RELATIONSHIP BETWEEN BIOETHANOL PRODUCTION AND AGRICULTURAL COMMODITY PRICES: FOR THE CASE OF THAILAND

BY

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DECLARATION

We hereby declare that:

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

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

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

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Abstract

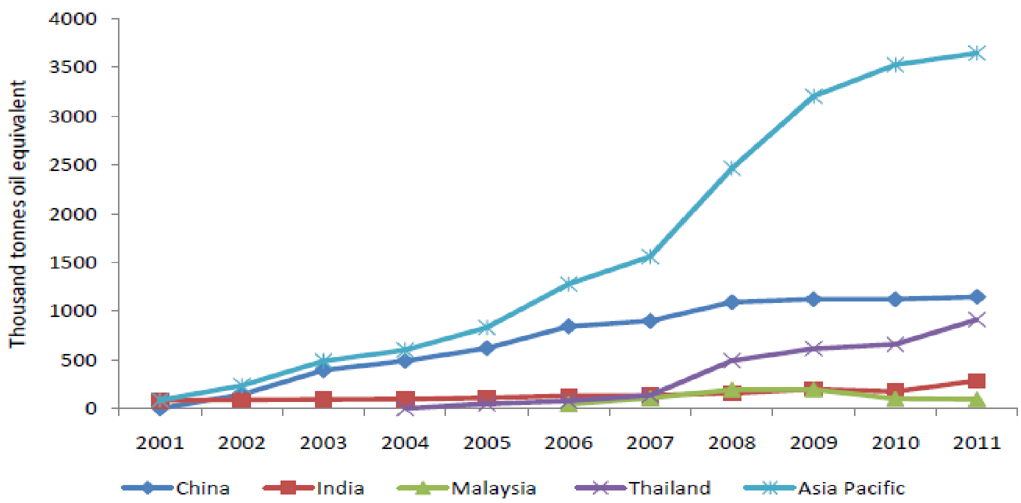
Food security issue arises when more amount of agricultural commodity act as a bioethanol feedstock is being directed into the production of that renewable energy. At the same time, the sustainability of those feedstock supplies is another concern for the continuous production of bioethanol to substitute the expensive imported fuel oil. Thus, these concerns have drawn our interest to examine the relationship between bioethanol production and agricultural commodity prices in Thailand. The main feedstocks for producing bioethanol in Thailand are sugarcane, cane molasses and cassava. We have selected the monthly data from January 2006 to March 2014 to conduct this research. The existence of long-run relationships among the four variables – bioethanol production, sugarcane farm gate price, cane molasses export price and cassava farm gate price would be detected through the Auto Regressive Distributive Lag (ARDL) framework. Then, we will run the Granger Causality Test (Wald Test) to investigate the short-run causal relationship among those variables. From our result, we have found that when bioethanol production act as independent variable, long-run equilibrium exist between bioethanol production and sugarcane farm gate price, cane molasses export price and cassava farm gate price, respectively. Besides that, we also found that Granger causality exists among the variables. Sugarcane farm gate price and bioethanol production as well as cassava farm gate price and bioethanol production are found to be having unidirectional Granger causality effect. Meanwhile, bidirectional Granger causality effect is found between cane molasses export price and bioethanol production.

Chapter 1: Introduction

1.0 Introduction

Along with India, China, Philippines, Indonesia and Malaysia, Thailand has recently emerged to be one of the leading producers of biofuels in Asia (Zhou & Thomson, 2009). In five years time from 2005 to 2010, Thailand's biofuels production expanded greater than ten times as well as occupied the share of its production in Asia Pacific region from about 6% in 2005 to 19% in 2010 (Kumar, Salam, Shrestha, & Ackom, 2013) (Figure 1.1).

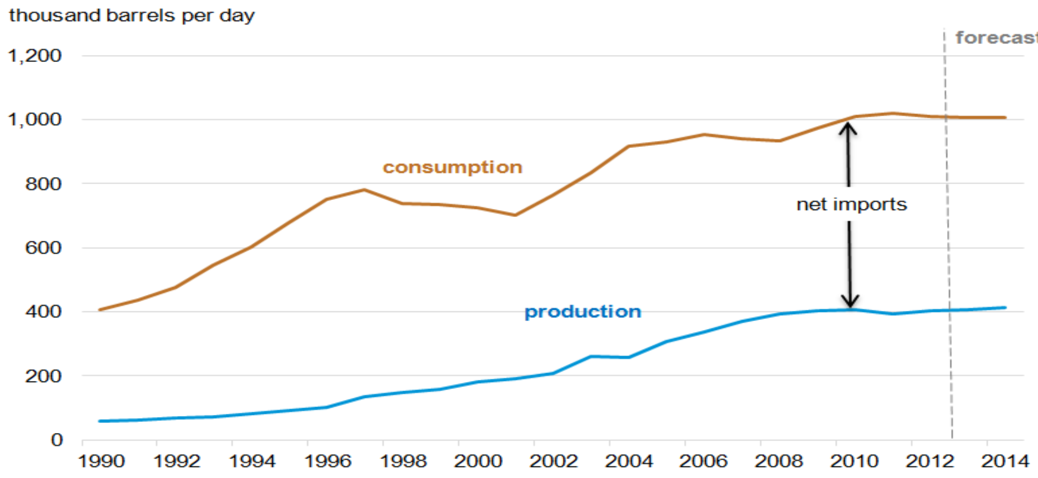
Figure 1.1: Thailand's Biofuels Production in Asia Pacific Region



Source: Kumar et al. (2013).

The accelerated production of biofuels over years is the result of Thailand's serious effort to reduce oil import dependency (Russell & Frymier, 2012). In year 2005, over 90% of the country's transportation fuel, such as crude oil, gasoline, and diesel was imported (Russell & Frymier, 2012). Hereafter, Thailand appeared to be the second largest net oil importer in Southeast Asia in year 2011 where the country consumed around 1 million bbl/d of oil and recorded total net imports of 627 thousands bbl/d (U.S. Energy Information Administration, 2013) (Figure 1.2). Even though the production of crude oil has increased in the recent years, the production is still below the consumptions levels for both actual and expected (U.S. Energy Information Administration, 2013) (Figure 1.2).

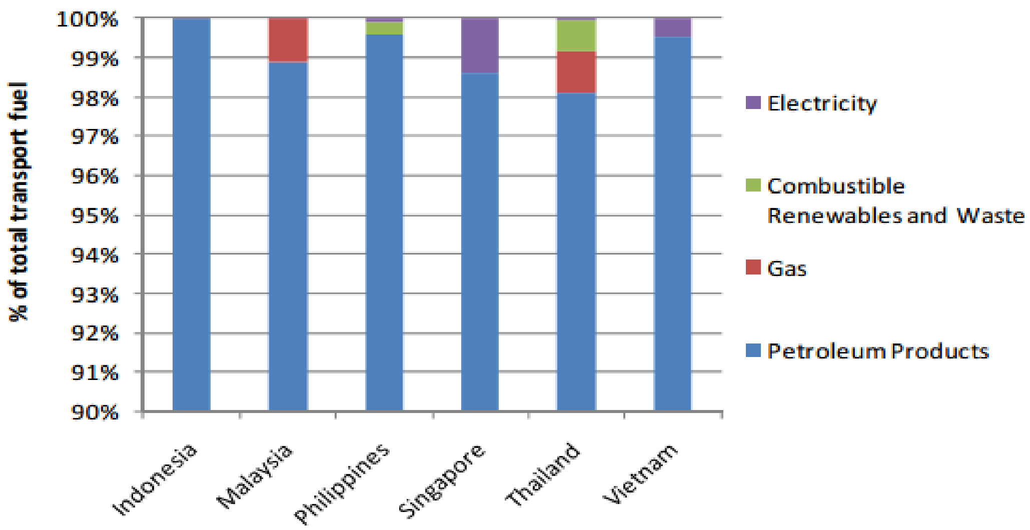
Figure 1.2: Total Oil Production and Consumption in Thailand from 1990 to 2014



Source: http://www.eia.gov/countries/cab.cfm?fips=TH

According to Figure 1.2, import remains taking a significant part of Thailand's oil consumption given that the country has finite domestic oil production and reserves, leaving Thailand highly subject to global oil markets and volatile prices (U.S. Energy Information Administration, 2013). During the oil shortages in 1970s, Thailand was affected by rousing oil prices due to limited supply and failed to manage the transportation energy costs effectively (Russell & Frymier, 2012). While in the period of 2000 to 2008, the reduction in global production of crude oil and increment in demand in countries like China and India had caused the crude oil prices to start rising significantly. Substantially, the retail price of gasoline per litre for Thailand had climbed from US $0.36 in 2002 to US $0.54 in 2004 to US $0.87 in 2008 (Russell & Frymier, 2012).

Figure 1.3: Transport Fuel Consumption in Year 2007



Source: OLZ and Beerepoot (2010).

While the economy continues to develop and undergoes industrialization, Thailand's consumption of oil for transportation and industrial uses will be getting greater (U.S. Energy Information Administration, 2013). According to studies, the country comprised of around 67 million people had an automotive density of 54 passenger cars per 1000 people in year 2004 (Russell & Frymier, 2012). Since the Gross Domestic Product (GDP) of Thailand was accelerating from $2.761 Billion in 1960 to $263.856 Billion in 2009, there will be expectation where GDP continues to increase, so does the ownership of car (Russell & Frymier, 2012). In fact, fossil fuels had been accounted for over 80 percent of the country's total energy consumption, therefore it appear to be the major primary energy sources (U.S. Energy Information Administration, 2013). In year 2007, the total consumption of energy for Thailand's transportation sector is mainly featured by petroleum products, accounting for about 98 percent in year 2007 (OLZ & Beerepoot, 2010) (Figure 1.3). In concern with the over-dependent on fossil fuel as well as imported energy, Thai government has emphasized biofuels as one of the crucial areas of national renewable energy policy, especially for the transportation sector (Kumar et al., 2013).

1.1 Brief Introduction for Biofuels

Both bioethanol and biodiesel are produced in Thailand in order to reduce its dependency on imported oil (Kumar et al., 2013). In Thailand, bioethanol and biodiesel were begun at the same time (year 2003) but Thai government is more concern on bioethanol rather than biodiesel due to its feedstock supply readiness (Kumar et al., 2013). Biodiesel is produced from palm oil plants (Silalertruksa, Bonnet, & Gheewala, 2012). However, there are several reasons that able to explain why Thai government pay less attention on biodiesel, which are the limited palm growing area due to competitive rubber plantations, lack of suitable land for palm plantation and unpredictable weather (Kumar et al., 2013).

1.2 Policies and Programs for Bioethanol

The fluctuation in oil prices and high price of imported crude oil lead Thailand to produce bioethanol by their own as an alternative energy for fuel. National Alternative Energy Development Plan (2004-2011) was the first plan adopted by Thai government in order to promote the biofuel production and to reduce its dependency on imported oil (Preechajarn & Prasertsri, 2010).

In year 2009, Thai government implemented the second plan for biofuels which called as Alternative Energy Development Plan (2008-2022), featuring on retail price incentive, R&D support and public awareness promotion to encourage the production and consumption of biofuel (Preechajarn & Prasertsri, 2010). This plan has been divided into three phases in order to achieve the final goal, which is the share of alternative energy mix to be increased by 20 percent of the country's final energy demand by 2022 (Morgera, Kulovesi & Gobena, 2009). The short term (2008-2011) objective encourages proven technologies for alternative energy with high potential such as biofuels from biomass and biogas (Morgera et al., 2009). The target short term plan for bioethanol production and consumption of 3.0 million liters per day was set by Thai government (Preechajarn & Prasertsri, 2010). Furthermore, the goal of medium term plan (2012-2016) is to focus on alternative energy technology industry and supports on the development of new model of alternative energy technologies for biofuel production and development of Green City prototypes that enhance domestic alternative energy production (Morgera et al., 2009). Thai government targeted the production and consumption of bioethanol in medium term plan to be 6.2 million liters per day (Preechajarn & Prasertsri, 2010). Meanwhile, the objective of long term plan (2017-2022) is to encourage the technologies for substitute energy that are cost-effective (Morgera et al., 2009). In long term plan, bioethanol production and consumption of 9.0 million liters per day was set by the Thai government (Preechajarn & Prasertsri, 2010).

Although the plan of Alternative Energy Development (2008-2022) had been used for several years, it was unsuccessful due to the fall short in achieving its short term target, especially in bioethanol consumption (Preechajarn & Prasertsri, 2012). A bioethanol production surplus of around 40 to 50 million liters per day was incurred in 2011 due to the static bioethanol consumption at about 1.0 to 1.1 million liters per day since 2009 caused by the Thai government decision of reversing its previous planned policy in mandating compulsory use of gasoline/bioethanol mixes. The actual production of bioethanol in 2011 which was only 1.43 million liters per day also failed to reach its short-term target of 3.0 million liter per day. Therefore, Thai government had replaced the old 15-year plan (2008-2022) with the new 10-year Alternative Energy Development Plan

(2012-2021) in year 2012 (Preechajarn & Prasertsri, 2012). The target of bioethanol consumption for the new plan remained unchanged, which is 9.0 million liters per day by 2021 (Preechajarn & Prasertsri, 2012).

Figure 1.4: Consumption of Alternative Energy in Thailand from 2012 to 2015(January)

พลังงานทดแทน	หน่วย	เป้าหมาย 2564 Target 2021	ผลการดำเนินงาน Performance				unit	Alternative Energy
			2555	2556	2557	2558 (ม.ค.)		
			2012	2013	2014	2015 (Jan)		
ไฟฟ้า	**เมกะวัตต์**	**13,927**	**2,786**	**3,788**	**4,584**	**4,503**	**MW**	**Electricity**
	พันตันเทียบเท่าน้ำมันดิบ	**5,370**	**1,138**	**1,341**	**1,467**	**117**	**ktoe**	
1. แสงอาทิตย์	เมกะวัตต์	3,000	376.72	823.46	1,298.51	1,298.51	MW	1. Solar Energy
2. พลังงานลม	เมกะวัตต์	1,800	111.73	222.71	224.47	224.47	MW	2. Wind Energy
3. พลังน้ำขนาดเล็ก	เมกะวัตต์	324	101.75	108.80	142.01	142.01	MW	3. Small Hydro Power
4. ชีวมวล	เมกะวัตต์	4,800	1,959.95	2,320.78	2,541.82	2,451.82	MW	4. Biomass
5. ก๊าซชีวภาพ	เมกะวัตต์	3,600	193.40	265.23	311.50	311.50	MW	5. Biogas
6. ขยะชุมชน	เมกะวัตต์	400	42.72	47.48	65.72	74.72	MW	6. MSW
7. พลังงานรูปแบบใหม่	เมกะวัตต์	3					MW	7. New Energy
ความร้อน	**พันตันเทียบเท่าน้ำมันดิบ**	**9,801**	**4,886**	**5,279**	**5,775**	**505**	**ktoe**	**Heat**
1. แสงอาทิตย์	พันตันเทียบเท่าน้ำมันดิบ	100	3.50	4.50	5.12	5.12	ktoe	1. Solar Energy
2. ชีวมวล	พันตันเทียบเท่าน้ำมันดิบ	8,500	4,346	4,694	5,184	452	ktoe	2. Biomass
3. ก๊าซชีวภาพ	พันตันเทียบเท่าน้ำมันดิบ	1,000	458.0	495.0	488.08	40.0	ktoe	3. Biogas
4. พลังงานขยะ	พันตันเทียบเท่าน้ำมันดิบ	200	78.2	85.0	98.06	8.0	ktoe	4. MSW
เชื้อเพลิงชีวภาพ	**ล้านลิตร/วัน**	**39.97**	**4.20**	**5.50**	**6.10**	**6.55**	**million litre/day**	**Biofuels**
	พันตันเทียบเท่าน้ำมันดิบ	**9,467**	**1,270**	**1,612**	**1,783**	**163**	**ktoe**	
1. เอทานอล	ล้านลิตร/วัน	9.0	1.40	2.60	3.21	3.44	million litre/day	1. Ethanol
2. ไบโอดีเซล	ล้านลิตร/วัน	7.2	2.80	2.90	2.89	3.11	million litre/day	2. Biodiesel
3. เชื้อเพลิงใหม่ทดแทนดีเซล	ล้านลิตร/วัน	3.0					million litre/day	3. New Energy Replacing Diesel
4. ก๊าซชีวภาพอัด	ตัน/วัน	1,200					ton/day	4 Compressed Bio-methane Gas
การใช้พลังงานทดแทน (พันตันเทียบเท่าน้ำมันดิบ)		**24,638**	**7,294**	**8,232**	**9,025**	**785**	**Alternative Energy Consumption (ktoe)**	
การใช้พลังงานขั้นสุดท้าย (พันตันเทียบเท่าน้ำมันดิบ)		**99,838**	**73,316**	**75,214**	**75,804**	**6,585**	**Final Energy Consumption (ktoe)**	
สัดส่วนการใช้พลังงานทดแทน (%)		**25**	**9.95**	**10.94**	**11.91**	**11.92**	**Percentage of Alternative Energy Consumption (%)**	

Source: Department of Alternative Energy Development and Efficiency (DEDE) of Thailand (2015).

Once the new 10-year Alternative Energy Development Plan was initiated, the consumption for bioethanol had shown to be improved significantly from 1.4 million liter per day to 3.44 million liter per day within the period of 2012 to 2015 in Thailand (Figure 1.4). By January of 2015, the consumption of bioethanol has achieved around 10.91% out of the total of alternative energy consumption in Thailand[1].

To materialize those targets in the new plan, the Thai government had also developed several strategic plans focusing on both supply and demand sides as below (Preechajarn & Prasertsri, 2012). On the supply side, the yield of current feedstock has to be improved where an average yield of sugarcane above 94 tons per hectare with total production of 105 million tons per year, and an average yield of cassava above 31 tons per hectare with total production of 35 million tons per year by 2021. For the demand side, the government had terminated the sales of regular gasoline (Octane 91) in 2013. Subsidies for E20 gasohol (a blend of 20% ethanol and 80% gasoline) from the State Oil Fund is also provided at 3.0 baht per liter cheaper than Octane 95 gasohol. To encourage the sales of E20 gasohol, the gasoline stations are given an incentive of 0.5 baht per liter marketing margin above the sales of regular gasoline (Octane 91). The government even lower down the excise tax on automobile manufacturers by 50,000 baht per vehicle for FFV (flex-fuel vehicles) and 30,000 baht per vehicle for Eco-car (E20 vehicles). Likewise, the bioethanol laws and regulations would be liberalized for the sales of bioethanol in future. A budget for research and development to increase bioethanol demand, particularly for old vehicles and motorcycles, is been supported by the new plan.

[1] The calculation for consumption of bioethanol in January of 2015 = (3.44 / 6.55) x 163 = 85.61; (85.61/785) x 100% = 10.91%.

1.3 First-generation VS Second-generation of Bioethanol

Thailand was involved in first and second-generation of biofuels productions. First-generation production started since 2004 and it refers to the production of biofuels primarily from food crops (Eisentraut, 2010). Sugarcane, cane molasses and cassava are the base for first-generation bioethanol production in Thailand (Kumar et al., 2013). On the other hand, second-generation biofuels production was introduced on 2010 and can be derived from biomass production (Patumsawad, 2011). According to the Department of Alternate Energy Development and Efficiency (DEDE), the potential agricultural residues and by-product to produce second-generation biofuels are not specified, but some studies shows that bagasse (a by-product of sugar production) and rice husk are potentially used to produce second-generation bioethanol in Thailand (Kumar et al., 2013). Although there are several advantages of producing second-generation biofuels, such as it could reduce the use of land for planting energy crops, produce biofuels production at cost-competitive prices, offer better quality of fuel compare to first-generation biofuels, use wider range of biomass feedstock and more favourable to green house gases balance, there are also several challenges might be faced by the Thai government (Patumsawad, 2011). Thai government have to bear the high cost of production due to the second-generation biofuels cannot produced in a large scale as well as the technological breakthroughs and the infrastructure needs to produce biofuels (Patumsawad, 2011). Although second-generation molasses-based bioethanol production using cane bagasse is supported by the Thai government, biofuels production's operation is still in the experimental stage and it is expected to take several years before it turns into a usable economic production (Preechajarn & Prasertsri, 2013). Therefore, second-generation bioethanol production is not suitable for us to examine their relationship. If we do so, the final results of this study may be misleading due to the availability of data and studies. Hence, our study mainly focuses on the first generation bioethanol production.

