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Impacts of bioenergy on Thai agricultural sectors and households

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ABSTRACT: This study was conducted to analyze the impact of bioenergy policy on the agricultural sector and household income-groups in Thailand using the Computable General Equilibrium model (CGE), and estimate its welfare effect based on the compensating variation. This paper develops a CGE model to deal with the issue of ethanol and biodiesel policy on Thailand. In the long run, the ethanol and biodiesel policies had a positive impact on real GDP. Moreover, both policies had a positive effect on the agricultural sector, and appreciation of the baht led to more trade balance deficit. The ethanol and biodiesel policies had a similar effect on the export value, especially agricultural and agro-industrial exports. However, the compensating variation associated with the policies differed between household income groups, and the rich income groups benefitted more from the biofuel policy than the poor ones.

Keywords*:* bioenergy; ethanol; biodiesel; CGE

Introduction

Ethanol and biodiesel are widely used as bioenergy in Thailand, where ethanol is mainly produced from maize, cassava, and molasses, while biodiesel is made primarily from palm oil. Therefore, there is a strong linkage between bioenergy and the agricultural sector. Globally, the implementation of policies in support of bioenergy is driven by various motivational factors, including energy independence attainment, carbon emission reduction, and agricultural commodity price increase. Patton (2012) indicated that the expansion of biofuel in the EU strengthened the linkage between fuel oil and agricultural markets and showed a positive correlation between prices of crude oil, biofuel, and feedstock. Moreover, expansion of the bioenergy sector is known to impact the factor market, foreign trade, food security, and environment.

There are controversies over the economic impacts of bioenergy policies. The emergence of the biofuel industry in China and Mozambique stimulated an increase in the GDP growth rate (Arndt et al., 2009; Ge et al., 2010), whereas the biofuel industry led to a decrease in the GDP growth rate in Mexico and Thailand (Timilsina et al., 2012; Elizondo et al., 2017; Wianwiwat et al., 2013) In addition, bioenergy policy has a direct effect on households through the change in income and commodity prices. Higher energy crop

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prices generate additional income for agricultural households. On the other hand, an increase in food prices would affect vulnerable consumers. Therefore, an increase in income resulting from biofuel expansion may be offset by an increase in price. Furthermore, a change in food price impacts each income group differently. The poor are likely to suffer more from the effect of bioenergy policy than the rich because of their higher food expenditure share. On the other hand, the rich may benefit from the lower price of gasoline if they spend a substantial share of their income on energy. Thus, bioenergy policy may increase or decrease income inequality in the economy, which makes studying the overall impact of biofuel policy on the economy interesting.

In Thailand, the main objective of the "Alternative Energy Development Plan 2015-2036 (AEDP)," is to substitute bioenergy for conventional energy in the economy, with the target of increasing domestic ethanol and biodiesel consumption to 7.58 and 14 million liters per day respectively by 2036. In addition, the AEDP policy seeks to increase farmer income, boost rural development, and reduce carbon dioxide emission, while stimulating gasohol E10 and B2-biodiesel consumption through price subsidization and mandate policy. For example, the demand for ethanol in Thailand increased significantly from 1.4 million liters per day in 2012 to 3.91 million liters per day in 2017 mainly as a result of the 2013 government's policy on gasohol E10 along with the structured gasohol pricing subsidies (Ministry of Energy, 2018). Similarly, the demand for biodiesel increased from 1.72 million liters per day in 2011 to 4.9 million liters per day in 2019 with the government's revision of required B100 content in the diesel mix from 2% to 5% by 2012 and to 10% by 2020. The increase in bioenergy demand will stimulate the demand for agricultural inputs, which will impact other sectors of the economy.

General equilibrium analysis allows an encompassing assessment of the bioenergy policy impact on the whole economy as the models show multiple linkages. Computable general equilibrium (CGE) models, therefore, represent an appropriate tool to analyze the bioenergy sector effect on the economy as corroborated by Mukhopadhyay and Thomassin (2011), who employed CGE to study the impact of bio-energy policy on many sectors of the Canadian economy.

