volatility. *Energy Policy, 128*, 796-806. https://doi.org/10.1016/j.enpol.2018.12.043

Tan, A. H., & Yap, E. H., (2019). Energy Security within Malaysia's Water-Energy-Food Nexus—A Systems Approach. *Systems, 7*(1), 14. https://doi.org/10.3390/systems7010014

Tan, A. K. G., (2010). Demand for Food-Away-From-Home in Malaysia: A Sample Selection Analysis by Ethnicity and Gender. *Journal of Foodservice Business Research. 13*(3), 252–267. https://doi.org/10.1080/15378020.2010.500257

Tan, Z. Y. (2023, May 25). *Cover Story: Is Malaysia ready for the EU regulation on deforestation-free products?* The Edge Malaysia. https://theedgemalaysia.com/node/667766.

Tanaka, T., Guo, J., & Wang, X. (2023). Did biofuel production strengthen the comovements between food and fuel prices? Evidence from ethanol-related markets in the United States. *Renewable Energy, 217*, 119142. https://doi.org/10.1016/j.renene.2023.119142

Tang, T. C., and Lau, E., (2008). An Empirical Investigation on Sustainability of Balancing Item in Asian Countries. *Applied Economics Letters, 15*(2), 117- 123. https://doi.org/10.1080/13504850600706140

Teoh, C. H., (2002). The Palm Oil Industry in Malaysia: From Seed to Frying Pan. [Report].

The Star. (2022, April 5). Boost for grain corn to meet growing local demand. https://www.thestar.com.my/news/nation/2022/04/05/boost-for-grain-corn-to-meet-growing-local-demand.

Thompson, W., & Meyer, S., (2013). Second generation biofuels and food crops: Co-products or competitors? *Global Food Security, 2,* 89–96. https://doi.org/10.1016/j.gfs.2013.03.001

Timilsina, G., Mevel, S., & Shrestha, A., (2011), Oil price, biofuels and food supply, *Energy Policy, 39*(12), 8098-8105. https://doi.org/10.1016/j.enpol.2011.10.004

Toda, H. Y., & Yamamoto, H., (1995). Statistical inference in vector autoregressions with possibly integrated processes. *Journal of Econometrics, 66*, 225–250. https://doi.org/10.1016/0304-4076(94)01616-8

Tokgoz, S., & Bhandary, P., (2011). Comparison of Brazilian and U.S. Biofuel Demand: The Role of Vehicle Fleets and Prices in Meeting Policy Targets. *Green, 1*, 115-122. https://doi.org/10.1515/green.2011.003

Tomei, J., & Helliwell, R., (2016). Food versus fuel? Going beyond biofuel. *Land Use Policy, 56,* 320–326. https://doi.org/10.1016/j.landusepol.2015.11.015

Trading Economics (2017). Malaysia Export. Retrieved from: http://www.trading economics.com/malaysia/exports.

Trypolska, G. (2024). Unlocking the potential: Key factors shaping the liquid biofuels market in Ukraine. *Heliyon*, *10*(22), e40420. https://doi.org/10.1016/j.heliyon.2024.e40420

Tugcu, C. T. (2018). Panel Data Analysis in the Energy-Growth Nexus (EGN). In *The Economics and Econometrics of the EnergyGrowth Nexus*. *Elsevier Inc*. [https://doi.org/10.1016/B978-0-12- 812746-9.00008-0](https://doi.org/10.10

Tullis, P., (2019, February 19). How the world got hooked on palm oil. The Guardian. https://www.theguardian.com/news/2019/feb/19/palm-oil-ingredient-biscuits-shampoo-environmental.

U.S Energy Information Administration (EIA, 2019). Report extract Transport. https://www.iea.org/reports/renewables-2019/transport#abstract

Uchoa, C. F. A., De Jesus, C. S., & Cardoso, L. C. B., (2021). The asymmetric pattern of fuel demand in Brazil. *Economics Bulletin*, *41*(1), 155-160.

Uddin, M. J. (2023). Investigating the impulse responses of renewable energy in the context of China: A Bayesian VAR Approach. *Renewable Energy, 219*, 119485. https://doi.org/10.1016/j.renene.2023.119485

Uri, N. D., & Boyd, R., (1996). The Impact of Crude Oil Price Fluctuations on Unemployment in the United States. *International Journal of Energy Research, 20*, 1003-1014. https://doi.org/10.1002/(SICI)1099-114X(199611)20:11

Uri, N. D., (1983). The Energy Crisis and Its Impact on the Stability of the Demand for Factors of Production. *Applied Energy, 13*, 281-294. https://doi.org/10.1016/0306-2619(83)90002-7

USDA (2017)[a]. Malaysia Palm Oil Domestic Consumption by Year. Retrieved from: https://www.indexmundi.com/agriculture/?country=my& commodity=palm-oil &graph=domestic-consumption.