1.4 Ethanol Fuel

There is an energy crisis in Thailand due to high crude oil price and overdependence on imported petroleum products (Papong & Malakul, 2010). Bioethanol is one of the important substitutes for transportation fuels which can aid fuel supplies and reduce the imported crude oil (Papong & Malakul, 2010). Therefore, Thai government emphasizes a lot on bioethanol. In general, there are two types of bioethanol which are anhydrous ethanol and hydrous ethanol in the bioethanol market[2]. Bioethanol that we are using in this study is an anhydrous ethanol. This is because Thailand now mainly focuses in producing anhydrous ethanol for its domestic market, however some hydrous ethanol might be produced in future (Heng, 2012). The ethanol concentration of anhydrous ethanol has to be above 96% to avoid the separation of bioethanol from gasoline in the blended gasohol after certain period of time (Sorapipatana & Yoosin, 2011). Most of the unmodified or slightly modified vehicles are using this type of bioethanol. However, hydrous ethanol can only be used in specially modified vehicles and this type of vehicles only produced in Brazil (Whittington, 2006).

Today, the anhydrous ethanol is commonly used to blend with gasoline at the concentrations of 5%, 10%, 20% and 85% by volume to form different grades of gasohol fuel in Thailand. However, only E10 (10% ethanol concentration), E20 (20% ethanol concentration) and E85 (85% ethanol concentration) gasohol are sold in Thailand market (Silalertruksa & Gheewala, 2010). In year 2004, gasohol E10 was introduced which is a blend of 10% bioethanol and 90% gasoline. E20 (mixture of 20% bioethanol and 80% gasoline) was launched in early of 2008 whereas limited amount of E85 (consist of 85% bioethanol and 15% gasoline) was introduced since August 2008 (Silalertruksa & Gheewala, 2010).

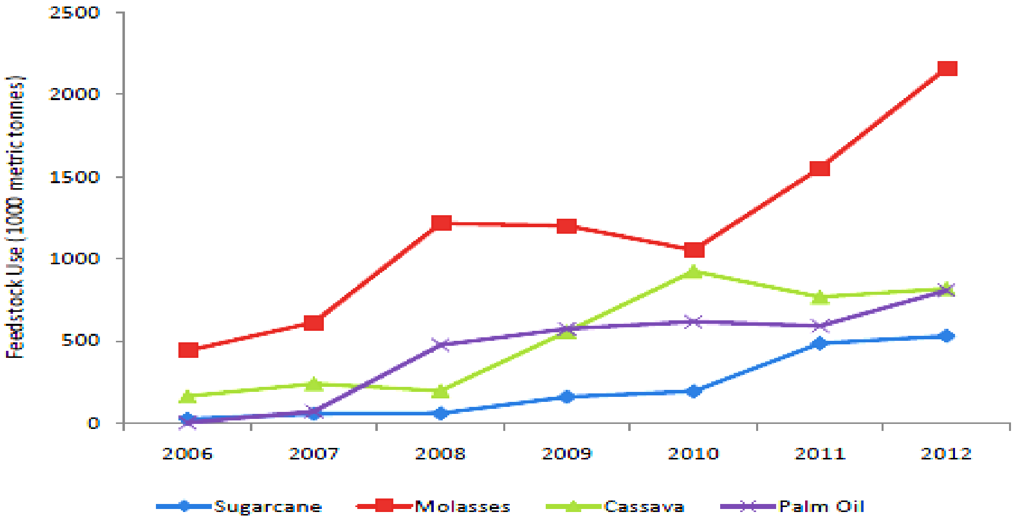
[2] Anhydrous ethanol means 99.5% alcohol concentration whereas hydrous ethanol means 95-96% alcohol concentration (Sorapipatana & Yoosin, 2011).

Initially, there are total of six types of fuels selling in Thailand market, regular gasoline (octane 91) and premium gasoline (octane 95) are imported gasolines, gasohol E10 Octane 91, gasohol E10 Octane 95, gasohol E20 and gasohol E85 (Preechajarn & Prasertsri, 2013). However, the sale of regular gasoline (octane 91) had been terminated by the Thai government in January 2013 and replaced it by gasohol E10 and E20 (Preechajarn & Prasertsri, 2013). This is because Thai government wants to achieve the plan of Alternative Energy Development Plan (2012-2021) by increasing the consumption of bioethanol to 9 million liters per day by 2021 (Preechajarn & Prasertsri, 2013).

1.5 Feedstock for Bioethanol Production

In Thailand, bioethanol is derived from sugarcane, cane molasses and cassava (Silalertruksa & Gheewala, 2010). According to the biofuels annual report for Thailand, the prices of molasses-based bioethanol is about 24 baht/liter ($3/gallon) whereas cassava-based bioethanol prices are approximately 26-27 baht/liter which are 2-3 baht/liter higher than molasses-based bioethanol prices (Preechajarn & Prasertsri, 2013).

Figure 1.5 The Feedstock Use for the Production of Bioethanol and Biodiesel.



Source: Kumar et al. (2013).

1.5.1 Sugarcane

Thailand's climate is very suitable for the growth of sugarcane. However, sugarcane has a very limited harvest period which is only available for 4-5 months in a year especially from December to March (Russell & Frymier, 2012). Therefore, harvest for sugarcane in Thailand is mainly used to produce sugar products and only a small portion amount of the sugarcane is use to produce bioethanol (Prasertsri, 2013). Sugarcane can be directly used to produce bioethanol in Thailand (Kumar et al., 2013). This is because the juice of the sugarcane contains sucrose which can be directly fermented by yeast to produce bioethanol (Silalertruksa & Gheewala, 2010). Approximately 12.5 to 14.3 kg of sugarcane can used to produce a liter of bioethanol (Russell & Frymier, 2012).

1.5.2 Cane Molasses

The outlook of a cane molasses is thick, black and viscous liquid (Gonsalves, 2006). It is a by-product of the sugar production (from sugarcane) which is a dominant in producing bioethanol in Thailand (Silalertruksa & Gheewala, 2010). Meanwhile, cane molasses contains about 50% sugars which can be fermented by yeast to produce bioethanol (Russell & Frymier, 2012). In 2008, around 78% of cane molasses are used to produce bioethanol in Thailand (Silalertruksa & Gheewala, 2010). Besides, Thailand produce one liter of bioethanol has to use about 4 kg of cane molasses (Russell & Frymier, 2012).

1.5.3 Cassava

In Thailand, cassava is the second largest industrial crop which can be categorized as "sweet" or "bitter" varieties (Russell & Frymier, 2012). Cassava contains around 25% of starch which is suitable to produce bioethanol (Gonsalves, 2006). Consumers can consume directly the "sweet" cassava while the "bitter" cassava cannot be eaten (Silalertruksa & Gheewala, 2010). This is because "bitter" cassava is poisonous which consists of high level of hydrocyanic acid compare to "sweet" cassava (Russell & Frymier, 2012). However, "bitter" cassava contains high level of starch which can be use to converted to fermentable sugar and use it to produce bioethanol (Silalertruksa & Gheewala, 2010). Thailand has no industrial production of "sweet" cassava because of it has limited market and it only grown in single household farms (Russell & Frymier, 2012). Besides, cassava is very well utilized in several industries in the past such as chip/pellet industry and starch derivative (Silalertruksa & Gheewala, 2010). Moreover, the advantages of cassava are it is able to grow in areas where other energy crops could not and it is easy to plant and do not need any control on insects and pests (Russell & Frymier, 2012). During low harvest period, cassava can be stored in high quantities such as dries chip and it does not have time limit for planting and harvesting (Russell & Frymier, 2012). Meanwhile, cassava also has high productivity of root and it is consists of high quantity of carbohydrate (Silalertruksa & Gheewala, 2010). According to Zhang’s study (as cited in Silalertruksa & Gheewala, 2010), cassava has been promoted as a feedstock for bioethanol production in Thailand due to the advantages of cassava. Although both cassava roots and dried chips can produce bioethanol, but dried chips are more recommended compare to roots because dried chips can be produced by farmers during the peak of harvesting season when the roots price is very low and it can be stored for use when roots are not harvested (Silalertruksa & Gheewala, 2010). Around 5.5 to 6 kg of cassava roots can produce a liter of bioethanol (Silalertruksa & Gheewala, 2010).

1.6 Problem Statement

In year 2011, the government had released its new 10-year Alternative Energy Development Plan (2012 – 2021), aiming to boost bioethanol consumption to 9 million liters per day by 2021(Preechajarn & Prasertsri, 2013). Consequently, the production of bioethanol increased to 2.6 million liters per day within the period of January to April in 2013 compared to 1.8 million liters per day for the same period in 2012 (Preechajarn & Prasertsri, 2013). Based on several studies on the overall effect of bioethanol program in Thailand, there is a rise in certain feedstock prices since the program was implemented (Mudiyanselage, Lin & Yi, 2013). Although the government has provided price supports, the prices of sugarcane and cane molasses have climbed and turned to be more volatile (Mudiyanselage et al., 2013). The food prices can be further increased if more farmers headed for higher-priced crops, thus leading to smaller areas of food crops (Business-in-Asia.com, 2007). Meanwhile, the arable land and the agricultural technology to increase crop yields are also seem to be limited (Silalertruksa &

Gheewala, 2010). Therefore, these could create a competition among food and fuel as the present feedstock is also used for foods (Patumsawad, 2011). To address the potential food shortages problem in Thailand, it is interesting to examine the linkage between bioethanol production and related agricultural commodity prices in a greater extent.

Thailand is firmly emerged to be the second largest sugar exporter in the world (The Indian Express, 2012). By this reason, the production of sugarcane is one of the crucial economic sectors in the country (Zeddies, 2006). Besides using sugarcane to produce sugar, only a small amount is involved to produce bioethanol (Prasertsri, 2013). It is expected where this trend will persist due to prices for sugarcane feed stocks in ethanol production remain low (Prasertsri, 2013). However, Thai government has given some flexibility to the sugarcane and sugar producers in which more sugarcane should be placed to produce sugar when the increment in sugar price is more profitable than bioethanol, whereas, more sugarcane should be placed as an input for bioethanol production when the sugar appears to be less profitable than bioethanol (Cane and Sugar Industry Policy Bureau, 2006). Turning to another focus, molasses is a by-product of sugar milling and has taken a major share of 80 percent of the total feedstock for ethanol production (Preechajarn & Prasertsri, 2013). Nevertheless, cassava-based bioethanol production seemed to be more favorable as the cane molasses prices are currently facing an upward pressure (Preechajarn & Prasertsri, 2013). This is resulted from the drop in cane molasses yield in 2013/14, which was a full 0.4% below 4.5% for previous year, leading to a fall in cane molasses supply by 500,000 million tonnes (UM Trading, 2014). On top of that, the expected contraction in molasses-based bioethanol supply has shed some spotlight on the cassava-based bioethanol (Preechajarn & Prasertsri, 2013). Price subsidies and discounted sales of government-owned cassava stocks are exercised to encourage the supplies of cassava-based bioethanol (Preechajarn & Prasertsri, 2013). In a summary, fluctuation in three feedstock prices may affect their ratio in bioethanol production. Hence, it is attentive to look at how each of the feedstock prices relate to bioethanol production in Thailand.

1.7 Objective of the Study

- General objective:
  - ❖ To study how the bioethanol production and agricultural commodity prices in Thailand are related.
    - Variable for bioethanol in this study will be bioethanol.
    - Variables for agricultural commodities in this study focus on sugarcane, cane molasses and cassava.
- Specific objectives:
  - ❖ To examine whether there is a correlation between bioethanol production and, sugarcane, cane molasses and cassava prices in Thailand.
    - To investigate the strength and direction of concurrent movement in both bioethanol production and the prices of sugarcane, cane molasses and cassava.
  - ❖ To determine whether there is a causal relationship between bioethanol production and, sugarcane, cane molasses and cassava prices in Thailand.
    - To test whether a change in bioethanol production will lead to a change in the prices of sugarcane, cane molasses and cassava separately.
    - To test whether individual price changes in sugarcane, cane molasses and cassava will cause the production of bioethanol to change.

1.8 Significance of the Study

The essence of this research paper is to serve as a guideline for Thailand policymakers in creating agricultural policies and biofuels policies. Thai government will get to know how the relationship between bioethanol production and agricultural commodity prices looks like, and subsequently determine whether and to which extent should both agricultural policies and biofuels policies coordinated with one another. According to the FAO Bioenergy and Food Security (BEFS) Project Thailand Technical Consultation, Thailand's exports of key biofuels feedstock crops could be decreased in the near future due to the requirement of substantial increases in agricultural yields and production to achieve the country's future biofuels targets (Damen, 2010). Therefore, boosting agricultural productivity has become a key issue today (Damen, 2010). Although good quality information on land suitability and agriculture practices is made available to farmers, there is a doubt whether this material is reaching them (Damen, 2010). On the other hand, the growing biofuels sector along with its targets is likely to impact the national economy and households via diverse channels such as the price of food produced by biofuels feedstock crops (Damen, 2010). In short, these issues above have shown the importance of formulating policies for better future developments in both agriculture and biofuels sectors.

Malaysia had developed the National Biofuel Policy with envisions to include biofuels as one of the five energy sources for the country, increasing the nation's prosperity and well being (Chin & H'ng, 2013). By the way, the country only concentrates on biodiesel from palm oil, instead of ethanol on the grounds that this feedstock is being produced domestically in a huge amount (APEC Biofuels, 2008). However, in year 2011, a new strategy added into the National Biomass Strategy 2020 was introduced, highlighting the production of bioethanol from lignocellulosic biomass (second-generation biofuels) especially the oil palm biomass and wood waste (Chin & H'ng, 2013). On the contrary, Thailand is more advance and had initiated its second-generation biofuels pilot project by using sugarcane bagasse in 2010 (Preechajarn & Prasertsri, 2010). It is still remain at an experimental stage by producing at 10,000 litres per day (Preechajarn & Prasertsri, 2013). Nevertheless, it is believed to be commercially practicable in the short term (Preechajarn & Prasertsri, 2013). After all, Thailand can be claimed to be the best role model for our country, Malaysia in implementing its new strategy to produce second-generation biofuels, during its infant stage in bioethanol production. Critically, by making Thailand as a reference to Malaysia, this study is able provide a clear picture of the relationship between bioethanol production and agricultural commodity prices to Malaysia, assisting the country in forming and implementing any bioethanol policy and program in the near future.

1.9 Outline of the Study

The following sections of this research paper will be arranged as: Chapter 2 provides a review on previous literatures related to this topic, Chapter 3 discusses about the theoretical and empirical framework as well as the data of variables used and the methodology, Chapter 4 shows the outcomes and interpretations and Chapter 5 makes conclusions on the outcomes obtained and lists out limitation of this study.

Chapter 2: Literature review

2.0 Introduction

Since the production of first-generation bioethanol was initiated, several studies on the relationship between bioethanol production and agricultural commodity prices were majorly conducted on those leading bioethanol producers, such as United States (U.S). Although there is one related study from Wianwiwat and Asafu-Adjaye (2013), focusing on the overall impact of biofuels-promoting measures in Thai government's 10-year alternative energy development plan (2012-2021), the researchers only allocate part of their attention on the investigated relationship under our present research paper[3]. Meanwhile, the wide impact of biofuels policies of U.S, EU and China are well-studied in past literatures, such as Banse, Meijl, Tabeau and Woltjer (2008), Kretschmer, Narita and Peterson (2009), Kim, Binfield, Parron, Zhang and Moss (2013), Saunders, Kaye-Blakea, Marshall, Greenhalghc and Pereiraa (2009), Qiu et al. (2010), Miljkovic, Shaik and Braun (2012) and McPhail and Babcock (2012)[4].

On the other hand, there are a significant number of researches which use many other related variables instead of just bioethanol and its feedstock. Few studies include Kanamura (2009), Ciaian and Kancs (2011a) and Ciaian and Kancs (2011b) have taken the upsurge of biofuels into account to investigate the traditional oil-agricultural commodities relationship. In the research of Kanamura (2009), the author has documented that since 2004, energy and soybean are found

[3] Wianwiwat and Asafu-Adjaye (2013) have developed a computable general equilibrium (CGE) model to investigate the short-run and long-run impacts of biofuels promoting measures on macroeconomics indicators, sectoral outputs and prices, and land allocation.

[4] Saunders et al. (2009), McPhail and Babcock (2012) and Miljkovic et al. (2012) examine the impact of U.S Renewable Fuel Standard (RFS) mandates; Banse et al. (2008), Kretschmer et al. (2009), and Kim et al. (2013) investigate the impact of EU biofuels policies; Qiu et al. (2010) tests the effect of China's current bioethanol program.

to be strongly correlated, in which it is argued that it may be linked to the current expanding biofuels use[5]. While including the variable of bioethanol, Natanelov, McKenzie and Huylenbroeck (2013), Cha and Bae (2011), Gardebroek and Hernandez (2013), Wu and Li (2013), and Du and McPhail (2012) look into the linkages of oil, bioethanol and corn. These authors argue that the rise in oil prices could have lead to an explosive demand for bioethanol, and therefore influencing the corn (bioethanol feedstock) market (Cha & Bae, 2011; Gardebroek & Hernandez, 2013; Wu & Li, 2013). Furthermore, Vacha, Janda, Kristoufek and Zilberman (2013) and Kristoufek, Janda and Zilberman (2012) have used more variables in their study for each of group of energy, bioenergy and agricultural commodities. For instance, they use gasoline, diesel, crude oil as energy; bioethanol and biodiesel as bioenergy; and, corn, sugarcane, wheat, soybeans as agricultural commodities (Vacha et al., 2013; Kristoufek et al., 2012). It is emphasized that a wide range of related fuels, biofuels and agricultural commodities are investigated to see whether a change in bioethanol prices have some effect on those variables (Vacha et al., 2013).

While reviewing the literatures, most of the studies test bioethanol variable in term of price rather than using the term of production in the papers like Monteiro, Altman and Lahiri (2012), Bryngelsson and Lindgren (2013), and Ge, Lei and Tokunaga (2014). All of these studies have employed the land-use framework to measure impact of production of bioethanol on food prices. This can be argued that the effect of expanding bioethanol production has induced more land competition between bioethanol and food crops (Ge et al., 2014). Monteiro et al. (2012) further explain that bioethanol could give impact on food prices, either shift produced food crops to produce fuel or convert agricultural land from food crops to energy crops. The overall structure of this literature review will be break into four subsections, which include theoretical or modelling framework, empirical testing procedures, empirical evidences and concluding remarks.

[5] Kanamura (2009) uses petroleum to represent energy and soybean to represent biofuels.

2.1 Theoretical / Modelling Framework

In the first subsection, we will discuss about theoretical or modelling framework employed in the past literatures. This is important as we could get some general insights in forming our own framework that supports the selection of relevant variables for our study.

The studies from Kristoufek et al. (2012), McPhail and Babcock (2012), and Monteiro (2009) are found to be introducing similar frameworks which considered meaningful for examining the relevant relationship under our present research paper. Kristoufek et al. (2012) develop a framework for biofuel market whereas McPhail and Babcock (2012) create a framework for corn market. Nevertheless, Monteiro (2009) has constructed a framework that links both markets of bioethanol and food.

Generally, the markets of bioethanol and agriculture commodity can be explained by applying the Law of Demand and Supply (McPhail & Babcock, 2012; Kristoufek et al., 2012). According to Kristoufek et al. (2012), the equilibrium price and quantity of biofuel are dictated through the interactions between biofuel demand curve, D (P_B, P_G) and biofuel supply curve S (P_B, P_F)[6]. The initial equilibrium is at point E shown in Figure 2.1.