The aims of this paper are to analyze the impact of biofuel policy on macroeconomic indicators such as GDP, agricultural GDP, households, and trade balance and evaluate the welfare effect of bioenergy policy on the Thai economy. Previous studies on the biofuel policy effect on the Thai economy did not consider differences in households' incomes. A CGE model was applied to capture the interactions between agricultural production, food commodity, international trade, and households' welfare as affected by the biofuel policy.

Literature reviews

The bioenergy industry has directly and indirectly impacted many sectors of the global economy, including households, factor markets, trade and budget deficits, income distribution, food security, and the environment. Arndt et al. (2009) reported that the biofuel industry increased Mozambique's annual economic growth and reduced the incidence of poverty over a 12-year phase-in period. Moreover, the implemented biodiesel policy was much more strongly pro-poor than the ethanol policy due to the greater use of unskilled labor and the accrual of land rents to smallholders rather than ethanol producers. Ge et al. (2010) and Gebregiorgis (2015) similarly reported accelerated economic growth linked to the biofuel industry. In contrast, Elizondo et al. (2017) found that ethanol promotion in Mexico led to lower social welfare and the contraction of households' consumption. Timilsina et al. (2012) indicated that biofuel expansion decreased global GDP. Contrasting findings on the impact of biofuel on income distribution have also been reported. GE et al. (2010) showed that this policy improved rural households' income and narrowed the gap between the rich and the poor, while Gebregiorgis (2015) claimed that the vast income inequality among the population groups remained unchanged. Studies on the effect of bioenergy policy on the agricultural sector have been conducted, given the linkage between both sectors. Higher demand for biofuel had a positive effect on the arable crop sector with increases in commodity prices and production (Gohin, 2008; Timilsina et al., 2012; Dodder, 2015) Moreover, the downstream industry, livestock industry, and competing crops such as soybean and wheat were affected by this policy. The livestock's price slightly decreased, and the production marginally expanded. Soybean and wheat supply also decreased, and their prices increased.

Many countries are net energy importers, which leads to a deficit of trade balance. Thus, one objective of biofuel policy is the independence of the energy sector by the replacement of imported energy with locally-sourced bioenergy. Dodder (2015) showed a reduction in energy import positively impacted the real exchange rate and led to the shrinkage of traditional export crops. Gebregiorgis (2015) showed that the biofuel policy in South Africa led to an increase in foreign exchange earnings. Cui et al. (2011) reported that the U.S. biofuel policy improved the economy through the betterment of terms of trade, particularly in the oil market.

Several studies have investigated the impact of ethanol policy in Thailand. Okiyama (2010) found that the income of farm households increased higher than that of non-farm households with an increase in biofuel consumption. Wianwiwat et al. (2013) showed that biofuel policy adversely affects GDP in the short run, but impacts it positively in the long run. Kaechan et al. (2016) suggested that enhancing ethanol volume has a positive effect on the economy. The Thai biofuel policy also seeks to boost farmer income and reduce income inequality in the economy, but there are conflicting reports regarding these. Kuma et al. (2013) found that the use of biofuel in Thailand led to increases in crop and food prices, which affected poor households who spend a greater proportion of their income on food expenditure. Kaechan et al. (2016) claimed that the income inequality did not change. Regarding food security, Wianwiwat (2013) showed that the biofuel policy did not affect the food security situation in Thailand. However, Silalertrukasa et al. (2011) suggested that the Thai biofuel policy could impact world food security as Thailand is a major cassava exporter.

Model description

The comparative-static CGE model used in this research consists of four economic agents: producers, households, investors, and the government. Households were divided into five income groups in order to assess the welfare effect of the biofuel policy. The decision making agents in this model are based on neo-classic assumptions: a perfectly competitive economy with a constant return to scale, cost minimization for producers, and utility maximization for households and market clearance.