USDA (2017)[b]. Malaysia Palm Oil Food Use Domestic Consumption by Year. Retrieved from: https://www.indexmundi.com/agriculture/?country=my & commodity=palm-oil&graph=food-use-domestic-consumption.

USDA Foreign Agricultural Service (2016). Malaysia Biofuel Annual report.

Usman, O., Alola, A. A., & Akadiri, S. S. (2021). Effects of domestic material consumption, renewable energy, and financial development on environmental sustainability in the EU-28: Evidence from a GMM panel-VAR. *Renewable Energy, 184*, 239-251. https://doi.org/10.1016/j.renene.2021.11.086

Usmani, R. A., Mohammad, A. S., & Ansari, S. S. (2023). Comprehensive biofuel policy analysis framework: A novel approach evaluating the policy influences. *Renewable and Sustainable Energy Reviews*, *183*, 113403. https://doi.org/10.1016/j.rser.2023.113403

Uysal, M., & Crompton, J. L., (1981). Determinants of Demand for International Tourist Flows to Turkey. *Tourism Management*, *5*(4), 288-297. https://doi.org/10.1016/0261-5177(84)90025-6

Voora, V., Larrea, C., Bernudez, S., & Balino, S., (2019). Global Market Report: Palm Oil. *Sustainable Commodities Marketplace Series 2019.* Retrieved from: https://www.iisd.org/system/files/publications/ssi-global-market-report-palm-oil.pdf

Voth, H. J., (2003). Living Standards During the Industrial Revolution: An Economist's Guide. *American Economic Review, 93*(2), 221-226. https://doi.org/10.1257/000282803321947083

Wadud, S., Gronwald, M., Durand, R. B., & Lee, S. (2023). Co-movement between commodity and equity markets revisited—An application of the Thick Pen method. *International Review of Financial Analysis, 87*, 102568. https://doi.org/10.1016/j.irfa.2023.102568

Wang, K. H., Su, C. W., Lobont, O. R., & Umar, M., (2021). Whether crude oil dependence and CO2 emissions influence military expenditure in net oil importing countries? *Energy Policy, 153,* 112281. https://doi.org/10.1016/j.enpol.2021.112281

Wang, N., Zhu, Y., & Yang, T., (2020). The impact of transportation infrastructure and industrial agglomeration on energy efficiency: Evidence from China's industrial sectors. *Journal of Cleaner Production, 244*, 118708. https://doi.org/10.1016/j.jclepro.2019.118708

Wang, X., Bai, M., & Xie, C., (2019). Investigating CO2 mitigation potentials and the impact of oil price distortion in China's transport sector. *Energy Policy, 130*, 320–327. https://doi.org/10.1016/j.enpol.2019.04.003

Wang, Y. S., (2009). The impact of crisis events and macroeconomic activity on Taiwan's international inbound tourism demand. *Tourism Management, 30*(1), 75-82. https://doi.org/10.1016/j.tourman.2008.04.010

Weyl, E. Glen., (2019). Price Theory. *Journal of Economic Literature, 57*(2), 329-84. https://doi.org/10.1257/jel.20171321

Wohlgemuth, N., (1997). World transport energy demand modelling: Methodology and elasticities. *Energy Policy, 25*(14-15), 1109-1119. https://doi.org/10.1016/S0301-4215(97)00103-1

Wong, K. K. S., Lee, C., & Wong, W. L. (2019). Impact of climate change and economic factors on Malaysian food price. *J. ISSAAS, 25*(1), 32-42.

Wong, K. K. S., & Shamsudin, M. N. (2017). Impact of Crude Oil Price, Exchange Rates and Real GDP on Malaysia's Food Price Fluctuations: Symmetric or Asymmetric? *International Journal of Economics and Management, 11*(1), 259-275.

World Bank (2017)[b]. *Inflation Rate of Malaysia from year 1980 to 2016*. Retrieved from http://databank.worldbank.org/data/reports.aspx?Code

=FP.CPI.TOTL.ZG&id=af3ce82b&report_name=Popular_indicators&populartype=series&ispopular=y#

World Bank (2017)[c]. *GNI per capita growth (annual %)*. Retrieved from https://data.worldbank.org/indicator/NY.GNP.PCAP.KD.ZG?contextual=max&locations=CN-IN-MY

World Bank (2023)[a]. Commodity Markets Outlook. https://www.worldbank.org/en/ research/commodity-markets.