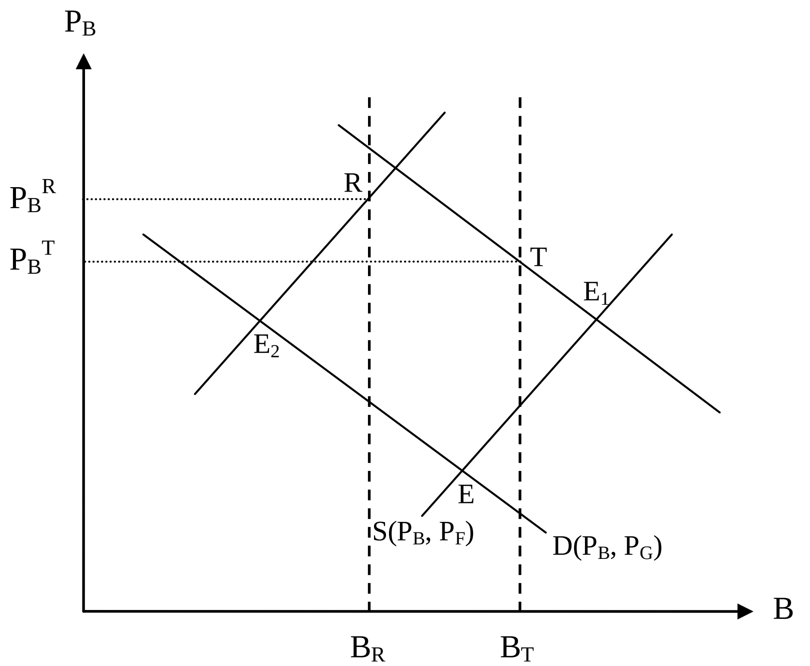
If the price of fossil fuel, P_G increases, the demand curve for biofuels, D(P_B, P_G) will shift to the right and achieve a new equilibrium point at E_1 (Kristoufek et al., 2012). Greater price and quantity of biofuel are resulted. Whereas, another new equilibrium, E_2 will be formed when a rise in feedstock

[6] P_B, P_F and P_G represent the prices of biofuel, feedstock and fossil fuel (Kristoufek et al., 2012).

price, P_F has caused a leftward shift in biofuel supply curve $S(P_B, P_F)$ and thus leading to higher biofuel price but lower biofuel quantity (Kristoufek et al., 2012).

In the case with several dominant forces which proposed in the biofuels development, there will be restrictions in terms of regulation and technology indicated by vertical straight lines at points B_R and B_T correspondingly[7]. In turn, these constraints have implied the minimal and maximal possible quantities of biofuels on the market. The biofuel market will achieved its equilibrium only at T or R, followed by each price at P_B^T and P_B^R.

Figure 2.1: Market Equilibrium of Biofuel



Source: Kristoufek et al. (2012).

[7] For the research of Kristoufek et al. (2012), the dominant forces of biofuels development include the regulatory support (blending obligations, mandates, subsidies and other measures encouraging the biofuels consumption) and technological feasibility (capacity of production and technological possibilities of biofuels utilization).

Likewise, the demand-supply framework is again been described for agricultural commodity in the study of McPhail and Babcock (2012). The researchers had provided a simple model of corn market via structuring both demand and supply equations. With consideration of the multi-use of corn, the demands for corn are modelled as below:

$$D_{ce} = a_{dce} + b_{dce}P_c + e_{dce} \quad (1)$$

$$D_{co} = a_{dco} + b_{dco}P_c + e_{dco} \quad (2)$$

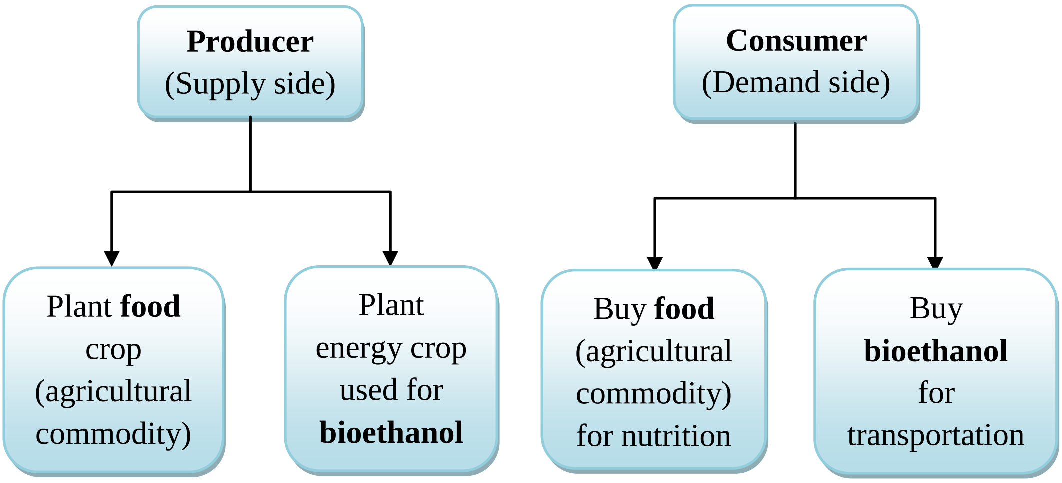
where a_{dce} indicates variables shifting the demand curves of corn from ethanol production, a_{dco} indicates variables shifting the demand curves of corn from other traditional source, P_c indicates the corn price, b_{dce} indicates the parameter of corn price for Eq.1, b_{dco} indicates the parameter of corn price for Eq.2, e_{dce} indicates the random demand shocks for Eq.1, and e_{dco} indicates the random demand shocks for Eq.2. The demand for corn from ethanol production, D_{ce} together with the demand for corn from other traditional source, D_{co} will represent the aggregate demand for corn, D_{cT}. From the supply perspective, McPhail and Babcock (2012) have formed the supply of corn shown as follow:

$$S_c = a_{sc} + b_{sc}P_c + e_{sc} \quad (3)$$

where a_{sc} indicates variables shifting the supply curves, P_c indicates the corn price, b_{sc} indicates the parameter of corn price for Eq.3 and e_{sc} indicates the random supply shocks for Eq.3. When demand and supply curves intersects with one another, the equilibrium state is achieved at $S_c = D_{cT}$ (= $D_{ce} + D_{co}$).

Unfortunately, the separate discussions on both biofuels and agricultural commodity markets cannot give a precise picture on how actually two markets are linked together. In fact, Monteiro (2009) had included the influences of both producer’s and consumer’s decision to study the changes in demand and supply of those markets concurrently.

Figure 2.2: The Decisions of Producer and Consumer



Source: Developed for the research

By referring to Figure 2.2, it is assumed that a producer will always produce both food and bioethanol with a fixed amount of land ($L_F + L_E \leq L_T$; where L_F is the land used to produce food, L_E is the land used to produce bioethanol, and L_T is the total number of land, respectively). The bioethanol production function is provided as below (Monteiro, 2009):

$$E = e(L_E) = A \cdot L_E^{\delta} \tag{4}$$

where L_E is the land used to produce bioethanol, A is the total factor productivity, and δ is the output elasticity of land. When the theory of profit maximization holds, the producer have to decide what proportion of bioethanol and food to plant on the same size of land to magnify the return after deducting the rental cost, w (Monteiro, 2009):

$$\pi = p_F L_F^{\gamma} - wL_F + p_E AL_E^{\delta} - wL_E \tag{5}$$

When $\frac{\partial \pi}{\partial L_E} = 0$, $\quad dL_E = \frac{\gamma(L_T - L_E)^{\gamma-1} dp_F + p_F\gamma(\gamma-1)(L_T - L_E)^{\gamma-2} dL_T - \delta L_E^{\delta-1} dA}{\delta A(\delta-1)L_E^{\delta-2} + p_F\gamma(\gamma-1)(L_T - L_E)^{\gamma-2}}$ (6)

where L_T is the total number of land, L_E is the land used to produce bioethanol, L_F is the land used to produce food, p_F is the price of food, p_E is the price of bioethanol, A is the total factor productivity, γ is the output elasticity of land for food, and δ is the output elasticity of land for bioethanol. From Eq.6, the price of food (dp_F) is negatively related to land used to produce bioethanol (dL_E), given that the sign of denominator is kept negative. This implies that higher food price will serve as an incentive for producer to allocate more land to produce more food (Monteiro, 2009). In other words, there is a competition for land between food and bioethanol while decreasing the production of one good indicates an increase in production of the other. Either decision of the producer will therefore affect the supply of bioethanol (Monteiro, 2009).

On the other hand, a consumer is expected to be consistently demand for both food and bioethanol with respect to a budget limit. The utility function and budget limit are shown as follow (Monteiro, 2009):

$$max\ U = F^{\alpha} \cdot E^{1-\alpha} \quad (7)$$

$$p_F F + p_E E = b \quad (8)$$

where $0 < \alpha < 1$, U is the consumer's utility level, F is the unit of food, E is the volume of bioethanol, p_F is the price of food, p_E is the price of bioethanol, and b is the total budget. Based on the theory of utility maximization, he or she has to decide which combination of both goods that will maximize his or her satisfaction after taking the total income into account (Monteiro, 2009). Any preference chosen by the consumer can definitely put an effect on the demand for bioethanol.

2.2 Empirical Testing Procedures

For this subsection, we would like to discuss about the use of different methods in previous studies by the researchers in order to suit their studies. This discussion can provide references for our study to identify the best method that provides the most information.

We found that there are several methods which are commonly used by researchers and also related to our study. These methods include Unit root test, Johansen cointegration test, Vector Error Corrections (VEC) model, Vector Autoregressive (VAR) model, Granger causality test, Impulse response function (IRF), Partial equilibrium model, Computable General Equilibrium (CGE) model, Autoregressive Conditional Heteroscedastic (ARCH), and Dynamic Conditional Correlation Multivariate GARCH (DCC-MGARCH) that will be discussed part by part as follow.

2.2.1 Unit Root Test

$$Y_t = \rho Y_{t-1} + u_t \qquad -1 \leq \rho \leq 1 \qquad (9)$$

Unit root test is important to the time series variable because we can only study its behaviour for the time period under consideration if the time series is nonstationary (Gujarati, 2004, p.798). From the general model (Eq.9) above, if ρ is 1, this means the unit root problem exists and shows a situation of nonstationary (Gujarati & Porter, 2009, p.744). In this case, the variance of Y_t will not be stationary. When $|\rho| < 1$, the time series Y_t is stationary. According to Monteiro's (2009) study, stationary time series can avoid the problem of spurious regressions.

Among the various researches, Dickey-Fuller (DF) test, Augmented Dickey-Fuller (ADF) and Philips-Perron (PP) unit root tests are normally used. Natanelov et al. (2013), Du and McPhail (2012), Wu and Li (2013), Monteiro et al.

(2012), Ciaian and Kancs (2011a) and Ciaian and Kancs (2011b) had used ADF and PP to test stationary of their variables. Moreover, Monteiro (2009) and Zhang, Lohr, Escalante and Wetzstein (2010) used DF and ADF to examine the stationary. Furthermore, Monteiro et al. (2012), Gardebroek and Hernandez (2013) and Kristoufek et al. (2012) only used ADF to carried out unit root test.

2.2.2 Johansen Cointegration

The Johansen cointegration test is used to examine the existences of three situations whether there is a deterministic trend, drift terms outside of the cointegrating vector or constants appearing in the cointegrating vector (Enders, 2004, p.372). Johansen cointegration test is applied on nonstationary time series (Natanelov et al., 2013). As long as the variables are integrated of order 1, Johansen's test for cointegration can be applied to examine whether a stable long-run relationship exists between the variables (Du & McPhail, 2012). According to Zhang et al. (2010), if the series is moving together in the long run, this means that the series is cointegrated. Ciaian and Kancs (2011a) and Ciaian and Kancs (2011b) also applied this test in their research.

2.2.3 Vector Error Corrections (VEC) Model

$$\Delta x_t = \Gamma_1 \Delta x_{t-1} + \ldots + \Gamma_{k-1} \Delta x_{t-k-1} + \Pi x_{t-1} + \mu_0 + \Psi D_t + \varepsilon_t \qquad (10)$$

VEC model is a model which describes short-run variation to show a long-run cointegrating relationship between variables (Stewart, 2005, pp.825-826).

Zhang et al (2010) also added that VEC model is a type of causality test that emphasize on the short-run dynamics of each series in a framework that binds the dynamics to long-run equilibrium relationships. This statement also supported by Ciaian and Kancs (2011a) and Ciaian and Kancs (2011b) stated that the long-run relationship between variables and the variations from their respective long-run trends. If the series are cointegrated, this model is more preferred instead of VAR model (Ciaian & Kancs, 2011a). According to Ciaian and Kancs (2011a) and Ciaian and Kancs (2011b), the researchers stated that it is important to carry out cointegration test. If not, the evidences may be very different towards detecting causality between variables. Besides, this model is also been used by Natanelov et al. (2013) and Ciaian and Kancs (2011b) to test long-run relationship between variables.

2.2.4 Vector Autoregressive (VAR) Model

$$\Delta y_t = \Pi y_{t-1} + \sum_{j-1}^{k-1} \Gamma_j \Delta y_{t-j} + c_t \quad (11)$$

VAR model is a method of resembling simultaneous-equation modelling by assuming almost no exogenous variables in the model (Gujarati, 2004, p.837). Each endogenous variable could be explained by its lagged or past value and the lagged value of all other endogenous variables in the model (Gujarati, 2004, p.837). There is only two researches use this method in their methodology, which are the studies of Cha and Bae (2011), and Du and McPhail (2012). The advantage of using this model is that it is easy to use without having to determine which variables are endogenous and which ones exogenous (Gujarati, 2004, p.853). This statement is supported by Ciaian and Kancs (2011a) and Ciaian and Kancs (2011b) explaining that the violation of exogeneity assumption of a regression equation can be solved by VAR model. However, the model has imposed a significant challenge in choosing the appropriate lag length. The larger the lag length, the greater the degree of freedom will be consumed. All the problems associated with that if the sample size is small (Gujarati, 2004, p.853). According to Cha and Bae (2011), the study suggest that a likelihood function is tend to be misbehaving given that a limited number of observation can caused the over-parameterization of the VAR model. In this case, there is no cointegration if $\prod$ is equal to zero but in most of the case $\prod$ is not equal to zero (Sorensen, 2005).

2.2.5 Granger Causality Test

Granger causality test examines the causality or the direction of influence between variables (Gujarati, 2004, p.696). In this test, a rough idea is usually introduced, stating that it is possible for events in the past to cause events to happen today but not the other way round (Gujarati, 2004, p.696). This test is commonly used by several researchers to carry out their research, which are Ciaian and Kancs (2011a), Ciaian and Kancs (2011b), Wu and Li (2013), Zhang et al. (2010), and Armah (2011). The assumption of this test is the error terms are uncorrelated (Gujarati, 2004, p.698). However, Sims's (as cited in Armah, 2011) study suggest that X and Y series should be pre-filtered to solve general suspicion on the existence of serial correlation problems between error terms in time series analysis.

Granger causality test is usually used to test two variables which called as bilateral causality. If there is multivariable causality, VAR model is more suitable than granger causality test (Gujarati, 2004, p.697). Natanelov et al. (2013) added that Granger causality with at least in one direction can be tested by Johansen cointegration test.

2.2.6 Impulse Response Function (IRF)

Impulse response function detects the feedback of the regressand in the VAR system to shocks in the error terms administered to one or more equations in the system (Gujarati, 2004, pp.853-854). There is few researchers who conduct this test in their studies such as Ciaian and Kancs (2011a), Ciaian and Kancs (2011b), Cha and Bae (2011), and Gardebroek and Hernandez (2013). However, there is one key issue concerned by Enders (2010, pp.311-312), pointing out that impulse response function are formulated using the estimated coefficients. This can cause this test to suffer from error due to the imprecision in estimating each coefficient (Enders, 2010, pp.311-312). Therefore, Enders (2010, p.312) suggests to construct confidence interval around impulse response to account for the parameter uncertainty inherent in the estimation process.

2.2.7 Partial Equilibrium Model

According to Krauss and Johnson (2008, p.13), partial equilibrium model can be defined as the economic is assumed to set a single market from the complicated network of market and ignore the feedback from particular market to another market and thus back into the market analysis. This model is used by Elobeid and Hart (2007), Saunders et al. (2009), Bryngelsson and Lindgren (2013), Kim et al. (2013), and McPhail and Babcock (2012). Bryngelsson and Lindgren (2013) stated that the advantage of partial equilibrium model is the model is able to provide high levels of detail and is often use to produce detailed scenarios. However, the concepts of demand and supply under this model might take a very long way to understand how the whole economic system works (Krauss & Johnson, 2008, p.13).

2.2.8 Computable General Equilibrium (CGE) Model

This model is suit for analyzing contemporary policy issues in a competitive market economy because CGE model carries the feature of price mechanism (Ge et al., 2014). Complicated trade-off problems which generated in the economy are able to solve by using the price mechanism (Ge et al., 2014). According to the Ge et al. (2014), they added that this model is widely used in various policy analysis due to CGE model can quantify the market behaviour and changes. The model is also specifically used to simulate policies or independent events (Ge et al., 2014). According to previous studies, we found that most of the researchers use GTAP database together with CGE model. Timilsina, Mevel and Shrestha (2011) added that the main data requirements are social accounting matrix (SAM) and elasticity coefficients. In the study of Narayanan and Walmsley (as cited in Timilsina et al., 2011) stated that SAM uses GTAP database to carry out. Furthermore, Timilsina et al. (2011), Yang, Huang, Qiu, Rozelle and Sombilla (2009), Banse et al. (2007), Ali, Huang and Yang (2013), and Huang, Yang, Msangi, Rozelle and Weersink (2012b) are using GTAP database in the CGE model. On the other hand, the CGE model also used by other researchers where they do not use GTAP database together with CGE model who are Wianwiwat and Asafu-Adjave (2013), Kretschmer et al. (2009), Ge et al. (2014).

2.2.9 Autoregressive Conditional Heteroscedastic (ARCH)

ARCH can be defined as a method of estimating the variance of a series at a specific point in time given the error variance is associated with the squared error term in the last term (Gujarati, 2004, p.488; Enders, 2004, p.120). In the study of Algieri (2014), the researcher stated that ARCH test allows the restrictive variance to change over time as a function of past innovations. According to Wu and Li (2013), ARCH effects have two methods to test it. One is using the usual F statistic for the regression on the squared residuals, while another one is to check for ARCH effects on residual series by using Ljung-Box Q-test or Lagrange Multiplier (LM) test on the first lags of squared residual series (Wu & Li, 2013). ARCH model has been used by Wu and Li (2013) and Algieri (2014).

2.2.10 Dynamic Conditional Correlation Multivariate GARCH (DCC-MGARCH)

According to Du and McPhail (2012), DCC-MGARCH is a model that examines a weighted average of the variables' correlations over the whole sample period with more weights given to more current history. This model also allows the amendment of correlation estimates based on instant past conditional variances (Du & McPhail, 2012). By comparing with other estimators, this model offers good approximation for different time-varying correlation processes and is often the most accurate (Du & McPhail, 2012). This is support by Kanamura (2009), stated that the DCC model can compute the conditional correlations after estimating the coefficients of the model. This model has been used by Du and McPhail (2012), Kanamura (2009), and Gordebroek and Hernandez (2013).

2.3 Empirical Evidences

Coming to this subsection, we discuss on the empirical findings in the past literatures. This could help us in estimating the direction and significance of relationships between variables for our study.

A number of researchers have found to be using similar variables of fossil fuels, biofuels and agricultural commodities to fit into each different research objectives. However, mix outcomes are commonly resulted among the researches although some of these studies have employed the identical research objective and variables.

There are several researchers looking at the relationships among oil, bioethanol and corn but the results are inconsistent among them. Natanelov et al. (2013) have shown that the relationship between corn and bioethanol appears to be less direct as well as the two markets are not firmly connected by a long-run cointegrating relationship. It is argued that the price transmission is accelerated more by the government's mandated levels of bioethanol use in gasoline production instead of the marketplace. Their finding is supported by the result of Zhang et al. (2010), further suggesting that the sugar price is found to be the dominant force in influencing agricultural commodity prices as it acts as the largest input for world bioethanol production[8]. However, the results from Cha and Bae (2011) have somehow disagreed with those statements above. As a result of an oil price shock, the price of corn is raised in the short run by higher bioethanol demand for corn which is a substitute for petroleum (Cha & Bae, 2011). In fact, in the long run, the progress of quantity adjustments from the reduction in export demand for corn and feed demand for corn would eventually offset such price increment in corn market (Cha & Bae, 2011).