Commodity demands by producers, households, government and investors are derived from their constrained optimization problems. Producers maximize their profit (or minimize cost) under competitive market prices and constant-return-to-scale production technology. The production structure is presented as two nested levels (**Figure 1**), applied from ORANI-G (Horridge, 2014). The production sector output, at the top level, is derived from the Leontief function, which is a fixed proportion of the intermediate inputs and primary factor composite. At the second level of the nested production structure, the intermediate inputs are aggregates of domestic and imported commodities based on a constant elasticity of substitution (CES) function, and the primary factor composite is a CES aggregation of labor and capital.

The production sector consists of 54 industries and 63 commodities. To analyze the bioenergy policy impact on the economy, we considered the molasses, sugarcane juice, and cassava-derived ethanol, as well as biodiesel from palm oil refining according to Wienwiwat et al. (2013).

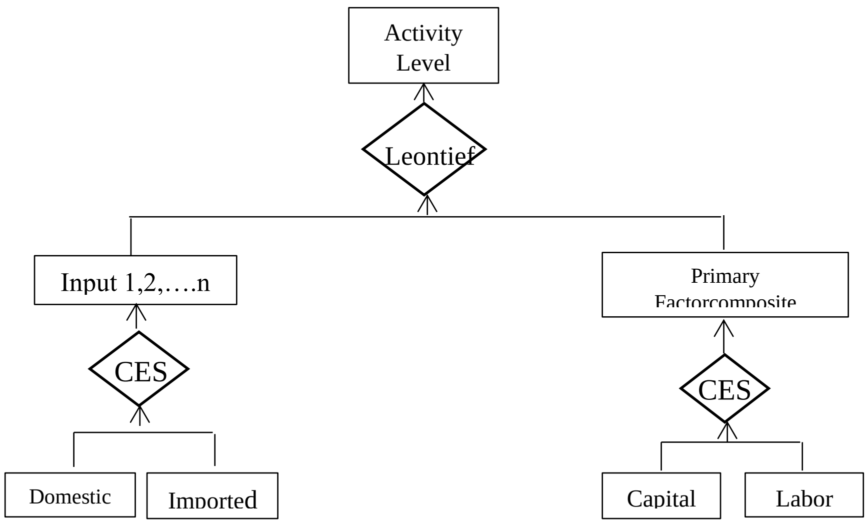

Figure 1 Structure of Production

Households maximize their utility subject to budget constraint. Household consumption commodities were categorized into five groups: food, nonfood, beverages, transportation, and services. As the household demand function, the five commodities were combined via a linear expenditure system (LES) at the top. At the second level of the nested structure, domestic and imported commodities were aggregated based on a constant elasticity of substitution (CES) function.

The government's demand for commodities was characterized using the Leontief function, which allows substitutability only between domestic and import commodities. The government earns revenue from direct and indirect taxes and spends it on consumption expenditure. The investment expenditure is equal to the sum of households' savings, governments' savings, and foreign financial inflow. Export demand is dependent on the price of domestic goods. The equations of CGE model show in the **Table 1**.

In order to ensure a result, the number of equations in the model must equal the number of endogenous variables. Thus, the number of exogenous variables must be held in order to ensure correct "closure." The models comprise 54 industries, 63 commodities, 15,724 equations and 20,373 variables. Therefore 4,649 exogenous variables were needed to obtain a result