World Bank (2023, April 6)[b]. *Russia's Invasion of Ukraine and Cost-of-Living Crisis Dim Growth Prospects in Emerging Europe and Central Asia.* https://www.worldbank .org/en/news/press-release/2023/04/06/russian-invasion-of-ukraine-and-cost-of-living-crisis-dim-growth-prospects-in-emerging-europe-and-central-asia.

World Health Organization (WHO, 2017). Air Pollution Indicator of Year 2016. Retrieved from: http://gamapserver.who.int/mapLibrary/app/searchResults. Aspx.

Xiao, Z., & Phillips, P. C. B., (1998). An ADF Coefficient Test for A Unit Root in ARMA Models of Unknown Order with Empirical Applications to the US Economy. *Econometric Journal, 1*(1), 27-43. https://doi.org/10.1111/1368-423X. 00003

Yang, T., Liu, C., Yang, Y., & Chen, S. (2023). The dynamic effect of trading between China and Taiwan under exchange rate fluctuations. *Humanities and Social Sciences Communications, 10*(1), 1-9. https://doi.org/10.1057/s41599-023-01903-8

Ying, T. X., (2019, October 11). *Govt allocates RM550m for palm oil smallholders, plans B20 biodiesel rollout in 2020*. The Edge Market. https://theedgemalaysia.com/article/govt-allocates-rm550m-palm-oil-smallholders-plans-b20-biodiesel-rollout-2020.

You, P. S., Hsieh, Y. C., (2007). An EOQ Model with Stock and Price Sensitive Demand. *Mathematical and Computer Modelling*, *45*(7-8), 933–942. https://doi.org/10.1016/j.mcm.2006.09.003

Young, K. H., & Young, L. Y. (1975). Estimation of Regressions Involving Logarithmic Transformation of Zero Values in the Dependent Variable. *The American Statistician, 29*(3), 118–120. https://doi.org/10.1080/00031305.1975.10477391

Yusoff, M. N. A. M., Zulkifli, N. W. M., Sukiman, N. L. (2021). Sustainability of Palm Biodiesel in Transportation: A Review on Biofuel Standard, Policy and International Collaboration Between Malaysia and Colombia. *Bioenergy Resources, 14*, 43–60. https://doi.org/10.1007/s12155-020-10165-0

Yusoff, M., Hizami, M., Abdullah, A. Z., Sultana, S., & Ahmad, M., (2013). Prospects and current status of B5 biofuel implementation in Malaysia.

Energy Policy, 62(C), 456-462. https://doi.org/10.1016/j.enpol.2013.08.009

Zapata, H. O., & Rambaldi, A. N., (1997). Monte Carlo evidence on cointegration and causation. *Oxford Bulletin of Economics and Statistics, 59*(2), 285–298. https://doi.org/10.1111/1468-0084.00065.

Zhang, B., Ai, X., Fang, X., & Chen, S. (2021). The Transmission Mechanisms and Impacts of Oil Price Fluctuations: Evidence from DSGE Model. *Energies, 15*(16), 6038. https://doi.org/10.3390/en15166038

Zhang, L., & An, Y. (2018). The government capacity on industrial pollution management in Shanxi province: A response impulse analysis. *Journal of Environmental Management, 223*, 1037-1046. https://doi.org/10.1016/j.jenvman.2018.07.010

Zhang, Z., Lohr. L., Escalante, C., & Wetzstein, M., (2009). Ethanol, Corn, and Soybean Price Relations in a Volatile Vehicle-Fuels Market. *Energies, 2*(2), 320-339. https://doi.org/10.3390/en20200320

Zimmermann, A., & Rapsomanikis, G. (2023). Trade and Sustainable Food Systems. In: von Braun, J., Afsana, K., Fresco, L.O., Hassan, M.H.A. (eds) *Science and Innovations for Food Systems Transformation* (pp. 685–701). Springer. https://doi.org/10.1007/978-3-031-15703-5_36

Zmami, M., Ben-Salha, O., (2019). Does Oil Price Drive World Food Prices? Evidence from Linear and Nonlinear ARDL Modeling. *Economies*, *7*(1), 12. https://doi.org/10.3390/economies7010012