Several studies also examine the volatility transmission between oil, bioethanol and corn markets by accounting for the structural break on 2008, which are Algieri (2014), Gardebroek and Hernandez (2013), Wu and Li (2013), and Du and McPhail (2012). It is found that there is a single directional spillover from crude oil market to corn market but the spillover between bioethanol and corn are in the form of double directions (Wu & Li, 2013). However, this is partly

[8] The agricultural commodities in the study of Zhang et al. (2010) have included corn, rice, soybeans, sugar and wheat.

supported by Algieri (2014) stating that oil and bioethanol have their impact on a range of agricultural commodities[9]. Nevertheless, the findings of Gardebroek and Hernandez (2013) have argued that none of volatility spillover from oil or bioethanol to corn is observed. Instead, it is only the shock in corn price volatility that induces a short-run shock in bioethanol price volatility (Gardebroek & Hernandez, 2013). Despite of that, different results are obtained by Du and McPhail (2012), stating the price variation in individual markets is defined by their own shocks before the structural break. While during the later period, all prices of corn, bioethanol and gasoline are found to be influencing one another positively and significantly (Du & McPhail, 2012). It is noticed that the shocks of ethanol have place the greatest effect on the price of corn, vice versa (Du & McPhail, 2012).

On top of that, these studies below are having different objectives to carry out their research but all of them are focusing on the relationship between oil price and agricultural commodities by taking the upsurge of bioethanol into account. Kanamura (2009) is testing the correlation while Ciaian and Kancs (2011a) and Ciaian and Kancs (2011b) are examining the cointegration as well as impact of these variables. According to Kanamura (2009), the researcher stated that there are significant strong correlations between energy and grain price return, between energy and biofuels and between petroleum and agricultural commodities excluding corn during high oil price[10]. The researcher added that petroleum and corn futures price returns do not have any correlation (Kanamura, 2009). In the studies of Ciaian and Kancs (2011a) and Ciaian and Kancs (2011b), it is found that the prices of agricultural commodities which included directly and indirectly used in bioenergy production are influenced by energy prices. Besides, the researchers found that the energy and food market are increasingly cointegrated over time (Ciaian & Kancs, 2011a; Ciaian & Kancs, 2011b) [11].

[9] These agricultural commodities consist of corn, wheat, sugar and soybeans (Algieri, 2014).

[10] Petroleum represents energy whereas soybean and soybean oil represent biofuels and agricultural commodities refer to sugar, wheat and corn (Kanamura, 2009).

[11] Those studies have considered three periods, which are 1993 to 1998, 1999 to 2004 and 2005 to 2010 (Ciaian & Kancs, 2011a; Ciaian & Kancs, 2011b).

Additionally, another group of the researchers have their interest on investigating the correlations between energy and agricultural commodities by concerning the food crisis in 2008. With the special use of wavelet coherence technique, it is observed that the weak connections from biofuels to almost all biofuels feedstock commodities in pre-crisis period have changed into a strong positive one after the crisis (Vacha et al., 2013) [12]. Similar changes have also been obtained by Kristoufek et al. (2012) by employing different methods, which are minimal spanning trees and hierarchical trees. The authors found that during the high food prices period, ethanol is well connected to corn, wheat and soybeans in short-run and even more strongly in medium-run (Kristoufek et al., 2012). Meanwhile, there is a mild correlation between biodiesel and the rest of the system in short-run but in the medium-run, biodiesel is strongly connected with other fuels commodities (Kristoufek et al., 2012) [13]. The authors continue add on that before the food crisis, the agricultural commodities (corn, wheat and soybeans) are strongly connected with the whole network except sugars (Kristoufek et al., 2012). However, the same correlations are comparably higher for post-crisis period than that in pre-crisis period (Kristoufek et al., 2012).

Likewise, the issue of food security has motivated a few researchers to study on the impact of biofuels expansion on food prices through the allocation of land use. From the finding of Ge et al. (2014), an increase in bioethanol production will lead food prices to rise, given that there is no potential land input. This result is consistent with what Bryngelsson and Lindgren (2013) has observed where food prices increase as the outcome of increased bioenergy demand. This is due to the increasing competition for land has raised the cost of land rents (Bryngelsson & Lindgren, 2013) [14]. However, Monteiro et al. (2012) argued that

[12] In the study of Vacha et al. (2013), biofuels refer to ethanol and biodiesel. The feedstock for ethanol includes corn, wheat, and sugarcane. Meanwhile, soybeans and rapeseed oil are the feedstock for biodiesel.

[13] The commodities consisted in the study of Kristoufek et al. (2012) are crude oil, ethanol, corn, wheat, sugarcane, soybeans, sugar beets, biodiesel, German diesel, US diesel, German gasoline and US gasoline.

[14] The cost of land rents occupies a great share of production costs, especially for food which are produced in extensive system (Bryngelsson & Lindgren, 2013).

in US, ethanol area does not have impact on food price significantly and the researchers found that ethanol area has negative impact on food price in Brazil[15].

Several complex studies which are not being discussed in this section are tabulated in Appendix 2.1.

2.4 Concluding Remarks

In a nutshell, there are many researchers carry out unit root test to examine whether the variables are stationary or non-stationary before they use the variables to test in other method. The common unit root tests used by the researchers are ADF, PP and DF. We also notice that most of the researchers who test the relationship between variables of energy, bioenergy and agricultural commodities will run Johansen cointegration test first, followed by VAR model or VEC model. On the other hand, many authors analyze contemporary policy issue or simulate the policies through the method of CGE. Furthermore, several researchers have used uncommon methods to carry out their research. For example, Ordinary Least Square (OLS) in the paper of Monteiro et al. (2012), EGARCH test in the paper of Wu and Li (2013), GARCH test in the paper of Algieri (2014) and Two-Stage Least Square (2SLS) in the paper of Miljkovic et al. (2012).

It is found that most researchers choose to use the high frequency data. Moreover, the usual variables used to indicate biofuels are bioethanol and biodiesel whereas to indicate biofuel feedstocks are corn, sugarcane, rapeseed oil and soybeans. Meanwhile, Thailand as one of the major producers of bioethanol in Asia has not recently spurred any researcher’s interest to look into detail of the

[15] In the study of Monteiro et al. (2012), ethanol area for both US and Brazil refer to planted area of cane and planted area of corn used to produce ethanol.

same relationship. Therefore, it can be said that there is still a wide extent provided to explore in the relationship between biofuels and its feedstock.

Chapter 3: Methodology

3.0 Introduction

This chapter deals with the methodology to test the relationship between bioethanol production and its feedstock prices. At first, we discussed about the theoretical framework that applied in this study. Then, we state out our general model in precise.

Next, we will discuss on empirical testing procedures that we will employed in this study to achieve the objective of this study. At first, the unit root test will be used to examine whether the variables are stationary or not. Then, the Auto Regressive Distributive Lag (ARDL) test is adopted to check for the long-run relationship. Lastly, the short-run Granger causality test (Wald test) under ARDL framework is held to observe the direction of influence between variables. Further discussion on the tests will be in the next part. Hereafter, we will discuss on the data sources that we collected from Thailand and the period of time we choose to study in the data description part.

3.1 Theoretical / Modelling Framework

3.1.1 Theory

The relationship between bioethanol production and its feedstock prices can be theoretically explained by the Supply Theory and also the Input-Price Effect. The Basic Supply Theory introduces the concept of quantity supplied and supply of a good (Perloff, 2011). A change in quantity supplied of a good is shown by a movement along the supply curve, given that the price of the good itself changes, holding other variables constant (Perloff, 2011). On the other hand, a change in supply of a good is indicated by a shift in supply curve, which is the result of a change in variables other than the price of the good itself (Perloff, 2011)[16]. Meanwhile, the Input-Price Effect illustrates the picture of how the supply of a good is affected when there is a change in input price initiated by any changes in production of that good (Hirshleifer, Glazer & Hirshleifer, 2005). To be more precise, Figure 3.2 is used to apply both theories in similar relationship.

Figure 3.1 shows the shift of supply curve due to the factor of production (input price) had change. According to Perloff (2011), the change in other input for a good other than the price of the good itself will cause the supply curve to shift. In Figure 3.1, price of good represented as P and quantity of good represented as Q. In our research, price of bioethanol denoted as P and quantity of bioethanol denoted as Q. Initially, bioethanol industry produces bioethanol production at Q_0 and the price level of bioethanol is at P_0. Since the shift of supply is only caused by other factors like capital, labor and material (input or price) but the price of bioethanol (P_0) remain unchanged, increase in input price of bioethanol production (sugarcane, cane molasses and cassava) will cause the cost

[16] According to Perloff (2011), other variables or inputs can be divided into three categories which are capital, labor and materials (input of production).

of bioethanol production increase. When the cost of bioethanol production had been increased, the producers will find that it is more costly to produce the same amount of bioethanol production. Therefore, in order to cut down cost, the producers will produce less bioethanol and supply less quantity of bioethanol to the market. As shows in Figure 3.1, the supply curve of bioethanol shifts to the left from SS_0 to SS_1 due to higher cost of production. The quantity of bioethanol reduces from Q_0 to Q_1. On the other way round, when the feedstock price reduces, the producers find that the cost of production is relatively cheaper than before. Therefore, they will produce more bioethanol and supply more quantity of bioethanol to the market. As shown in the graph, the supply curve of bioethanol shifts to the right from SS_0 to SS_2 due to lower cost of production. The quantity of bioethanol increases from Q_0 to Q_2.

Figure 3.1: The Theory of Supply (Shift of Supply Curve)

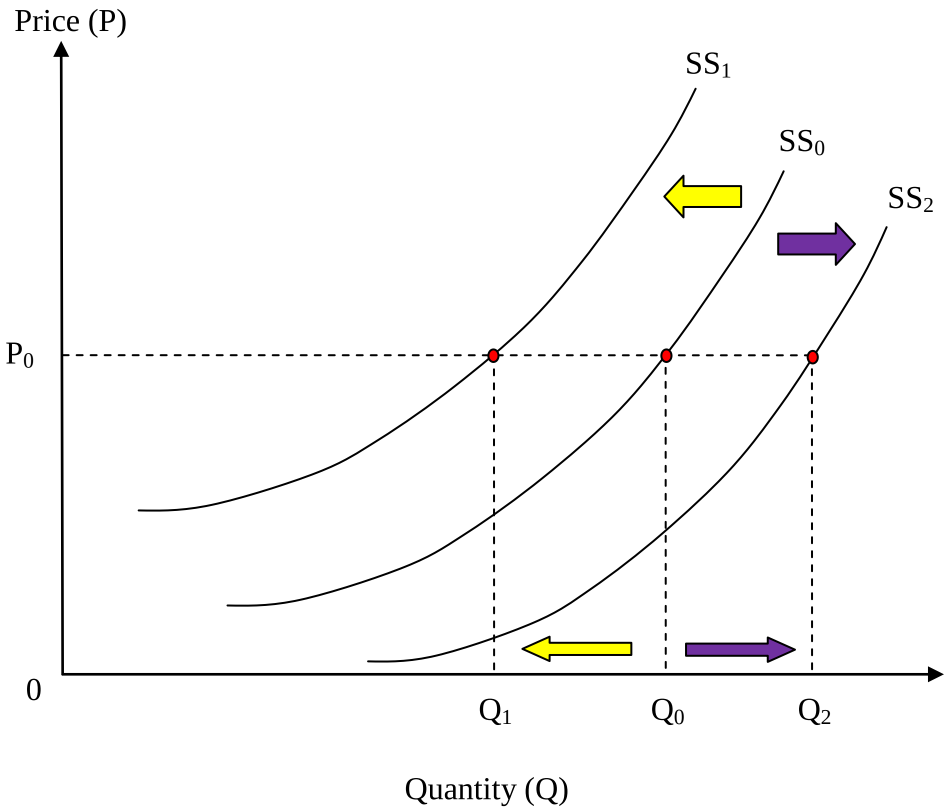
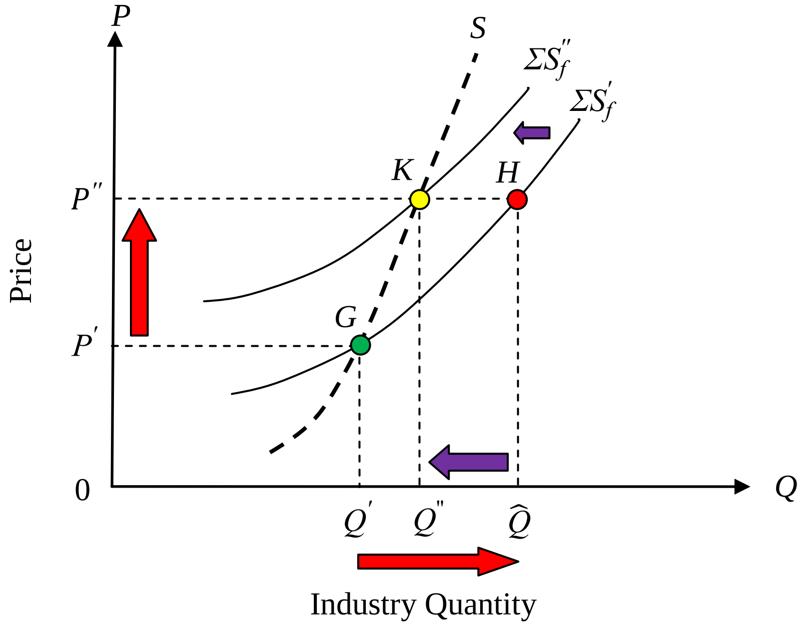


Figure 3.2 is used to explain the relationship between bioethanol production and its feedstock price (input) using the theory of supply (based on the theory discussed in Figure 3.1) and Input-Price Effect.

In our case, the Figure 3.2 shows the initial supply curve for bioethanol industry, $\Sigma S_f'$ which horizontally total up all individual firms' supply curves at every price level for bioethanol in the market. At the price level of P' (price of bioethanol), the whole industry is willing to supply the quantity of bioethanol at Q', thus determining point *G* on $\Sigma S_f'$. When the price level is increase from P' to P'', there will be a movement along the supply curve and reach point *H*, given the assumption of constant input prices (price of sugarcane, cane molasses and cassava). As an effect, the producers will demand more input to produce more output of bioethanol because the producers can sell bioethanol at higher price (P'') compare to previous price (P'). Therefore, the production of bioethanol expanded from Q' to $\widehat{Q}$.

However, if the Input-Price Effect is taken into account, the expansion of industry production will actually cause a rise in its input prices (Hirshleifer et al., 2005). This means that there will be more demand on its input (feedstock) to produce additional quantity of bioethanol. When producers increase demand on input, it will push up the price of input. In turn, the cost of production will increase due to increasing price of input. In order to cut down the cost of production, producers will produce less bioethanol and supply less quantity of bioethanol to the market. This situation will lead to a parallel shift in industry supply curve from $\Sigma S_f'$ to $\Sigma S_f''$ at the same price level, P''. Then, point *K* is resulted on $\Sigma S_f''$. A new industry supply curve, *S* will be formed by joining point *G* and point *K* together.

Figure 3.2: The Theory of Supply and Input-Price Effect



Source: Hirshleifer et al. (2005).

3.1.2 Model

As mentioned in theoretical framework, changes in input price and changes in bioethanol production can affected one another through Input-Price Effect. Therefore, we have design two bivariate models (Eq.12 and Eq.13) in general form to investigate the relationship between bioethanol production and the agricultural commodity prices. To avoid any model misspecification bias, we choose to employ a linear-logarithmic model which used in the study of Fanaei, Khansari and Maskooki (2008)[17].

$$ETH_t = \beta_0 + \beta_1 FS_t + \varepsilon_{1t} \tag{12}$$

$$FS_t = \alpha_0 + \alpha_1 ETH_t + \varepsilon_{2t} \tag{13}$$

[17] Fanaei et al. (2008) had used a linear-logarithmic model for modelling the new acid hydrolysis step for bioethanol production from waste wood. Total amount of fermentable sugar produced (mg/100ml) in hydrolysis step using 2%, 5%, 10% and 20% acid concentrations is predicted by depending on the logarithm of process duration time (minute).

where ETH_t = Production of bioethanol (Million liter per month)

FS_t = $\ln SGC_t$, $\ln MOL_t$ and $\ln CAS_t$

$\ln SGC_t$ = Farm gate price of sugarcane (Baht per ton)

$\ln MOL_t$ = Export price of cane molasses (Baht per kilogram)

$\ln CAS_t$ = Farm gate price of cassava (Baht per kilogram)

ε_{1t} , ε_{2t} = Residual of the models

In the Eq.12, the dependent variable is bioethanol production and the independent variable is feedstock (sugarcane farm gate price, cane molasses export price and cassava farm gate price, respectively).

According to Felix, Cardona and Quintero (n.d), feedstock price is significant to biofuel cost of production. Therefore, when sugarcane farm gate price rise, cost of production for bioethanol will increase and lead to bioethanol production to reduce. The reason of choosing farm gate price for sugarcane as independent variable (Eq.12) is because of its role as an input for bioethanol production. At the same, this price is also faced by other industries which treat sugarcane as their input, especially for the sugar sector.

When the export price of cane molasses increase, it is more attractive to export cane molasses overseas compare to use it to produce bioethanol. Therefore, the production of bioethanol will be decrease. We choose export price of cane molasses as our independent variable (Eq.12) rather than domestic farm gate price is due to this following issue.

> The Government is also thinking of banning the exports of molasses and using this supply as feedstock for ethanol manufacture. Thailand normally exports about 1.3 million tons of molasses (excluding the recent

drought-related sugarcane shortage); and at a conversion rate of 250 litres of alcohol per ton of molasses, this represents 328 million litres annually. Thailand plans to become a major ethanol producer and export centre. Asian economies such as Japan, China, the Republic of Korea and India represent a major ethanol demand. Japan is importing 300-400 million litres of ethanol a year and will increase this to 600 million litres. Instead of exporting relatively low-valued commodities such as sugar and cassava chips, Thailand can profit by converting sugarcane and cassava to ethanol (Gonsalves, 2006, p.12).

Referring to the issue discussed on top, the cane molasses from export can produce extra bioethanol when Thai government ban all the exports activities of cane molasses. This happens after the bioethanol producers have propose to raise the price of bioethanol that sold to petroleum distillation factories just to match with the increasing price of cane molasses (ES Power, 2013). However, from the view of sugar producers, banning cane molasses exports may lower the price of cane molasses and thus affecting the revenue of sugar and cane system which is indebted with sugar and cane foundation and financial institutions about 18 billion Baht. At the same time, Thailand is the largest cane molasses exporter in the world who averagely exports 1.4-1.5 million tons, which is even greater than around 1 million tons been utilized in domestic continuing industries in 2006[18]. In short, the issue mentioned above has highlighted the significance of cane molasses export price on bioethanol production.

Similar issue is observed by referring to the study of Schoonover and Muller (2006). Since United States has its bioethanol production expanding at an extraordinary rate, the U.S. Department of Agriculture (USDA) has declare that

[18] Domestic continuing industries have include the liquor and alcohol production industry, animal feeding production industry, monosodium glutamate, vinegar and so on (ES Power, 2013).

much of the additional corn needed for bioethanol production will be transferred from exports. However, there is little attention or discussion on the effect of corn-based ethanol on United States corn exports. Therefore, it is proposed that the significance of the bioethanol's potential impact on corn exports should be concerned and also alerts the policymakers to reconsider their long-standing focus on exports.

Similar to sugarcane, we choose to use farm gate price for cassava as our independent variable (Eq.12) because it is a part of the bioethanol production cost. Meanwhile, cassava is also an input for the productions of dry chips, pellets and powder for both domestic and export use in other industries aside from using it to produce bioethanol (Poramacom, Ungsuratana, Ungsuratana & Supavititpattana, 2013; Ratanawaraha, Senanarong & Suriyapan, n.d). When the farm gate price of cassava decrease, the cost of production for bioethanol will be reduce. Hence, the bioethanol production will increase.

Eq.13 shows independent variable is bioethanol production and the dependent variables are sugarcane farm gate price, cane molasses export price and cassava farm gate price, respectively.

We choose bioethanol production as independent variable for its feedstock (sugarcane farm gate price and cassava farm gate price) in Eq.13, because changes in bioethanol production will affect the price of its feedstock. According to Auld (2012), the researcher found out that the increase in feedstock demand due to increase in bioethanol production is significantly increasing the price of the feedstock. As a link to the Input-Price Effect theory, expansion of bioethanol production will cause a rise in input price due to the higher demand for the input. Thus, bioethanol production should have some relationship with both sugarcane and cassava farm gate price.