Table 1 The equations of CGE model

Production	
Demand for intermediate commodities	$X_c^{1C} = X_i^{1TOT}\ for\ i \in IND$
Intermediate demand for domestic and imported commodity	$x_{cs}^{1C} = x_c^{1C} + \sigma_c^{1c}(p_c^{1C} - p_{cs}^{1C})\ for\ c\epsilon COM, S\epsilon SCR$
Demand for primary good	$X_i^{1EF} = X_i^{1TOT}\ for\ i \in IND$
Demand for capital	$x_i^{1K} = x_i^{1EF} + \sigma_1^{1EF}(p_i^{1EF} - p_i^{1K} - p_i^{1L})\ for\ i \in IND$
Demand for Labor	$x_i^{1L} = x_i^{1EF} + \sigma_1^{1EF}(p_i^{1EF} - p_i^{1L} - p_i^{1K})\ for\ i \in IND$
Domestic supply of output	$x_c^{0Dom} = x_c^{0Com} + \sigma_c^{0CET}(p_c^{0Dom} - p_c^{0Com})\ for\ c \in COM$
export output of commodity c.	$x_c^{4C} = x_c^{0Com} + \sigma_c^{0CET}(p_c^{0Exp} - p_c^{0Com})\ for\ c \in COM$
Final Demand	
Household demand for each commodity output	$x_{cs}^{3C} = x_c^{3C} + \sigma_c^{3c}(p_c^{3C} - p_{cs}^{3C})for\ c\epsilon COM, S\epsilon SCR$
Investment Final Demand	$X_c^{2C} = X_i^{2TOT}\ for\ c \in COM, i \in IND$
Investment demand for domestic and imported commodity	$x_{cs}^{2C} = x_c^{2c} + \sigma_c^{2C}(p_c^{2C} - p_{cs}^{2C})\ for\ c\epsilon COM, S\epsilon SCR, i\epsilon IND$
The individual export demand function	$x_c^{4C} - f_c^{4Q} = \varepsilon_c^4(p_c^{4C} - p^{Exc} - f_c^{4P})\ for\ c \in COM$
Government Demand	$X_c^{5C} = X^{5TOT}\ for\ c \in COM$
Government demand for domestic and imported commodity	$x_{cs}^{5C} = x_c^{5C} + \sigma_c^{5c}(p_c^{5C} - p_{cs}^{5C})\ for\ c\epsilon COM, S\epsilon SCR$
Market Clearing	$x_c^{0DOM} = x_{1c}^{1C} + x_{1c}^{2C} + x_{1c}^{3C} + x_{1c}^{4C} + x_{1c}^{5C}\ for\ c \in COM$
Market Clearing	$x_c^{0imp} = x_{2c}^{1C} + x_{2c}^{2C} + x_{2c}^{3C} + x_{2c}^{4C} + x_{2c}^{5C}\ for\ c \in COM$

** The variable description show in the appendix

Scenarios

This paper examines the impacts of various combinations of domestic subsidies in the context of an open economy. Two scenarios were considered.

Scenario 1: To analyze the impact of Thailand's 15-year renewable energy development plan, focusing on the replacement of gasohol E10 by gasohol 85 and gasohol E20. To achieve this target, ethanol use ought to increase from 3.52 million liters/day, as of 2016, to 7.58 million liters/day by 2026. However, we stimulated an ethanol consumption increase of up to 5.5 million liters/day in this study.

Scenario 2: To analyze the impact of the biodiesel policy, which seeks to increase the biodiesel proportion of mixed diesel from 5 percent to 10 percent.

Under these scenarios, we studied the long-run impact of the integrated liquid biofuel policy on social welfare and macroeconomic indicators such as real GDP, agricultural GDP, real household consumption, CPI, aggregate investment, and trade balance.

Consumer Welfare Analysis

In order to estimate the welfare impact of bioenergy policy, a second-order approximation was used to estimate the compensating variation. This second-order approximation was computed using the equation below according to Renner (2016)

$$SO = \sum_{i=}^{n} w_i \left[\frac{\Delta p_i}{p_i^0}\right] + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} w_i \, e_{ij} \left[\frac{\Delta p_i}{p_i^0}\right]\left[\frac{\Delta p_j}{p_j^0}\right]$$

Sensitivity Analysis

This paper analyzed the expansion effect of bioenergy on the economy. Therefore, a sensitivity analysis was conducted by varying the expenditure elasticity of demand, own price elasticity of demand, and Arminton function parameters by 20%.