In Eq. 13, we had chosen cane molasses as dependent variable and bioethanol production as independent variable. This is because bioethanol production can affect the export price of cane molasses in term of demand. As mentioned above, since Thai government had set a target for bioethanol production, more amounts of cane molasses as input will be demanded to produce more bioethanol. The increase in demand for cane molasses will cause shortage in the commodity and this will lead to a rise in cane molasses price. Similarly, export price of cane molasses will also increase because this price is adjusted by Thai government due to a shortage in cane molasses. Similar relationship between input and production could be observed in the issue of US wheat export. According to Wilson and Mulvany (2015, January 29), the action of shifting the cattle feed from wheat to corn by US cattle producers had became one of the causes for the export price of wheat to drop through a decline in demand[19].

3.2 Empirical Testing Procedures

3.2.1 Unit Root Tests

In general, stationary stochastic process indicates that the mean and variance are constant over time (Gujarati, 2004, p.797). On the other hand, nonstationary means that the time series have time varying mean or time varying variance or both (Gujarati, 2004, p.798). Having a nonstationary time series may provide misleading regression result (Monteiro, 2009). In fact, integrated stochastic processes can solve the problem of nonstationary (Gujarati, 2004, p.804).

[19] The other reasons that cause the US wheat export price to drop had included the wheat surplus in global market, lesser demand from China, Brazil and Nigeria, and the strengthening of US dollar (Wilson & Mulvany, 2015, January 29).

There are many unit root tests that can help to test whether the time series variables are stationary or non-stationary. DF test assumes that the error term was uncorrelated (Gujarati, 2004, p.817). Whereas, ADF test is to test stationary if the error terms are correlated by adding the lagged difference terms of the dependent variable (Gujarati, 2004, p.817). PP unit root test uses nonparametric statistical methods to take care of the serial correlation in the error term without adding lagged difference terms (Gujarati, 2004, p.818).

3.2.1.1 Augmented Dickey-Fuller (ADF) Test

ADF test is used to detect unit root or non-stationary in a time series. Compare to DF test, ADF had try to solve the serial correlation in error term (u_t) by adding enough lagged difference terms of dependent variable (Gujarati & Porter, 2009, p.758). This is to ensure the presence of autocorrelation in the DF test will not provide bias result (Mahadeva & Robinson, 2004). According to Kirchgassner and Wolters (2007), ADF test has the advantage in parametrically model the serial correlation of error terms that enable the checking of autocorrelation in the error terms of the estimated test equation.

$$\Delta y_t = \alpha + \beta t + \delta y_{t-1} + \sum_{i=1}^{k} \gamma_i \Delta y_{t-i} + \varepsilon_t \tag{14}$$

From the general model (Eq.14) above, Δy_t refers to the first difference of series (ETH_t, $\ln SGC_t$, $\ln MOL_t$, and $\ln CAS_t$), α represents the intercept term, βt is the trend variable, δy_{t-1} is the lagged term of series, $\sum_{i=1}^{k} \gamma_i \Delta y_{t-i}$ indicates the total lagged differences in series and ε_t refers to white noise error term.

Under the ADF test, the null hypothesis is δ equals to zero while the alternative hypothesis is δ less than zero. Given that the estimated coefficient of y_{t-1} is follow the τ (tau) statistic, the estimated coefficient of y_{t-1} has to be divided by its standard error to calculate the τ (tau) statistic (Gujarati & Porter, 2009, p.755). We will reject the null hypothesis (δ < 0; time series is stationary) if the computed value of τ (tau) statistic is smaller than its critical τ (tau) values. Otherwise, we do not reject null hypothesis (δ = 0; time series is non-stationary).

3.2.1.2 Phillips-Perron (PP) Test

$$\Delta y_t = \mu + \beta \left[t - \frac{n}{2}\right] + \delta y_{t-1} + \varepsilon_t \qquad (15)$$

The Eq.15 is the general model for PP test. This test is an alternative unit root test for ADF test which had try to solve serial correlation in error term by 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 impose any impact on the estimated parameters as well as if the autocorrelation coefficients tend towards zero, they are at best with little impact on the estimated variance (Kirchgassner & Wolters, 2007). Meanwhile, these features of PP test are able to solve the reduction power in the ADF test aroused from too large amount of lagged differences. Too small amount of lags also affect the accuracy of ADF test because of the autocorrelation in estimated residuals (Kirchgassner & Wolters, 2007). On top of that, PP test also perform additional function by solving heteroscedasticity in the error terms (Phillips & Perron, 1988).

3.2.2 Auto Regressive Distributive Lag (ARDL) Bounds Testing Approach of Cointegration

ARDL bound testing approach was developed by Pesaran (1997), Pesaran and Shin (1997), and Pesaran, Shin and Smith (2001) to examine the long-run relationship among the variables. It is a general dynamic specification model which includes the lags of the endogenous variable and the lagged of exogenous variables to estimate the short-run effects directly and the long-run equilibrium relationship indirectly (Royfaizal, 2009). As discussed by Chan and Lau (2004), the general model for ARDL is displayed as follow:

$$\phi(L,P)y_t = \sum_{i=1}^{k} \beta_i\,(L,q_i)x_{it} + \delta' w_t + \mu_t \qquad (16)$$

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

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

L refers to the lag operator where $Ly_t = y_{t-1}$; 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 $p = 0,1,2,\ldots,m$; $q_i = 0,1,2,\ldots,m; i = 1,2,\ldots,k$ with a total of $(m+1)k+1$ARDL models can be estimated by OLS. An optimal lag selection is based on information criterion such as Akaike information criterion (AIC), Schwarz Bayesian criterion (SBC), or the Hannan-Quinn criterion (HQC). With appropriate lag length and asymptotic inferences, the long-run and short-run parameters can be obtained through OLS regardless whether the independent variables are exogenous or not.

As compared to other conventional cointegration tests [e.g. Johansen and Juselius (1990), Engle and Granger (1987)], several advantages of ARDL bound testing approach have been highlighted in the studies of Sari and Soytas (2009), and Duasa (2007):

i. ARDL is able to solve the problems aroused from the non-stationary series. Therefore, the pretesting for unit root on series is not necessary at all. The underlying series can be in different order of integration, either purely I(0) or purely I(1) or both.
ii. Even though the sample size is small, cointegrating relationship can be determined efficiently[20].
iii. ARDL does not require large amount of specifications to be made, including decisions on the number of regressors and regressands to be added, the treatment of deterministic elements, and the appropriate amount of lags to be included.
iv. ARDL enables different variables to have different optimal lags.
v. To test the long-run relationship, ARDL uses only one reduced form equation.

By using the ARDL approach, we would like to specify the unrestricted bivariate regressions (Eq.17a and 17b) for the long-run relationship between bioethanol production and agricultural commodity prices as constructed below:

$$\Delta ETH_t = \alpha_0 + \sum_{i=1}^{k} \alpha_1 \Delta ETH_{t-i} + \sum_{i=0}^{k} \alpha_2 \Delta \ln FS_{t-i} + \delta_1 ETH_{t-1} + \delta_2 \ln FS_{t-1} + \varepsilon_{1t} \qquad (17a)$$

$$\Delta \ln FS_t = \gamma_0 + \sum_{i=1}^{k} \gamma_1 \Delta \ln FS_{t-i} + \sum_{i=0}^{k} \gamma_2 \Delta ETH_{t-i} + \eta_1 ETH_{t-1} + \eta_2 \ln FS_{t-1} + \varepsilon_{2t} \qquad (17b)$$

[20] Narayan (2005) had tabulated the critical values for the sample size of 30 to 80 based on his own argument that the two existing sets of critical values developed by Pesaran (1997) and Pesaran et al. (2001) can only be applied on large sample size ranging from 500 to 1,000 observations and 20,000 to 40,000 replications respectively.

The short-run parameters are represented by α and γ. The long-run parameters are denoted as δ and η. $\ln FS$ represents $\ln SGC$, $\ln MOL$ and $\ln CAS$ respectively.

To examine the cointegrating relationship, the Wald test (F statistic) is conducted such that restrictions are imposed on the estimated long-run coefficients of bioethanol production and FS (sugarcane farm gate prices, cane molasses export price and cassava farm gate price respectively). The null and alternative hypotheses for Eq.17a and 17b are set as below:

$H_0: \delta_1 = \delta_2 = 0$ (No existence of long-run relationship)
$H_1: \delta_1 \neq \delta_2 \neq 0$ (Existence of long-run relationship)

$H_0: \eta_1 = \eta_2 = 0$ (No existence of long-run relationship)
$H_1: \eta_1 \neq \eta_2 \neq 0$ (Existence of long-run relationship)

Since our sample size contains of 99 observations, we prefer to use the sets of critical values created by Pesaran (1997) and Pesaran et al. (2001) rather than the sets of critical values reported by Narayan (2004). This is because our sample size is consider as big and do not fall between the sample size of 30 to 80 which considered as small sample size. From the two sets of critical values given by Pesaran (1997) and Pesaran et al. (2001), critical values bounds are provided for all categories of the variables into purely I(0), purely I(1), or a mixture of both[21]. If the F-statistic exceeds the upper bound critical value, we should reject the null hypothesis and conclude that there is a long-run relationship between the variables. However, the null hypothesis will not be rejected when the F-statistic is smaller than the lower bound critical value, thus a long-run relationship does not exist. For the case where the F-statistic falls within the critical bound values, our decision

[21] The upper bound is tabulated on the basis where the variables are I(0) while the lower bound on the basis that they are I(1) (Chan & Lau, 2004).

about the existence of long-run relationship will be inconclusive unless we carry out the unit root tests to know the order of integration of the underlying variables before continuing with the ARDL approach (Narayan, 2004; Pesaran, 1997; Pesaran et al., 2001).

3.2.3 Granger Causality Test (Wald Test)

Granger causality test (Wald test) under ARDL framework also known as short-run causality test (Nathan & Liew, 2013). This causality test is used to determine the directions of causality among variables in a model once the ARDL cointegration test had identified the variables are having a long-run relationship (Ozturk & Acaravci, 2010). Meanwhile, if the variables in a model are cointegrated, there must be at least one way causality (Ferda, 2008; Narayan & Smyth, 2004; Tang & Abosedra, 2014). Furthermore, when cointegration among variables exists in a model, the standard Granger-type causality test is augmented with lagged error correction term (ECT) (Narayan & Smyth, 2004). As discussed by Ferda (2008), the general error correction model (ECM) used for Wald test is displays as follow:

$$\Delta f_t = a_0 + \sum_{i=1}^{m} a_{1i}\Delta f_{t-i} + \sum_{i=0}^{m} a_{2i}\Delta y_{t-i} + \sum_{i=0}^{m} a_{3i}\Delta p_{t-i} + \lambda EC_t + \mu_t \qquad (18)$$

where speed of adjustment parameter represented as λ and EC_t is the error correction term derived from ARDL cointegration model.

ECT in a model captures the long-run causality information whereas the individual coefficients of the lagged term capture the short run dynamics (Alimi, 2014). According to Narayan and Smyth (2004), the authors stated that if the variables in a model are not cointegrated, ECT does not need to be included in ECM (Eq.18). Besides, the optimal lag length in the ECM is based on Information

Criterion such as Schwarz Bayesian Criterion and the dependent variable is regressed based on its own past values and other variables as well (Narayan & Smyth, 2004; Ozturk & Acaravci, 2010).

The following equations are the causality test model for bioethanol production and its feedstock price (sugarcane farm gate price, cane molasses export price and cassava farm gate price respectively):

$$\Delta \ln ETH_t = \alpha_0 + \sum_{i=1}^{m} \beta_{1i} \Delta \ln ETH_{t-i} + \sum_{i=1}^{k} \beta_{2i} \Delta \ln FS_{t-i} + \mu_1 EC_t + \varepsilon_{1t} \qquad (19)$$

$$\Delta \ln FS_t = \theta_0 + \sum_{i=1}^{k} \varphi_{1i} \Delta \ln FS_{t-i} + \sum_{i=1}^{m} \varphi_{2i} \Delta \ln ETH_{t-i} + \mu_2 EC_t + \varepsilon_{2t} \qquad (20)$$

where lag operator denoted as Δ. The estimated coefficients are represented as $\alpha_0, \beta, \theta_0$ and φ. m and k are the optimal lag of the series. ε_{1t} and ε_{2t} are the error term for each model. μ is the speed of the adjustment for each model and the EC_t is the ECT. $\ln FS$ represents $\ln SGC$, $\ln MOL$ and $\ln CAS$ respectively. The null and alternative hypotheses for Eq.19 and Eq.20 are set as below:

$H_0: \beta_{2i} = 0$ (Feedstock price does not Granger cause bioethanol production)

$H_1: \beta_{2i} \neq 0$ (Feedstock price does Granger cause bioethanol production)

$H_0: \varphi_{2i} = 0$ (Bioethanol production does not Granger cause feedstock price)

$H_1: \varphi_{2i} \neq 0$ (Bioethanol production does Granger cause feedstock price)

If β_{2i} and φ_{2i} are jointly significant, the null hypothesis should be rejected (Nathan & Liew, 2013). Otherwise, we will not reject the null hypothesis.

3.3 Data Description

We have collected the secondary data from Thailand for this study. This includes the production of bioethanol, *ETH* as a fuel from Department of Alternative Energy Development and Efficiency (DEDE) of Thailand, farm gate price of sugarcane, *SGC* and farm gate price of cassava, *CAS* from Office of Agricultural Economics (OAE) of Thailand, as well as the export price of cane molasses, *MOL* from The Customs Department of Thailand.

Our studied period would be from January 2006 to March 2014 with monthly data frequency. Although Thailand had began its bioethanol program since 2004, the selection of this time period is based on the availability of data provided by the government departments of Thailand. Overall, we will have a total of 99 observations.

Table 3.1: Data Description in Detail

Data	Unit	Source
Production of bioethanol (ETH)	Million liter per month	Department of Alternative Energy Development and Efficiency (DEDE) of Thailand
Farm gate price of sugarcane (SGC)	Bath per ton	Office of Agricultural Economics (OAE) of Thailand
Export price of cane molasses (MOL)	Bath per kilogram	Customs Department of Thailand
Farm gate price of cassava (CAS)	Bath per kilogram	Office of Agricultural Economics (OAE) of Thailand

Chapter 4: Empirical Results

4.0 Introduction

We will interpret and analyze our results of methodology introduced in Chapter 3. First, we run the unit root tests – ADF and PP to examine the stationary of our variables. Then, we proceed with ARDL bounds testing approach to check whether there is any long-run relationship exists among the variables. At last, we conduct the short run Causality test (Wald test) to test the causal relationship between the variables.

4.1 Unit Root Test Result

Although ARDL does not require any unit root test on variables in initial, Duasa (2007) stated that these test could tell us whether the ARDL model is appropriate to be used. Table 4.1 and 4.2 show the results of ADF and PP tests. These unit root tests have the null hypothesis of the existence of a unit root versus the alternative hypothesis of the absence of a unit root.

In order to check whether the series have unit root or not, we test all the series using ADF test and PP test. Based on the previous researches, DF, ADF and PP unit root tests are normally used. Natanelov et al. (2013), Du and McPhail (2012), Wu and Li (2013), Monteiro et al. (2012), Ciaian and Kancs (2011a) and Ciaian and Kancs (2011b) had used ADF and PP to test stationary of their variables. Moreover, Monteiro (2009) and Zhang et al. (2010) used DF and ADF to examine the stationary. Furthermore, Monteiro et al. (2012), Gardebroek and Hernandez (2013) and Kristoufek et al. (2012) only used ADF to carry out unit root test.

For ADF test, we test the bioethanol production at level form first which include trend and intercept. After that, we will compare the test statistic and critical value of τ statistic. If the test statistic is smaller than critical value of τ statistic, we will reject H_0. Otherwise, do not reject H_0. If we do not reject H_0, this means that the series is non-stationary at level form. Therefore, we need to run first difference of the series which include intercept in the equation. Then we compare again the test statistic with the critical value of τ statistic. The whole process keeps going on until the series is stationary. However, for bioethanol production, the series is stationary at level form. Other series will be interpreted in the same manner.

Table 4.1: ADF Unit Root Test Result for Thailand

Variables	Augmented Dickey-Fuller test		
	Level		First Difference
	Intercept	Trend and Intercept	Intercept
ETH	-	-4.8494*	-
$\ln SGC$	-	-2.4888	-11.6690*
$\ln MOL$	-	-5.8024*	-
$\ln CAS$	-	-2.6213	-6.6859*

Critical Value	Level			First Difference		
	Trend and Intercept			Intercept		
	10%	5%	1%	10%	5%	1%
ETH	-3.1540	-3.4563	-4.0544	-	-	-
$\ln SGC$	-3.1540	-3.4563	-4.0544	-2.5828	-2.9816	-3.4992
$\ln MOL$	-3.1540	-3.4563	-4.0544	-	-	-
$\ln CAS$	-3.1543	-3.4568	-4.0554	-2.5830	-2.8919	-3.4999

Notes: All variables had been transformed to natural logs except bioethanol production. Asterisks (*), (**) and (***) indicate statistical significant at 1%, 5% and 10% levels, respectively.

For PP test, we adopt the same process like how we run for ADF test. Firstly, we test the bioethanol production at level form which include trend and intercept in the equation. Next, we compare the test statistic with the critical value of τ statistic at 1%, 5% and 10% significance levels, respectively. If the test statistic is less than critical value of τ statistic, H_0 is rejected. Otherwise, do not reject H_0. If we do not reject H_0, this indicates that the series have a unit root at level form. Therefore, we need to run the series at first difference which include intercept in the equation. After that we compare again the test statistic with the critical value of τ statistic. The whole process will continue until the series is stationary. However, for bioethanol production, the series is stationary at level form. Other series will be interpreted in the same manner.

Table 4.2: PP Unit Root Test Result for Thailand

Variables	Phillips-Perron test		
	Level		First Difference
	Intercept	Trend and Intercept	Intercept
ETH	-	-4.8438*	-
$\ln SGC$	-	-2.4888	-11.8145*
$\ln MOL$	-	-5.7850*	-
$\ln CAS$	-	-2.1931	-6.4281*

Critical Value	Level			First Difference		
	Trend and Intercept			Intercept		
	10%	5%	1%	10%	5%	1%
ETH	-3.1540	-3.4563	-4.0544	-	-	-
$\ln SGC$	-3.1540	-3.4563	-4.0544	-2.5828	-2.8916	-3.4992
$\ln MOL$	-3.1540	-3.4563	-4.0544	-	-	-
$\ln CAS$	-3.1540	-3.4563	-4.0544	-2.5828	-2.8916	-3.4992

Notes: All variables had been transformed to natural logs except bioethanol production. Asterisks (*), (**) and (***) indicate statistical significant at 1%, 5% and 10% levels, respectively.

Both tests have produced a consistent result. Variables of bioethanol production and cane molasses export price are significant at their level form, by rejecting the null hypothesis at 1% significance level. However, the variables of sugarcane and cassava farm gate price are significant at their first difference, by rejecting the null hypothesis at 1% significance level. Seems our variables is a mixture of I(0) and I(1), hence the ARDL model is applicable.

4.2 ARDL Bounds Testing Approach Results

There are mainly two steps while we estimate whether cointegration exists among the variables. The first step is to select the optimum lag length for the ARDL models (Eq.17a and 17b). According to Ibarra (2011), the optimal lag of the model is traditionally determined by the information criterion but at the same time, the suggested lag has to pass all the diagnostic tests before proceeding to the next step. We will select the optimal lags for each model based on minimum SBC value. This information criterion is adopted due to its ability to give the first preference to parsimony of the model with respect to the fitness (Abrishami & Mehrara, 2002). SBC will tend to choose the smallest possible lag length whereas AIC is likely to choose the relevant maximum lag length (Sari & Soytas, 2009). In the second step, we will use the bounds test to detect the existence of cointegration among variables. Lastly, we conduct the stability tests to test whether the short-run and long-run coefficients in Error Correction models are stable along the data period.