DATA

The Social Accounting Matrix (SAM), constructed from the 2010 input-output table of Thailand, produced by the National Economic and Social Development Board (NESDB), was the main database for our CGE model as it is the most recent. Using the data from the year 2010, we assumed that the structure of economic transaction between sectors remain unchanged. The SAM consisted of 54 industries, 63 commodities, 5 households, the government, and the rest of the world. Parameters in the model were obtained from the GTAP 6 database and previous studies.

The household expenditure data was based on the Household Budget Survey data from the National Statistical Office (NSO). The household income was collected from the National Accounts Office of the National Economic and Social Development Board. The household income and consumption data were disaggregated to five household groups according to different income levels, ranging from the poorest to the richest.

Results and discussion

This paper examines two scenarios: the impacts of ethanol policy and biodiesel policy; we examined the long-run impact of the integrated liquid biofuel policy on macroeconomic indicators, agricultural sectors, and social welfare.

Scenario 1: The effect of ethanol policy

Macroeconomic impacts

The gasohol 85 and gasohol E20 policy had a macroeconomic impact on the economy. Real GDP increased by 0.50 percent due to a 0.42 percent increase in real household expenditure and a 0.54 percent increase in investment. The real government expenditure and export values decreased by 0.027 and 0.26 percent, respectively. The disposable income of households increased due to a 0.49 percent increase in the labor wage and a 0.39 percent increase in capital price. Moreover, the policy resulted in -0.43 deflation. Increases in households' disposable income and deflation led to an increase in real household expenditure. Appreciation of the baht led to the contraction of foreign trade, and the trade balance improved as the export value decreased lower than the import value.

Table 2 Macroeconomic impacts of the ethanol policy (Scenario 1)

Macro Impacts	Long –run (percent change)
Real GDP	0.50
Household Consumption	0.42
Government expenditure	-0.027
Investment	0.54
Export volume	-0.26
Import volume	-0.83
Agricultural GDP.	0.44
Real wage	0.49
Real return of capital	0.39
CPI	-0.43
Exchange rate	-0.22
Total savings	0.01

Source: from calculation

Agricultural and agro-industrial sector impacts

The gasohol E20 and E85 policy, which affected many sectors of the Thai economy, led to a 315.95 percent increase in ethanol output. The results showed that the cassava-based ethanol production expanded by 108.38 percent, while molasses and sugarcane juice-derived ethanol expanded by 207.57 percent. In the long run, the increase in ethanol supply over demand led to lower prices, approximately corresponding to a price decrease of 0.17 and 5.05 percent, respectively. Also, the price of gasohol E85 decreased approximately by 0.73 percent.

The expansion of the ethanol industry directly affected the supply of relevant agricultural feedstock. For example, the increase in ethanol supply led to a 19.5 percent increase in cassava supply and a 12.6 percent increase in sugarcane supply. However, in the long run, the increase in cassava and sugarcane supply over demand led to price decreases of 0.08 and 0.13 percent, respectively. As cassava milling and sugar refining industries utilize similar input as the ethanol industry, they were directly affected by the latter's expansion. The cassava milling industry expanded by 13.77 percent, and sugar refinery by 11.21 percent.

Furthermore, the increase in ethanol usage directly affected other agricultural sectors. Results showed the ethanol policy caused a 0.44 percent increase in agricultural GDP, mainly from the increases in the values of cassava, sugarcane and palm oil by 19.54, 12.67 and 0.08 percent, respectively. However, the values of paddy, para rubber, livestock, and fish-farming decreased by 0.21, 1.32, 0.35, and 0.29 percent. Paddy, which is a competing crop of cassava, was impacted by the expansion of cassava and sugarcane. Capital was reallocated from the paddy sector to cassava and sugarcane production, resulting in a 0.21 percent decrease in paddy supply. Similarly, para-rubber supply decreased by 1.3 percent due to a 2 percent decrease in its export value associated with the baht appreciation.

The food processing industry, an agricultural downstream sector, was affected by the ethanol policy as its output decreased by 0.38 percent. The lower prices of crops, including sugarcane, as well as livestock and fishery products led to a 0.14 percent decrease in the cost of processed food production.

Household sector impact

Households were categorized into 5 income groups, while consumption goods were divided into 5 groups: food, nonfood, beverage, transportation, and services to analyze the effect of ethanol policy on each. An increase in nominal wage and decreased nominal rent led to an approximate 0.002 percent increase in the disposable income of the first income group (the poorest) but decreased the disposable income of other income groups. Households in the first income group derived their income mainly from wages than rents. The results showed that food, nonfood, beverage, transportation and service prices decreased by 0.20, 0.30, 0.17, 1.79 and 0.19 percent, respectively. The resulting changes in households' incomes and decreased consumption goods' prices affected the household's expenditure. The consumption expenditure of the first household income group, whose income increased, increased by 0.001 percent, while that of the second, third, fourth and fifth income groups decreased by 0.002, 0.05, 0.007 and 0.007 percent, respectively.

The poor income groups benefited more from the decrease in food prices, and their consumption increased by 0.19 percent compared to the wealthiest income group's expenditure, which decreased by 0.05 percent. Similarly, the change in transportation price affected the first income group more than others.

The increase in real income led to the expansion in demand for consumption goods. Demand for food, nonfood, beverage, transportation and service increased by 0.04, 0.55, 0.40, 1.07 and 0.39 percent, respectively. The cost of transportation also decreased due to the lower price of gasohol. Consequently, the households' expenditure on transportation was higher than on consumption goods.

Agricultural and agro-industrial trade balance

Thailand is a net energy importer, which causes a deficit of trade balance. Thus, one objective of bioenergy policy is to improve the trade balance by reducing the importation of energy. The ethanol policy did decrease natural gas and benzene import values, but also affected the foreign exchange rate and competitive advantage of Thailand. After the government's implementation of the ethanol policy, the baht appreciated by 0.22 percent. Thailand, however, lost its competitive advantage in the foreign market, and the export value decreased by 0.59 percent. The export values of agricultural and agro-industrial products such as crops, para rubber, milled rice, refined sugar and processed foods contracted by 2.02, 0.75, 0.73, 2.52 and 0.6 percentage. On the other hand, the import value decreased by 0.83 due to 3.29 and 2.30 percent decreases in the import volume of raw natural gas and petroleum, resulting in an 8.13 percent trade surplus.

Scenario 2: The effect of biodiesel policy

Macroeconomic impacts

The biodiesel policy had an impact on the macro economy. Real GDP was expanded by 0.15 percent due to the 0.42 percent increase in real consumer expenditure, 0.13 percent decrease in real government expenditure, 2.25 percent decrease in export value, 2.3 percent decrease in import value, and 0.188 percent decline in real investment. The disposable income of households increased due to a 0.18 percent increase in capital price and a 0.22 percent increase in labor wage. The baht value also appreciated by 0.04 percent, which led to a deficit of trade balance.

Agricultural and agro-industrial sector impacts

The biodiesel policy increased the biodiesel output by 300.06 percent. The expansion of biodiesel led to a higher demand for oil palm. In the long run, producers could adjust their capital stock in response to the high demand. Oil palm supply expanded by 44.51 percent; the biodiesel expansion resulted in an approximate 0.32 percent increase in the oil palm price. The palm oil and oil industries that use the same input as the biodiesel industry respectively expanded by 9.43 and 5.72 percent in response to the expansion of oil palm supply.

Table 3 Results of scenario 2 on the macro economy

Macro Impacts	Long-run percent change
Real GDP	0.15
Household Consumption	0.42
Government expenditure	-0.13
Investment	-0.18
Export volume	-2.25
Import volume	-2.30
Agricultural GDP.	0.63
Real wage	0.22
Real return of capital	0.18
CPI	0.16
Exchange rate	-0.04
Total savings	-0.008

Source: calculation

This policy increased agricultural GDP by 0.63 percent. The values of paddy, para rubber, livestock and fishery products decreased by 0.22, 3.82, 0.58 and 0.38 percent, while values of cassava, sugarcane and oil palm increased by 0.30, 17.43 and 45.07 percent, respectively.