4.2.1 Bounds Test and Diagnostic Tests Results

Table 4.3 presents the results of bounds test and diagnostic tests for all combinations of variables. At first, we run the 1st model (DETH-DlnSGC) with OLS by using the Microfit software. From the result of OLS, we are able to obtain the value of AIC and SBC for maximum 12 lag lengths. After that we check for minimum value of SBC in order to obtain optimal lag. Next, we use the best lag length (lag 11) suggested by SBC to run diagnostic tests. We will base on the probability value to decide whether to reject the null hypotheses of no serial correlation, no model misspecification bias, normality of error term and homoscedasticity. For this model, we found that the model had passed all the diagnostic tests. Therefore, we can proceed to test the model with bounds test to check whether long-run relationship exists among variables. For bounds test, we are comparing the F-test statistic with two sets of critical values reported by Pesaran et al. (2001). If the F-test statistic is lower than the lower bound critical value, we will reject H_0 (no long-run relationship). If the F-test statistic is more than the upper bound critical value, we do not reject H_0 (have a long-run relationship). F-test statistic falls in between lower bound critical value and upper bound critical value indicates inconclusive result. For this model, the F-test statistic is lower than the lower bound critical value. Therefore, we can conclude that the variables in this model do not have a long-run relationship. Other models will be interpreted in the same manner. If the suggested optimal lag based on SBC does not pass all the diagnostic tests, we will reselect the lag length based on another lowest SBC value until the model does not suffer any econometric problems before we proceed to the cointegration test under ARDL approach. The details on lag order selection based on SBC, F-test statistic and diagnostic tests results are attached in Appendix 4.1 and Appendix 4.2.

The optimal lag with minimum SBC value falls at lag 12 for 3rd and 5th model. These models have passed all the diagnostic tests at 5% significance level which shown in Table 4.3. Therefore, these models are ready to be estimated for the existence of cointegration among variables. For 2nd model, SBC shows lag 10 is the best lag. However, the model at this lag does not pass all the diagnostic tests except Ramsey's RESET test at 5% significance level. By taking into account of the diagnostic tests results, the optimum lag length (which suffers only non-normal error terms problem) has range from lag 1 until lag 4. So, we reselected the optimal lag based on minimum SBC value, which is lag 4. Although SBC has provided the best lag length for 4th model at lag 2, the model suffers from three econometric problems excluding serial correlation problem. The same econometric problems continued to exist until lag 12 and even more critical for lag 1(suffers all econometric problems). Among lag 2 to 12, we follow the lowest SBC value and thus select lag 2 as the best lag. For the last model, minimum SBC value appears to be at lag 12 but the model at this lag has serial correlation and non-normality problems. Based on the diagnostic tests results, the best lag length (which suffers only non-normality problem) for this model is lag 1 until lag 8 and lag 10. Hence, we choose lag 10 as the optimal lag with minimum SBC value.

In overall, 2nd, 4th and 6th models appear to be suffering from non-normality problem. However, Greene (as cited in Muhammad & Zheng, 2010, p.726) argued that, "*normality is not necessary for validity of the classical linear regression model*". Based on the study of Hakan, Hidayet, Murat, and Canan (2012), the researcher did not attempt to take any solution upon the rejection of the null hypothesis of Jarque-Bera normality test. Besides, there are additional econometric problems exist in 4th model, these include functional form error and heteroscedasticity problem. For functional form misspecification, Ahmed, Muzib and Roy (2013, p.87) stated that it is no surprise to have this problem in a model. According to the authors, "*Pesaran et al. (2001) assert that this type of functional form misspecification may exist due to the presence of some non-linear effects or asymmetries in the adjustment process*". On the other hand, Shrestha and Chowdhury (2005, p.25) claimed that it is tolerable to have heteroscedasticity problem for a model, by saying "*since the time series constituting both the equations are of mixed order of integration, i.e., I(0) and I(1), it is natural to detect heteroscedasticity*".

After we had selected the optimal lag for each model, we conducted the bounds test to detect the existence of cointegration among variables for each model. From Table 4.3, the F-test statistic (5.5655) for 4th model is more than the upper bound critical value (4.78) at 10% significance level. The null hypothesis is rejected and this shows that cointegration exists between bioethanol production and cane molasses export price. Meanwhile, the F-test statistic (5.6048) for the last model also exceeds the upper bound critical value (4.78) at 10% significance level. Again, the null hypothesis has been rejected. This means that the cassava farm gate price and bioethanol production have a long-run relationship.

Whereas, the rest of the models shown in Table 4.3 indicate that there is no long-run relationship exist among the variables because their F-test statistic are lower than the lower bound critical values at 1%, 5% and 10% significance levels. This has shown to be supported by the findings of previous similar studies in our literature review. Noted by Natanelov et al. (2013), the evidence of loose connected long-run relationship between bioethanol and its feedstock is due to the price transmission is accelerated more by the government's mandated levels of bioethanol use in gasoline production instead of the marketplace. On the other hand, Cha and Bae (2011) explained even though the higher demand from bioethanol causes the price of feedstock to increase in short run, this price increment will eventually offset by the progress of quantity adjustments from the reduction in export demand for feedstock and feed demand for feedstock in the long run.

Table 4.3: Bounds Test and Diagnostic Tests Results

ARDL Model		Optimal lag	F-test [Prob]	Serial Correlation[a] [Prob]	Functional Form[b] [Prob]	Normality[c] [Prob]	Heteroscedasticity[d] [Prob]
Dependent variable	Independent variable						
DETH	DlnSGC	11	4.1827 [0.020]	9.8428 [0.630]	2.2494 [0.134]	1.9333 [0.380]	0.069232 [0.792]
DlnSGC	DETH	4	1.0569 [0.352]	16.5700 [0.167]	3.0712 [0.080]	380.3548 [0.000]	0.30281 [0.582]
DETH	DlnMOL	12	2.7661 [0.071]	9.5057 [0.659]	0.74820 [0.387]	1.1440 [0.564]	3.6371 [0.057]
DlnMOL	DETH	2	5.5655*** [0.005]	19.1004 [0.086]	31.8897 [0.000]	306.6749 [0.000]	12.0290 [0.001]
DETH	DlnCAS	12	2.1758 [0.123]	14.0993 [0.294]	1.3658 [0.243]	1.5871 [0.452]	1.4911 [0.222]
DlnCAS	DETH	10	5.6048*** [0.006]	19.9047 [0.069]	0.11768 [0.732]	29.5817 [0.000]	0.26536 [0.606]

The critical values are 1% (6.84 - 7.84), 5% (4.94 - 5.73) and 10% (4.04 - 4.78) significant level. Asterisks (*), (**) and (***) indicate statistical significant at 1%, 5% and 10% levels, respectively. The critical values were obtained from Pesaran et al., (2001), Case III: Unrestricted intercept and no trend. Notes: The optimum lag was selected using SBC. The maximum lag was fixed at 12. [a]Lagrange multipier test of residual serial correlation. [b]Ramsey's RESET test using the square of the fitted values. [c]Based on a test of skewness and kurtosis of residuals. [d]Based on the regression of squared residuals on squared fitted values.

To double confirm our results in the bounds test, we had estimated all models by including the Error Correction Representation (ECT) and the results are shown in Table 4.4. A negative and significant of ECT indicates that the long-run relationship among variables is exist (Ferda, 2008). The significance of the ECT will refer to the probability value. For the 2nd model, the coefficient value of ECT (-0.091004) is negative and significant at 5% significance level. This shows that the deviation from the long-term sugarcane farm gate price is corrected by 9.10% over each month. Surprisingly, this significant ECT has suggested that the sugarcane farm gate price and bioethanol production actually have a long-run relationship. Although this result is not consistent with the bounds test result above (as shown in Table 4.3), this result is more accurate to confirm that there is a long-run relationship.

We also found that the ECT coefficient value for 4th model (-0.51047) and 6th model (-0.078513) are negative and significant at 1% and 5% significance levels respectively. For 4th model, the deviation from the long-term export price of cane molasses is corrected by 51.05% over each month. For 6th model, the deviation from the long-term cassava farm gate price is corrected by 7.85% over each month. These results are consistent with bounds test results as shown in Table 4.3. Thus, there are long-run relationships between cane molasses export price and bioethanol production as well as between cassava farm gate price and bioethanol production.

The ECT coefficient values for the rest of the models are not significant at 1%, 5% and 10% significance levels. This indicates that no cointegration among the variables in these models. The results are also consistent with the bounds test results in Table 4.3.

Table 4.4: Results of Estimated Error Correction Representation for the Selected ARDL Model

ARDL Model		Optimal lag	Error Correction Term (ECT)	
Dependent variable	Independent variable		Coefficient	T-ratio [Prob]
DETH	DlnSGC	11	-0.068186	-1.1165 [0.267]
DlnSGC	DETH	4	-0.091004	-2.3212 [0.022]**
DETH	DlnMOL	12	-0.029234	-0.64983 [0.518]
DlnMOL	DETH	2	-0.51047	-5.6755 [0.000]*
DETH	DlnCAS	12	-0.060665	-1.2220 [0.225]
DlnCAS	DETH	10	-0.078513	-2.5355 [0.013]**

Notes: Asterisks (*), (**) and (***) indicate statistical significant at 1%, 5% and 10% levels, respectively.

After using bounds test and ECT value to confirm the existence of cointegration among variables for each model, we have to run the models that have long-run relationship among variables to estimate the long-run coefficients under ARDL approach. This test is to check whether the long-run coefficients are significant or not. Table 4.5 displays the models consist of variables that have long-run relationships. The significance of independent variable in explaining the dependent variable for every model is interpreted by using probability value. Among the three models, the long-run coefficient of bioethanol production has appeared to be significant only in 1st model at 5% significance level. From the T-ratio shown in Table 4.5, bioethanol production has a significant effect on the sugarcane farm gate price. The sugarcane farm gate price will increased by 2.31% for every one million liter increase in bioethanol production. Differently, based on 2nd and 3rd models, the long-run coefficient of bioethanol production is not significant at all in determining the export prices of cane molasses and farm gate price of cassava.

Table 4.5: Results of Estimated Long-Run Coefficients Using ARDL Approach

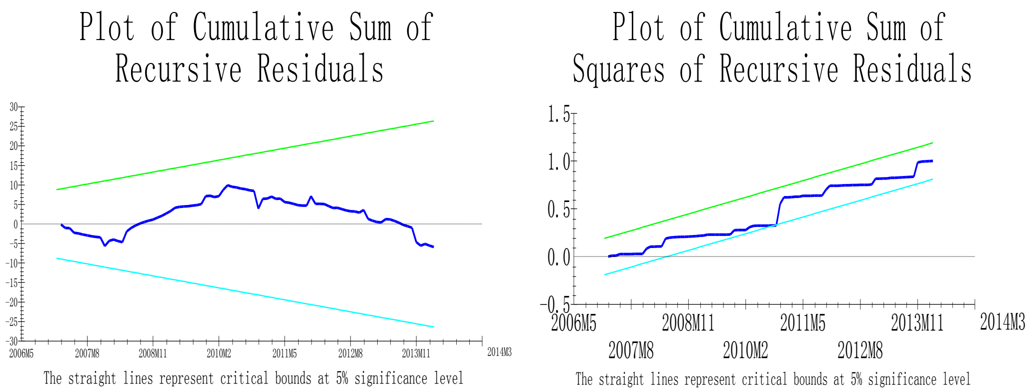
ARDL Model		Coefficient	Standard Error	T-ratio[Prob]
Dependent variable	Independent variable			
lnSGC	ETH	0.0062845	0.0027199	2.3106[0.023]**
lnMOL	ETH	0.0001667	0.0044626	0.037351[0.970]
lnCAS	ETH	0.00006815	0.0052777	0.012913[0.990]

Notes: Asterisks (*), (**) and (***) indicate statistical significant at 1%, 5% and 10% levels, respectively.

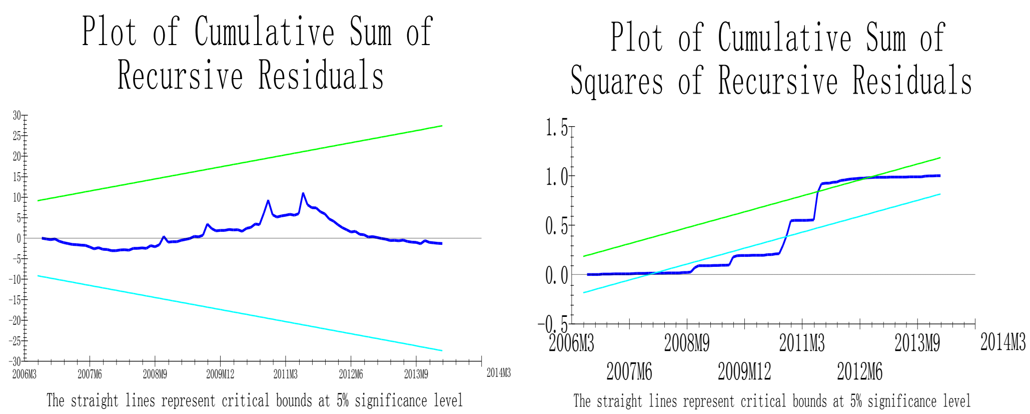
4.2.2 Stability Tests

Cumulative sum of recursive residuals (CUSUM) and the CUSUM of square (CUSUMSQ) tests are the stability tests that used to detect structural breaks and to check whether the estimated long-run and short-run parameters in Eq. 17a and 17b are stable over the data period. These tests are applied to the residuals of the ECM models (Eq.17a and 17b). From Figure 4.1, all plots of CUSUM are within the critical 5% bounds. This indicates the stability of coefficients, thus confirming the long-run relationships among the variables. For CUSUMSQ plots, only the CUSUMSQ statistics for the cane molasses export price-bioethanol production model are greater than the 5% critical bounds of parameter stability within the data period. However, it is still considered as stable as long as at the end of the period, the plot of CUSUMSQ is within the critical 5% bound.

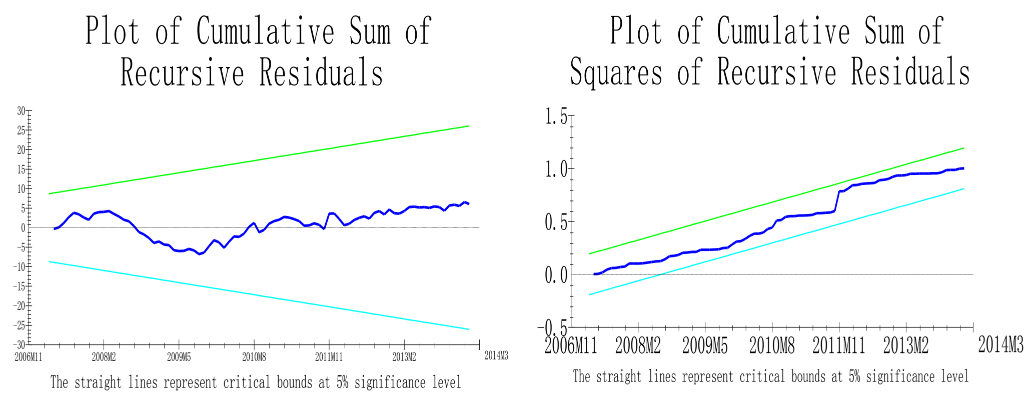
Figure 4.1: Plot of CUSUM and CUSUMSQ Tests for the Parameter Stability from ARDL Models



(a) lnSGC-DETH



(b) lnMOL-DETH



(c) lnCAS-DETH

4.2.3 Granger Causality Test (Wald Test)

ARDL bounds test can only indicate whether long-run relationship exists among variables in each model, but it is not able to detect the direction of causality (Ozturk & Acaravci, 2010). Hence, we are using Wald test under ARDL Framework to determine the causal relationships among variables once we confirm the existence of cointegration in some models. The results of Granger causality test is shown in Table 4.6.

Table 4.6: Result of Granger Causality Test (Wald Test F-statistic)

Null Hypothesis	Wald Test		Direction
	Chi-square	Prob	
lnSGC does not Granger cause ETH	0.47775	0.489	
ETH does not Granger cause lnSGC	5.3829	0.020**	ETH ⟶ lnSGC
lnMOL does not Granger cause ETH	3.0528	0.081***	lnMOL ⟶ ETH
ETH does not Granger cause lnMOL	32.1854	0.000*	ETH ⟶ lnMOL
lnCAS does not Granger cause ETH	1.5662	0.211	
ETH does not Granger cause lnCAS	8.7588	0.003*	ETH ⟶ lnCAS

Note: Asterisks (*), (**) and (***) denote the rejection of the null hypothesis at 1%, 5% and 10% significance levels, respectively.

The significance of causal effect is determined by using the probability value in Wald test. According to Narayan and Smyth (2004), there must be at least one way causation for each model once the cointegration test had indicated the existence of long-run relationship among variables. All the models with long-run relationship among variables had found to have at least one way causal effect which had fulfilled the assumption of Narayan and Smyth (2004). We had examined the causality test for all of the models regardless of the existence of long-run relationship among variables. Out of six models, we found that there are four models having causal effect which had rejected the null hypothesis of no Granger causality.

The result shows that the bioethanol production does Granger cause sugarcane farm gate price at 5% significance level. This means that the changes of bioethanol production in the past can be used to predict the occurrence of event of the sugarcane farm gate price. This finding is consistent with the theory discussed in chapter 3, when production of bioethanol increases, it will cause the farm gate price of sugarcane to increase due to higher demand of sugarcane. However, there is no inverse causal effect from sugarcane farm gate price to bioethanol production. This indicates that the changes in sugarcane farm gate price in the past cannot used to forecast the occurrence of event of bioethanol production.

From the results, we found that there is bidirectional causal effect for bioethanol production and cane molasses export price. Cane molasses export price does Granger cause bioethanol production at 10% significance level. This implies that the changes in cane molasses export price in the past can be used to predict the occurrence of event of bioethanol production. Meanwhile, bioethanol production does Granger cause cane molasses export price at 1% significance level. This indicates that changes in bioethanol production in the past can be used to forecast the occurrence of the event of cane molasses export price. This finding indicates that when bioethanol production increase, demand for cane molasses will also increase and hence cause the price of cane molasses increase. Export price of cane molasses will also increase due to the shortage in supply of cane molasses to international market.

There is only one way causal effect found in the model of cassava farm gate price and bioethanol production. The result shows that bioethanol production does Granger cause cassava farm gate price at 1% significance level but causal effect do not occur in another way round. This means that the change in bioethanol production in the past can used to predict the occurrence of event of cassava farm gate price but the change in cassava farm gate price in the past cannot used to forecast the occurrence of the event of bioethanol production. The finding is consistent with the theory discussed in the earlier part which suggested that when bioethanol production increases, the demand for cassava will increase which will push up the farm gate price of cassava.

Chapter 5: Conclusion

5.0 Introduction

In our study, we are interested to look into the relationship between bioethanol production and agricultural commodity prices in Thailand. Obviously, we have achieved the objective of this research and will summarize our major findings from Chapter 4 in this chapter. We would also provide the policy recommendations based on our major findings. Then, we will end our research by discussing the limitations of this study and recommendations for future studies as well.

5.1 Summary of Major Findings

From the previous chapter, we began our empirical testing with the unit root tests – ADF and PP. Based on Table 5.1, we found that variables of bioethanol production and cane molasses export price follow I(0), which are stationary at their level form. However, variables of sugarcane and cassava farm gate price follow I(1), which are stationary at their first difference.

Table 5.1: Summary of Unit Root Tests Results

Variables	Order of Integration, I(d)
Bioethanol Production	I(0)
Sugarcane Farm Gate Price	I(1)
Cane Molasses Export Price	I(0)
Cassava Farm Gate Price	I(1)

The result from the unit root tests had confirmed that ARDL bound testing approach can be used in this study. Therefore, we proceed to conduct the bounds test and found the long-run relationships between bioethanol production and cane molasses export price as well as between bioethanol production and cassava farm gate price (refer to Table 5.2). While continued with the checking on the sign and significance of ECT in each ARDL model, another long-run relationship is observed between bioethanol production and sugarcane farm gate price. The negatively significant ECT has further confirmed the long-run relationships among these variables. However, among the three long-run models, only one model has significant independent variable, which is bioethanol production, in determining the dependent variable, which is sugarcane farm gate price.

Lastly, we carry out the Granger Causality Test (Wald Test) to detect any short-run causal relationship among the variables. We had noticed that bioethanol production had significantly Granger cause sugarcane farm gate price but not another way round (refer Table 5.2). Meanwhile, two ways causality are found significantly between the variables of bioethanol production and cane molasses export price (refer Table 5.2). We had also found that bioethanol production is significantly Granger cause cassava farm gate price (refer to Table 5.2).