Paddy, other crops, para-rubber, livestock and fish production contracted by 0.61, 0.08, 4.19, 0.96 and 0.76 percent (Table 4). Consequently, prices of paddy, cassava, sugarcane, para rubber, oil palm, livestock and fishery products increased. Para rubber and oil palm are competing crops; thus, the former was affected by the expansion of oil palm production. The agro-industry was also affected by the contraction of the agricultural outputs, leading to decreases in the supply of milled rice and processed foods by 0.6 and 1.1 percent. The contraction of food processing and rice milling led to price increases of 0.26 and 0.30 percent.

Household sector impact

The increases in wage and rent increased the households' income and consumption expenditure. The disposable income of all income groups increased approximately by 0.3 percent. At the same time, prices of food, nonfood, beverage, transportation and service commodities increased by 0.23, 0.17, 0.20, 0.05 and 0.22 percent. The higher price of food processing, rice milling and other agricultural crops led to an increase in the food commodity price. Although the mixed diesel price increased, the cost of transportation increased lower than other consumption goods, due to the lower prices of gasohol and LPG. When we compared the income groups' expenditure, that of the third group increased the highest, by 1 percent. The expenditure of the first income group increased only by 0.21 percent, the lowest of all.

Although the food commodity price was higher, the first income group increased its food expenditure by 0.12 percent. This showed the impact of higher households' income on food demand offset the negative impact of higher food prices. On the other hand, the fifth income group consumed 0.02 percent less food commodity. Similarly, the first income group increased their transportation expenditure by 0.5 percent, notwithstanding the transportation sector was 0.05 percent more expensive, whereas the fifth income group increased its transportation expenditure only by 0.29 percent.

The increase in households' income and changes in consumption goods' prices led to demand changes in the consumption good sector. The aggregate demand for food, nonfood, transportation and service commodities increased by 0.02, 0.42, 028, 0.33 and 0.25 percent. (**Table 5**)

Agricultural and agro-industrial trade balance

The biodiesel policy effect on the foreign trade sector was similar to the ethanol policy. Following the implementation of the biodiesel policy, the baht appreciated by 0.04 percent. The export value decreased by 2.22 percent, which was higher than the ethanol policy effect. Major export commodities such as agricultural crops, para rubber, milled rice, refined sugar and processed foods contracted in value by 1.7, 5.8, 2.1, 1.52 and 2.5 percent. The import value decreased by 2.3 percent from the 12.12 percent decrease in diesel importation, leading to a trade deficit of 0.32 percent.

Table 4 Effects of scenario 1 and 2 on sectors of the economy

	Ethanol Policy		Biodiesel policy	
	output	price	output	price
Cassava	19.55	-0.08	4.73	0.33
Sugarcane	12.66	-0.13	16.96	-0.34
Oil palm	0.08	-0.13	44.51	0.32
paddy	-0.21	-0.07	-0.61	0.32
Para rubber	-1.32	-0.05	-4.19	0.35
Other crops	0.03	-0.10	-0.08	0.33
livestock	-0.35	-0.11	-0.96	0.31
fishing	-0.29	-0.10	-0.76	0.42
Rice milling and starch	-0.18	-0.12	-0.61	0.30
Cassava milling	13.77	-0.17	5.24	0.33
oil	-0.07	-0.21	5.72	0.20
Palm oil	-0.017	-0.21	9.43	0.20
Sugar refinery	11.21	-0.19	20.61	0.31
food	-0.38	-0.14	-1.19	0.26
Ethanol				
Cassava ethanol	108.38	-0.17	-1.24	0.31
Molasses ethanol	94.10	-5.05	-2.4	3.07
Sugarcane juice ethanol	113.47	-5.0	1.7	3.07