Table 5.2: Summary of ARDL Bounds Testing Approach and Granger Causality Test (Wald Test) Results

Variables	Bounds test (F-test)	Granger Causality Test (Wald Test)
Bioethanol -Sugarcane	No long-run relationship	Unidirectional causality
Sugarcane-Bioethanol	Long-run relationship exists	
Bioethanol-Molasses	No long-run relationship	Bidirectional causality
Molasses-Bioethanol	Long-run relationship exists	
Bioethanol-Cassava	No long-run relationship	Unidirectional causality
Cassava-Bioethanol	Long-run relationship exists	

5.2 Policy Recommendations

From our result, sugarcane farm gate price has found to be having a long-run relationship with as well as positively significantly affected by the bioethanol production in the long run. This implies where higher demand from bioethanol will reduce the supply of sugarcane for other purposes, especially food, hence cause its price to increase. Meanwhile, there is also a long-run relationship exists between cassava farm gate price and bioethanol production.

5.2.1 Policies for Sugarcane

With the concerns on food security and sustainability of feedstock supply, the Thai government has already set the yield targets for sugarcane and cassava on the existing agricultural land[22]. Besides, the new 10-year Alternative Energy Development Plan (2012-2021) also aims to encourage the production of necessary feedstock on the existing agricultural land. However, there is no clear guidance on how these targets can be reached. From here, we would like to recommend the Thailand policymakers to come out with government program similar to *Social Fuel Seal* which introduced in Brazil (Dallinger, Saswattecha & Sinsuphan, 2013). The aim of this program is to integrate smallholder farmers in the biodiesel supply chain. Under this program, biofuels producers are required to (i) purchase certain shares of feedstock supplied by these farms, (ii) provide technical assistance and training to them, and (iii) enter into legally binding agreements with smallholder farmers, before those biofuels producers are eligible to obtain government biofuels subsidies (Ismail & Rossi, 2010). Meanwhile, the smallholder farmers are being guided and encouraged to form the ‘Family Farmer Cooperatives’, which may play the role as intermediaries between themselves and biodiesel producers, thus strengthening the bargaining power of the smallholder farmers (Biopact Team, 2007; Ismail & Rossi, 2010).

This program has been introduced since the year of 2004 and appears to have a positive performance as shown by Figure 5.1.The convincing result below seems to enhance the feasibility of this program on Thailand too. Around 70% of sugarcane production is from small-scale farms (Dallinger et al., 2013). Given that bioethanol production is closely consolidated with the sugar industry, sugar producers actually depend heavily on the nearby farmers to support their sugar mills[23]. Thailand is currently applying the Contract Farming Model in sugarcane production to supports the farmers with a secure market and a stable income[24]. As compared to the Brazilian program, this model is still lacking because there is no measures on improving the sugarcane production. On the other hand, the

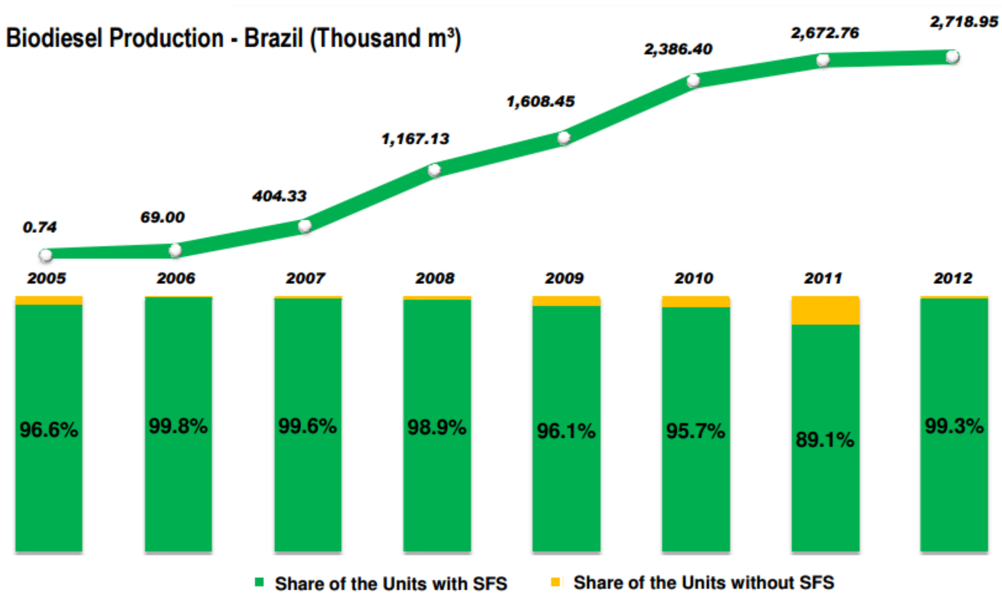
[22] Under the new 10-year Alternative Energy Development Plan (2012-2021), one of the strategic plan is to improve the yield of current feedstock where an average yield of sugarcane above 94 tons per hectare with total production of 105 million tons per year, and an average yield of cassava above 31 tons per hectare with total production of 35 million tons per year by 2021(Preechajarn & Prasertsri, 2012).

[23] Sugar producers have limited access to land resources and need to meet high investment requirements to purchase land (Dallinger et al., 2013).

[24] Dallinger et al. (2013, p.26) stated that “*The share in returns from revenues from the sugar industry is set at seventy percent (70%) for sugarcane planters and thirty percent (30%) for sugar processors, which is prescribed in the Cane and Sugar Act (1984)*”.

effectiveness of the newly introduced Agricultural Zoning System to reach those farmers is still questionable (Dallinger et al., 2013)[25]. Besides, farmers who use the system are excluded from government support programs such as buying schemes and price subsidies.

Figure 5.1: Social Fuel Seal Performance



Source: Leal (2013).

In overall, by referring to the *Social Fuel Seal* program, the Thai government could actually improve further on the Contract Farming Model by introducing the technical assistantship between the sugar producers and farmers. The farmers will have easier access to better production technology to boost the sugarcane yield instead of incurring more government spending to familiarize the farmers with the Agricultural Zoning System.

[25] For a better regulation on food provision and feedstock supply for energy, the Agricultural Zoning System provides the information on land suitability and availability for the six major agricultural crops in Thailand (Dallinger et al., 2013).

5.2.2 Policies for Cane Molasses

Thailand is the largest cane molasses exporter in the world who averagely exports 1.4-1.5 million tons, which is even greater than around 1 million tons been utilized in domestic continuing industries in 2006 (ES Power, 2013). However for today, in the whole cane molasses production, only around 22% of cane molasses is exported and 78% of cane molasses is used in domestic industries (Russell & Frymier, 2012; Silalertruksa & Gheewala, 2010)[26]. Although it is obvious that the Thai government has taken its initiative to reduce the export volume of cane molasses, we would like to recommend the Thai government to ban all the exports activities of cane molasses (22%) based on the result of our study. By supporting on this idea, the portion of cane molasses available for bioethanol production will be even more, which is up to a total of 59%. Since Thailand wishes to become a major ethanol producer and export centre, this extra amount of cane molasses from export is crucial for producing more bioethanol just to meet both international and domestic demands (Table 5.3 and Table 5.4).

Table 5.3: Bioethanol Production, Exports and Consumption from 2009 to 2014

	Production (million liters)	Export (million liters)	Average Production per day (million liters/day)	Average Consumption (million liters/day)
2009	482	16	1.32	1.25
2010	521	48	1.42	1.24
2011	613	139	1.68	1.23
2012	790	304	2.16	1.39
2013	1048	64	2.87	2.60
2014	1115*	10*	3.05*	2.92

Notes: Asterisks (*) refers to estimated value.

Source: Preechajarn and Prasertsri (2014).

[26] In the total molasses production of 78%, 37% of it is use in bioethanol industries, 11% is using in animal feed and Monosodium glutamate (MSG) production and 30% is used for distilleries (Russell & Frymier, 2012; Silalertruksa & Gheewala, 2010).

Table 5.4: Thailand's Exports of Bioethanol (millions of liters)

	2009	2010	2011	2012	2013
Philippines	-	5.5	61.3	142.3	45.9
Singapore	3.1	19.3	68.5	76.8	-
Japan	7.4	20.0	16.5	24.9	8.8
Australia	-	-	2.1	-	-
Taiwan	3.1	1.2	3.2	1.5	-
Indonesia	-	-	-	1.5	-
Europe	-	-	-	9.3	9.1
South Korea	-	2.1	12.8	45.5	-
Other	2.0	-	2.6	2.1	-
Total	15.6	48.2	167	303.9	63.8

Source: Preechajarn and Prasertsri (2014).

5.2.3 Policies for Cassava

Similar to sugarcane, cassava has its own yield target under the government strategic plan. Cassava is majorly been produced in small-scale agriculture in rural areas. There will be extra demand from bioethanol production for cassava as a feedstock when the farmers face a low or fluctuating price. This has also stimulated the rural economic growth. Dallinger et al. (2013) has mentioned where the recent cassava yields are far below their potential and can be doubled up quickly if better production technology is available. Unfortunately, it is a challenge for Thailand in transferring new technologies and implementing good agricultural practice at the farm level.

Similar issue from sugarcane production can also been observed in the cassava production. The need for accessibility to new technologies is highlighted here. Therefore, the Thai government should really consider about enforcing the same program like *Social Fuel Seal* on both cassava and sugarcane to increase these crops' productivity.

5.3 Limitations of the Study

Along our study, there are several limitations to be mentioned here. First, the process of collecting secondary data is quite difficult. The bioethanol and agricultural commodity relevant data can only be obtained from the Thai government websites or through emailing or phone calling to these government authorities. We had tried to search these data from the website of some international independent bodies such as U.S. Energy Information Administration (EIA) and Food and Agriculture Organization (FAO) of United Nations, however, there are only a few or incomplete information on Thailand’s data.

Secondly, we have used the export price of cane molasses to represent the domestic price because we are not able to get domestic farm gate price for cane molasses from Thailand. This is because the sugar miller is closely integrated with bioethanol industry. Certain amount of cane molasses produced together with sugar is directly used as input for bioethanol production. At the same time, the domestic price of molasses for the use in other industries is set by these sugar millers. Therefore, this price is not under the control of Thai government.

Thirdly, we have conducted our research without accounting for the global food crisis on 2008. This issue can affect the agricultural commodity prices and cause them to be more volatile. Different results might be obtained from the same relationship studied under this research by considering the global food crisis on 2008.

Lastly, our study concern on the relationship only in term of the production cost. Any price increment in either agricultural commodity as the feedstock of bioethanol will reduce the bioethanol production. However, the relationship in term of the production efficiency does not examined by this study.

Various combinations of agricultural commodities as the feedstock of bioethanol may affect the efficiency in producing bioethanol. Comparably, the term of production efficiency could be more meaningful than the term production cost for the same relationship.

5.4 Recommendations for Future Studies

From the limitations above, future researchers could examine the same studied relationship with the consideration of global food crisis on 2008. It is suggested to divide the data period into pre-crisis period and post-crisis period. This enables the future researchers to obtain more details as well as to observe any changes in the relationship between bioethanol production and agricultural commodity prices before and after the crisis.

To improve the current study, we would also suggest the future researchers to examine the same relationship in term of production efficiency. Stronger theories such as Cobb-Douglas Production theory or Total Factor Productivity (TFP) are able to include other factors of production (for example, labor, land and capital) to better explain the relationship between bioethanol production and agricultural commodity prices.

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Appendices

Appendix 2.1

Authors' Name (Year)	Data	Methodology	Findings
Algieri (2014)	• Country, United State (U.S). • Variables are corn, rapeseed, soybeans, soybean oil, sugar, wheat, oil, biofuels, economic and financial factors. • Time period, 2005-2013, daily data. • Bloomberg database and Chicago Board of Trade (CBOT).	• Generalized Autoregressive Conditional Heteroskedasticity (GARCH). • Autoregressive Conditional Heteroskedasticity (ARCH) test.	• The result indicated that the Standard and Poor's 500 is significant and shows that there is significant effect of stock market return on commodity price returns, especially sugar, wheat and soybean market. • The study shows that economy does not immediately affected by monetary policy. • Corn, wheat, sugar and soybean had significantly influenced by oil and ethanol returns. • Energy markets significantly affect price changes which can increase the volatility of agricultural markets.
Ali, Huang, & Yang (2013)	• Country Pakistan. • Variables are maize (ethanol 1), sugarcane, sugar beet (ethanol 2), soybean, rapeseed, sunflower, and biodiesel. • Time period, 2004-2020. • Global Trade Analysis Project	• Computable General Equilibrium (CGE).	• The prices, supply and trade of agricultural commodities are affected by the development of biofuels especially in United State (US), European Union (EU) and Brazil. • Foreign exchange spend on traditional agricultural in Pakistan will increase.

	(GTAP) database (version 7).		• The study shows that if ethanol becomes the substitution of gasoline in 2020, biofuel technology using food crop will be very hard to develop and adopt because Pakistan need to ensure food self-sufficiency.
Armah (2011)	• Country, U.S. • Variables are corn-based livestock feed (field corn), crude oil, ethanol and beef. • Time period, 1994-2009. • Energy Information Administration (EIA), NASS and Nebraska Energy Office.	• Graphical price relationships. • Correlation price relationships. • Causality analyses.	• From graphical analysis, the result shows that the trend of crude oil, ethanol, field corn, feed and beef prices have close relationships. • The result from correlation analysis shows that there is feedback causality between the variables. • Regression analysis's result shows that there is weak bi-directional relationship between crude oil and livestock feed prices. • Beef, ethanol, and crude oil prices have strong causality to livestock feed prices. • There are a strong relationships between corn-based livestock feed prices, crude oil, ethanol and beef prices. • The study shows that rises in the demand of biofuels due to the higher prices of crude oil is a key factors that increase the price of corn-based livestock feed.
Banse et al. (2008)	• Country European Union (EU). • Time period, 2010. • GTAP database (version 6)	• CGE.	• Result indicated that under the EU biofuel directive, agriculture at global and European level had strongly affected by increasing demand for biofuel crops.

Bryngelsson & Lindgren (2013)	• The whole world. • Variables are intensively-produced edible-type and forage crops (IP), extensively produced permanent pasture and forage crops (EP), and bioenergy crops (BE). • IPCC workgroup 3 special report and FAOSTAT.	• Partial equilibrium model.	• As a result of increased bioenergy demand for all scenarios illustrated in this paper, the food prices has increase because of increased land rents from increased competition for land. • The price impact of bioenergy on intensively produced food crops is reduced via prohibiting production of bioenergy on the fundamentally most productive land reduces. • The relative price increase is much greater for food produced in extensive systems compared to food produced in intensive systems.
Cha & Bae (2011)	• Country U.S. • Time period, 1986- 2008, quarterly data. • Variables are oil prices, bioethanol demand for corn, feed and other residual demand for corn, export demand for corn, and corn prices. • EIA of the U.S. Department of Energy (DOE) and U.S. Department of Agriculture Economic Research Service (USDA ERS).	• Vector Autoregressive (VAR) model. • Impulse response function.	• The result shows that in short run, rapid increase in bioethanol demand for corn as a substitute of petroleum in turn increases the price of corn. • It is found that oil prices did not significantly respond to export demand shock, but corn prices immediately give response in the very short term, and increase in export demand for corn has caused the reduction in feed and bioethanol demand for corn in the short term. • The study shows that the price of feedstock increase in short run but this increase can be eliminate in long run through reducing export demand for corn

			and other uses for feedstock. • Larger increase in petroleum prices may raise the bioethanol production cost by increasing feedstock prices in the short run.
Ciaian & Kancs (2011a)	• Country EU and U.S. • Variables are price of crude oil, corn, wheat, rice, sugar, soybeans, cotton, banana, sorghum and tea. • Time period, 1993-2010, weekly data. • Statistics of Norway, EIA, Food and Agriculture Organisation (FAO)	• VAR model. • Box-Jenkins method. • Vector Error Correction Model (ECM). • Granger causality test. • Augmented Dickey-Fuller (ADF). • Phillips Perron Tests (PP). • Impulse response analysis. • Johansen cointegration test	• The study shows that when the country produces the biofuels production, the impact of fuel price on agricultural commodity prices is stronger than without the productions of biofuels. • The study finds that price of energy had affected the price of commodities and their interdependencies are keeping increase over the period. • There is no any cointegration relationship exist in the first period (1993-1998). • Only corn and soybeans are cointegrated with crude oil prices in second period (1999-2004), indirectly used in bioenergy production. • All the agricultural commodities are cointegrated with crude oil prices in the third period (2005-2010), directly used in biofuel production. • Oil had long run granger caused agricultural commodity prices but not vice versa. • Energy prices affect all the agricultural commodities including the commodities that are not directly used for bioenergy

			production.
Ciaian & Kancs (2011b)	• Country EU and U.S. • Variables are corn, wheat, rice, sugar, soybeans, cotton, banana, sorghum, crude oil and tea. • Time period, 1994-2008, weekly data. • Statistics of Norway, EIA and FAO.	• VAR model. • VECM. • Granger causality test. • ADF. • PP test. • Johansen cointegration tests.	• The study shows that the impact of fuel prices on agricultural prices is stronger than without the production of bioethanol. • Agricultural commodities are affected by energy prices and the interdependencies between energy and food markets are raise over time. • The researchers found that cointegration relationships between energy and agricultural commodities do not exists in the first period (1994-1998) • In second period (1999-2003) cointegration relationship exist only between corn, soybeans and crude oil prices, indirectly used in bioenergy production. • All agricultural commodities prices are cointegrated with crude oil prices in third period (2004-2008), directly used in bioenergy production. • Study found that oil had long run Granger caused agricultural commodity prices but not vice versa. • The study suggests that bioenergy prices affect all the agricultural commodity prices included those commodities are not directly used in the productions.
Du & McPhail (2012)	• Country, U.S. • Variables are corn, ethanol, light	• VAR model. • ADF.	• The researchers found that the variables responses in one market to price changes

	sweet crude oil (WTI) and RBOB gasoline. • Time period, 2005-2011. • Chicago Mercantile Exchange (CME) and New York Mercantile Exchange (NYMEX).	• PP test. • Johansen cointegration tests. • Dynamic Conditional Correlation Multivariate Generalized Autoregressive Conditional Heteroscedasticity (DCC-MGARCH) model.	in another market in the earlier period are not significant and their own shock can explain why the price variations of individual markets. • The study suggests that the prices of corn, ethanol and gasoline are significantly and positively influencing each another. • Study shows that ethanol (corn) shocks have the biggest effect on corn (ethanol) prices.
Elobeid & Hart (2007)	• All major agricultural commodities producing and consuming countries. • Time period, 2007-2016. • Variables are supply and utilization data, macroeconomic data, prevalence of undernutrition, the food consumption patterns of the main food items by country and U.S refiners' acquisition cost of crude oil. • F.O. Lichts Online Database, FAO of the United Nations (FAOSTAT Online), Production, Supply and Distribution View (PS&D) database of the U.S. Department of Agriculture	• Partial equilibrium model.	• The finding indicated that Sub-Saharan Africa and Latin America would face the greatest food price pressures. These regions share the characteristics where corn is the dominant grain for food consumption. • Given a condition of higher oil prices and with an ethanol demand constraint in the United States, the projected corn prices rises by 20%, resulted in food basket cost changes of about over 10% for several African nations. • Given another condition removing the ethanol demand constraint, the projected corn price and food basket cost changes around double. • Regions in which rice is the main food

	(USDA), International Monetary Fund, Global Insight, FAO's Statistics Division and U.S. Department of Energy's Energy Information Administration.		grain show the smallest increases in food basket costs. • Countries that devote a large portion of their total consumption to food are the most affected countries in terms of food costs. Thus, there will be a reduction in their total purchasing power since the rise in food costs will also impact their non-food consumption significantly.
Gardebroek & Hernandez (2013)	• Country U.S. • Time period, 1997-2011, weekly data. • Variables are prices of U.S crude oil, ethanol and corn. • EIA, CBOT and FAO.	• DCC-MGARCH. • T-BEKK model. • DCC model. • ADF. • KPSS test. • Impulse response function.	• There are no evidence on the volatility spillovers from oil or ethanol to corn. • In short run, volatility in ethanol price caused by a shock in corn price volatility. • In recent year, ethanol market had found to be more directly exposed to past spillovers and persistence from other markets. • The existence of volatility spillovers from corn to ethanol have been confirmed prior to 2006 and after 2008. • The correlation between oil and ethanol price volatility does not adjusted much over the time, while, the correlation between crude oil and corn, and particularly, between ethanol and corn has increased after 2007.
Ge, Lei & Tokunaga (2014)	• Country China. • Time period, 2007. • SAM database, National Bureau of Statistics of China, The People's	• CGE.	• The study found that reduction in local supply of food without potential land input is caused by the raising of fuel ethanol production.

	Bank of China, Ministry of Finance, People's Republic of China, National Agricultural Production Cost and Revenue Information Summary 2008 and FAO.		• The researchers shows that when land supply increase, food price will reduce, food supply will raise and the consumption of food will increase. • The study also shows that there are negative impacts between production of fuel ethanol and food price. When there is potential land can be use, the impact is lighter.
Huang et al. (2012a)	• Developing countries. • Time period, 2020 (2006 base year). • GTAP database (version 7), United Nations Commodity Trade Statistics Database (UNCOMTRADE) and FAO.	• Standard GTAP model. • General Equilibrium model.	• The study shows that expansion in biofuels will affect the economies of agricultural in major producing countries. • International oil price and degrees of possible substitution between biofuels and gasoline are the two main factors that influence the effect of biofuels on developing countries.
Huang et al. (2012b)	• Country China. • GTAP database, UNCOMTRADE and FAO.	• Standard GTAP model. • CGE.	• The researchers found that increase in biofuel supply through meeting government requirement have significant effect on global markets for biofuel feedstocks. • The study shows that increase biofuels production by using policy will leads prices and productions of energy crops rise. • The poor in China will be hurt by the increase in production of biofuels and rises in food prices.
Kanamura	• Country U.S.	• DCC-MGARCH.	• The result shows that when the periods

(2009)	• Variables are energy, petroleum, grains, soybean, soybean oil, sugar, wheat and corn. • Time period 1991-2007, daily data. • Dow Jones.		consist of high energy prices, the correlations between energy and grain price returns will increase. • There are positive and increasing correlations between petroleum, biofuels and agricultural products except corn. • The study also shows that the recent high correlations between agricultural commodity markets and energy are due to the increase in biofuels which will generate more positive outcomes than low correlations among those commodities before 2004. • The result shows that petroleum and corn future price returns are not correlated.
Kim et al. (2013)	• Country United Kingdom (U.K) and EU. • Variables are wheat, barley, maize, rapeseed, soybeans, sunflower, sugar beet, soy oil, palm oil, rape oil, oil from tallow, used cooking oil, biodiesel and ethanol. • Time period, 2018 (based year 2008).	• Partial equilibrium.	• Vegetable oil, oil meal and oilseed had been affected by the rise of biodiesel productions. • Increase in productions of EU bioethanol had slightly influence the demand and price of wheat. • The study shows that the larger the share of biofuels in total transport fuel use, the greater the demand for biofuel which leads to larger price increase for biodiesel and bioethanol. • Demand for feedstock used to produce biofuel has positively related to demand for biofuels.
Kretschmer,	• Countries divided into 12 regions,	• CGE.	• The biofuels production is been slightly

Narita, & Peterson (2009)	consisting major bioenergy-producing regions and main bioenergy-consuming regions. • Time period, 2020 (based year 2005). • GTAP6 database.	• DART (Dynamic Applied Regional Trade) model.	increased by the EU emission targets alone. • The demand for biofuels induced by the 10% biofuels target considerably influences its trade flows, especially for the EU and for Brazil, but also for some other regions such as the US. • It is found that there are differences in competitiveness of the biofuel sectors among EU regions. • Agricultural prices are considerably increased along with the biofuel target.
Kristoufek, Janda, & Zilberman (2012)	• Variables are Brent crude oil, ethanol, corn, wheat, sugar cane, soybeans, sugar beets, consumer biodiesel, German diesel and gasoline, and U.S diesel and gasoline. • Time period, 2003-2011, weekly and monthly data. • U.S Energy Information Administration.	• Minimal spanning trees. • Hierarchical trees. • Granger-causality. • ADF. • KPSS.	• The study found that biofuels are weakly connected to whole network during pre-crisis period. • In post-crisis period, ethanol is well connected with corn, wheat and soybeans and it getting stronger in medium run. • In short run, biodiesel is very weak connected with the whole network but in the medium run, it becomes strongly connected with other fuel commodity. • The study also shows that in pre-crisis period, corn, wheat and soybeans are well connected with whole system but sugar is weak connected. • The correlations between variables in post-crisis period are higher than pre-crisis period.
McPhail &	• Country U.S.	• Partial equilibrium	• When the RFS is eliminated, the price

Babcock (2012)	• Variables are monthly data for demand and supply of ethanol and gasoline markets from 2006 to 2010, and quarterly data for elasticities of demand for corn feed, FAI, and export from 2000 to 2010. • Time period, 2000-2010. • USDA Economic Research Service feed grains database, U.S. EIA., Board of Governors of the Federal Reserve System, Renewable Fuel Association, Nebraska Energy Office, U.S. Bureau of Economic Analysis, and U.S. Census.		variability for both corn and gasoline falls. • Corn prices are found to be increase less when corn yields fall. Meanwhile, gasoline prices decline less when crude oil prices decrease. • The researchers found that Renewable Fuel Standard (RFS) mandates had reduced the price elasticity of demand for corn and gasoline and hence price variability increase.
Miljkovic, Shaik & Braun (2012)	• Country, U.S. • Variables are corn, grains, cattle, dried distillers' grains (DG) and ethanol. • Time period, 1990-2008, quarterly data. • Livestock Marketing Information Center (LMIC), United States Department of Agricultural, Economic Research Service, Chicago Market and Renewable Fuels Association (RFA).	• Breusch-Godfrey Lagrange multiplier test. • Weighted two-stage least squares method (2SL2).	• There are positive time trend for both corn quantity and distiller's grains quantity in indirect effects of ethanol policy on cattle production. • Corn price and corn quantity has significantly and negatively related. • Corn quantity and cattle quantity has significantly and positively direct relationship. • Distiller's grains quantity and corn quantity are not affected by ethanol price. • Renewable Fuels Standard (FRS) is significantly and positively affects corn supply.

Monteiro, Altman & Lahiri (2012)	• Country U.S and Brazil. • Variables are cereal, vegetable oils, meat, seafood, sugar, bananas, oranges, U.S corn, Brazil ethanol production, U.S ethanol, dollar exchange rate, oil, live animals, and imported food • Time period, 1980-2007. • IMF,EIA, Brazilian Ministry of Agriculture (MAPA), Brazilian Institute of Geography and Statistic (IBGE), Brazilan Sugarcane Industry Association (UNICA),RFA, Attache Reports of USDAs Foreign Agriculture Service and FAO.	• OLS. • ADF.	• The study suggests that food prices do not significantly affected by ethanol area in U.S. • Food price is negatively affected by ethanol area in Brazil. • The researchers found that sugar and ethanol production in Brazil is highly correlated. Thus, increase in ethanol production in Brazil is not an expense for food production.
Monteiro (2003)	• Country U.S and Brazil. • Variables are weighted cereal, vegetable oils, meat, seafood, sugar, bananas, oranges, U.S corn, Brazil ethanol production, U.S ethanol, dollar exchange rate, oil, live animals, and imported food • Time period, 1980-2007. • MAPA, UNICA, IBGE, EIA, RFA, IMF and FAO.	• OLS. • ADF.	• The researchers found that Brazilian market share increase will exert upward pressure on relative food prices. • The result shows that the greater the planted area of cane used to produce ethanol in Brazil, the depressing effect on relative food prices. • The increase in world food price index does not significantly affected by the increase in Brazilian cane ethanol area. • This study show that higher food prices are due to the increase in oil prices. • The relationship between dollar exchange rate and food price is negatively related.

Natanelov, Mckenzie & Huylenbroeck (2013)	• Country U.S. • Variables are price of crude oil, corn and ethanol. • Time period, 2005-2011, daily data. • Intercontinental exchange (ICE) and CBOT.	• Maximum likelihood (ML). • Johansen cointegration. • ADF. • PP test. • VECM.	• The study finds that crude oil granger causes corn and ethanol. • The study shows that there are strong relationship between crude oil and corn market and between crude oil and ethanol. • Corn and ethanol has less straightforward relationship. • In long run, ethanol and corn market prices had weak cointegrating relationship. • The researchers argue that government mandated levels of ethanol use in production of gasoline had determined the price transmission between two sectors.
Qiu et al. (2010)	• Country China. • Variables are maize, wheat, sweet sorghum, cassava, sweet potato, sugarcane, rice, other grains, soybean, other crops, other oilseed, beef and mutton, milk, pork and poultry, vegetables and fruits, fibers and bioethanol. • Time period, 2007-2020. • GTAP database.	• General equilibrium.	• The study found that feedstock price had minor impact on prices of other agricultural commodities. • There is positive and significant relationship between price of major feedstock and production of these commodities. • The effect of China's "non-grain crops" based bioethanol program on its food security is minimal.
Saunders et al. (2009)	• Country U.S and New Zealand. • Variables consist of 3 oilseed complex commodities and 5 dairy industry commodities. • Time period, 2005-2015. • OECD database.	• Lincoln Trade and Environment Model (LTEM). • Partial equilibrium.	• Increase in producer price for corn caused by the increase in corn demand in U.S. • The huge increase in corn prices in US is not exclusively caused by ethanol production or ethanol policies. • Increment in corn demand and reduction

			in livestock production overseas together raise world prices for meat and milk and encourage increased production in New Zealand. • The study found that competition between food and fuel uses of agricultural production are not borne out the level of ethanol production under FRS. • When world price is higher, New Zealand would increase the corn production.
Timilsina, Mevel & Shrestha (2011)	• 25 countries. • Variables are paddy rice, wheat, corn, cereal grains, vegetables and fruit, oilseeds, sugar (cane and beet), livestock, processed food, coal, crude oil, natural gas, sugar ethanol, corn ethanol, grains ethanol, biodiesel, gasoline, diesel, refined oil and gas distribution. • Time period, 2020 (2009 base year). • GTAP database and EIA.	• CGE.	• The study shows that oil price raise 66% will cause the share of biofuels will increase 5.4% in 2020. • The study found that the reallocation for land supply of rice, pasture and forest towards production of biofuel feedstock can explain why increase in oil price will have positive or negative impact on agricultural output in the major biofuel producing country. • The study shows that price of oil increase 25% would cause global food supply to reduce by 0.7% in 2020.
Vacha et al. (2013)	• Time period, 2003 -2011, weekly data. • Variables are consumer biodiesel (BD), ethanol (E), corn (C), wheat (W), soybeans (S), rapeseed oil (RS), sugarcane (SC), crude oil (CO), German diesel (GD) and US	• Wavelet coherence method.	• During the food crisis 2007-2008, it is observed that the strong interactions in the connections have broadened to higher frequencies. • For pre-crisis period, it is proven that corn leads ethanol at lower frequencies but after the crisis, this strong leadership has

	gasoline (USG). • Bloomberg database, Datastream database and EIA.		disappear whereas strong positive correlation exists between them. • Similarly, the intensity of leadership and magnitude of correlation between biodiesel and German diesel for before and after the crisis becomes weaker in time at low frequencies.
Wianwiwat & Asafu-Adjaye (2013)	• Country Thailand. • Time period, 2012-2021. • Variables are 51 industries and 62 commodities. • National Economics and Social Development Board, Department of Alternative Energy Development and Efficiency, and GTAP 6 database.	• CGE.	• Generally in the short run, the real output is negatively affected by the integrated bio-liquid fuel promoting policy, due to a shortage of biofuel feedstock, resulting in a decline in aggregate employment. • However, in the long-run, the impact of integrated bio-liquid fuel promoting policy on real GDP is positive due to an increase in aggregate investment resulting from an increase in foreign investment, and a general increase in sectoral output. • The biofuels promoting policy is unlikely to endanger food security in the long run as the manufactured food price increases only marginally. • The major beneficiaries of the polices is cassava based ethanol production.
Wu & Li (2013)	• Country China. • Time period, 2003-2012, weekly data. • Variables are price returns of crude oil, corn and fuel ethanol at the wholesale levels.	• ADF. • PP test. • Granger Causality Analysis. • ARCH test. • EGARCH model.	• ARCH effect significantly exists in the crude oil, corn and fuel ethanol markets where a large volatility is always followed by large volatilities, and a small volatility is always followed by small volatilities. • For crude oil market, a positive shock

	• National Bureau of Statistics of China.		increases volatility more than a negative shock. Whereas, for corn market, a negative shock stimulates larger volatility more than a positive shock does. • The existences of unidirectional spillovers from crude oil market to corn market and fuel ethanol market, as well as, double-direactional spillovers between corn market and ethanol market are found. • The correlation among the crude oil, corn and ethanol markets had raised since the third quarter of 2008. • Corn and fuel ethanol markets had close linkage.
Yang et al. (2009)	• 5 countries of Greater Mekong Subregion (Cambodia, Lao PDR, Myanmar, Thailand and Viet Nam) • GTAP database (version 6), UNCOMTRADE and FAO.	• CGE.	• The effects of biofuel in the 5 countries on agricultural commodities world prices are very little excluded cassava and sugar. • The increase in development of biofuels will significantly rise up the price of cassava and sugarcane in future. • Biofuel development have small effect on global agricultural price and production and significantly effect on local agricultural production and land use. • The study show that world agricultural prices and production had significantly affected by biofuel programs in USA, EU and Brazil.
Zhang et al. (2010)	• Time period, 1989 -2008, monthly data.	• Dickey–Fuller tests. • ADF.	• There are no relations between fuel and agricultural commodity prices in the long

	• Variables are prices of corn, rice, soybeans, sugar, and wheat, and prices of ethanol, gasoline, and oil. • Dated Brent, West Texas Intermediate, Dubai Fateh, US wholesale spot prices, FOB Gulf of Mexico, Chicago Soybean futures contract (first contract forward) No. 2 yellow, Free Market, Coffee, Sugar and Cocoa Exchange (CSCE) contract no. 11 nearest future position, and Thailand nominal price quote.	• Johansen trace tests. • VECM. • Granger causality test.	run. • However, it is observed that the series of sugar price is formed within all three of the agricultural commodity long-run price relations (soybean-sugar-rice, wheat-sugar-rice and sugar-corn-rice). • The direction of other agricultural commodities prices is determined by sugar. • When sugar price raise, it causes other agricultural commodity price to increase.

Appendix 4.1

Statistics for Selecting the Optimum Lag Order for the ARDL Bound Co-integration Test

Optimum Lag (k)	AIC	SBC	Optimum Lag (k)	AIC	SBC
$f(DETH_t \| D\ln SGC_t)$			$f(D\ln SGC_t \| DETH_t)$		
1	342.7327	346.5948	1	144.6082	140.7462
2	339.7400	346.1509	2	140.9435	134.5327
3	338.1905	347.1291	3	139.0582	130.1197
4	331.0558	342.5007	4	135.4110	123.9662
5	329.4854	343.4147	5	132.2606	118.3313
6	327.7462	344.1378	6	128.3137	111.9221
7	322.6955	341.5269	7	125.1026	106.2712
8	318.9590	340.2074	8	121.8948	100.6464
9	316.4038	340.0458	9	118.2224	94.5804
10	313.9782	339.9903	10	114.7191	88.7070
11	310.5966	338.9546	11	117.5566	89.1986
12	308.5688	339.2482	12	119.4569	88.7775
$f(DETH_t \| D\ln MOL_t)$			$f(D\ln MOL_t \| DETH_t)$		
1	342.1456	346.0077	1	81.7748	85.6369
2	339.2149	345.6258	2	77.0987	83.5095
3	337.9077	346.8463	3	77.9712	86.9098
4	332.0806	343.5255	4	78.0322	89.4771
5	329.9269	343.8562	5	79.7356	93.6649
6	328.2141	344.6057	6	79.5119	95.9035
7	325.5850	344.4164	7	75.6491	94.4806
8	322.3825	343.6309	8	77.2821	98.4355
9	319.4671	343.1092	9	79.0271	102.6692
10	316.2311	342.2432	10	79.0303	105.0424
11	312.4436	340.8015	11	77.4288	105.7867
12	310.0124	340.6917	12	78.9817	109.6610
$f(DETH_t \| D\ln CAS_t)$			$f(D\ln CAS_t \| DETH_t)$		
1	341.0675	344.9296	1	111.2045	107.3424
2	338.0071	344.4180	2	110.8662	104.4554
3	335.7285	344.6671	3	109.9625	101.0239
4	328.9755	340.4203	4	108.6753	97.2305
5	325.9184	339.8477	5	105.4924	91.5631
6	324.7327	341.1243	6	102.1988	85.8071
7	322.6034	341.4349	7	98.7783	79.9469
8	319.1741	340.4225	8	95.1417	73.8933
9	315.6952	339.3372	9	93.0536	69.4115
10	313.6059	339.6179	10	94.4754	68.4633
11	310.3567	338.7147	11	93.8391	65.4812
12	307.3591	338.0385	12	94.2038	63.5244

Appendix 4.2

Lin-Log Model

1. DETH-DlnSGC

Optimum Lag	F-statistic	Serial Correlation	Functional Form	Normality	Heteroscedasticity
1	0.37496 [0.688]	x		x	
2	0.10986 [0.896]	x	x		
3	0.13891 [0.871]	x			
4	0.041887 [0.959]	x			
5	0.022726 [0.978]	x	x		
6	0.098126 [0.907]	x	x		
7	0.21936 [0.804]				
8	0.49518 [0.612]		x		
9	0.69737 [0.501]				
10	1.7875 [0.176]				
11	4.1827 [0.020]				
12	3.359 [0.042]				

2.DlnSGC-DETH

Optimum Lag	F-statistic	Serial Correlation	Functional Form	Normality	Heteroscedasticity
1	1.4134 [0.249]			x	
2	1.2870 [0.281]			x	
3	0.95163 [0.390]			x	
4	1.0569 [0.352]			x	
5	0.85372 [0.430]		x	x	
6	0.83248 [0.439]		x	x	
7	0.79902 [0.454]	x		x	
8	0.61432 [0.544]	x		x	
9	0.85534 [0.430]	x		x	x
10	0.88806 [0.416]	x		x	x
11	1.4653 [0.239]	x		x	x
12	1.7398 [0.184]	x		x	x

3. DETH-DlnMOL

Optimum Lag	F-statistic	Serial Correlation	Functional Form	Normality	Heteroscedasticity
1	0.23209 [0.793]	x	x	x	
2	0.064026 [0.938]	x	x		
3	0.062003 [0.940]	x	x		
4	0.0036002 [0.996]		x		
5	0.043931 [0.957]		x		
6	0.16416 [0.849]		x		
7	0.041339 [0.960]				
8	0.26016 [0.772]		x		x
9	0.43862 [0.647]				
10	1.5700 [0.216]				x
11	4.0124 [0.023]				x
12	2.7661 [0.071]				

4. DlnMOL-DETH

Optimum Lag	F-statistic	Serial Correlation	Functional Form	Normality	Heteroscedasticity
1	10.5461 [0.000]	x	x	x	x
2	5.5655 [0.005]		x	x	x
3	4.5285 [0.013]		x	x	x
4	3.2179 [0.045]		x	x	x
5	3.5719 [0.033]		x	x	x
6	2.6434 [0.078]		x	x	x
7	1.3970 [0.254]		x	x	x
8	1.4524 [0.241]		x	x	x
9	1.7776 [0.177]		x	x	x
10	1.2413 [0.296]		x	x	x
11	1.1676 [0.318]		x	x	x
12	0.95975 [0.389]		x	x	x

5. DETH-DlnCAS

Optimum Lag	F-statistic	Serial Correlation	Functional Form	Normality	Heteroscedasticity
1	0.66969 [0.514]	x	x	x	
2	0.46197 [0.632]	x	x		
3	0.80463 [0.451]	x			
4	0.21268 [0.809]				
5	0.50776 [0.604]		x		
6	0.53683 [0.587]		x		
7	0.70279 [0.498]		x		
8	0.86479 [0.426]	x		x	x
9	0.67616 [0.512]		x		
10	1.4158 [0.250]				
11	2.5396 [0.087]				x
12	2.1758 [0.123]				

6. DlnCAS-DETH

Optimum Lag	F-statistic	Serial Correlation	Functional Form	Normality	Heteroscedasticity
1	2.0916 [0.129]			x	
2	1.4922 [0.230]			x	
3	2.5043 [0.088]			x	
4	3.0440 [0.053]			x	
5	3.1177 [0.050]			x	
6	3.5994 [0.032]			x	
7	4.1844 [0.019]			x	
8	5.0574 [0.009]			x	
9	7.6003 [0.001]	x		x	
10	5.6048 [0.006]			x	
11	4.2487 [0.019]	x		x	
12	6.0880 [0.004]	x		x	