Source: calculation

Table 5 Effects of scenario 1 and 2 on consumption commodities

	Ethanol Policy		Biodiesel policy	
	output	Price	output	price
Food commodity	0.04	-0.20	0.02	0.23
Nonfood commodity	0.55	-0.30	0.42	0.17
Beverage commodity	0.40	-0.17	0.28	0.20
Transportation commodity	1.07	-1.79	0.33	0.05
Service commodity	0.39	-0.19	0.25	0.22

Source: calculation

Welfare Analysis

The ethanol policy induced slightly different welfare benefits on the income groups. The compensating variation of the fifth income group was lower than other groups, -0.65 percent of initial expenditure. The decrease in compensating variation meant consumers paid lower amounts of money to maintain the same level of satisfaction after a price change. In terms of the percent change, the richest income group was most affected by the ethanol policy.

The biodiesel policy had a different effect on the social welfare of consumers. The compensating variation of the first income group rose higher than others, 0.19 percent of initial expenditure. The compensating variation of the fifth income group increased by 0.17 percent of the initial expenditure. The findings showed the rich benefited less from this policy than the poor.

Table 6 Compensating variation

	Scenario 1	Scenario 2
First income group	-0.41	0.19
Second income group	-0.44	0.18
Third income group	-0.51	0.18
Fourth income group	-0.57	0.18
Fifth income group	-0.65	0.17

Source: calculation

Sensitivity Analysis

The result showed that the direction of change of the macroeconomic impacts, output and price from the ethanol and biodiesel policies, were not different. Despite the uncertainty surrounding the expenditure elasticity, owned price elasticity, and Arminton elasticity, the direction of change was not different.

Discussion

The policies to substitute 85 percent ethanol for conventional energy and increase the biodiesel blend with biodiesel from 7 percent to 10 percent had quite an impact on the economy. Both increased the real GDP in the long run, corroborating Wianwiwat et al. (2013), who reported that the biofuel policy resulted in a long term GDP increase. While the ethanol policy increased the total savings, the biodiesel policy decreased it. Therefore, the ethanol policy stimulated investment, but the biodiesel policy led to its decrease. Thus, the growth rate of real GDP from the ethanol policy was higher than the biodiesel policy. Moreover, the real GDP growth of the agricultural sector from ethanol policy was higher than its growth from the biodiesel policy.

Both policies had the same effect on the agricultural sector. The ethanol policy stimulated agricultural GDP from 153,067 million bath to 220,416 million bath, while the biodiesel policy increases the agricultural GDP from 153,067 million bath to 249,499 million bath. Thus the implementation of the policies could boost the expansion of the agricultural sector. However, while the ethanol policy boosted agricultural supply and led to a decrease in the prices of agricultural products, the biodiesel policy led to agricultural supply contraction and agricultural price increase.

Thus, the increase in prices of crops and mixed diesel, as a result of the biodiesel policy, resulted in increased costs for the processing food industry. This result is consistent with Jafari et al. (2015), Ge et al. (2010), and Chen and Khanna (2013), who found that the biofuel policy increased food prices. However, prices of agricultural commodities and food processing costs were not increased by the ethanol policy. Thus, the biodiesel policy had a more negative effect on the processing food industry than the ethanol policy.

As the foreign market is the main market for Thai agricultural and agro-industrial products, bioenergy policy effects on foreign exchange rates also directly impact export competitiveness. Appreciation of the baht led to the contraction of agricultural export values, especially for para rubber. Moreover, the export values of milled rice, refined sugar, and processed foods were mostly affected by the baht appreciation. However, the decrease in the export value due to the biodiesel policy was higher than that linked to the ethanol policy, a consequence of higher domestic prices and appreciation of the baht.

The change in disposable income, which resulted from the change in the primary factor price, affected households' expenditure. The lower nominal rent and higher nominal wage linked to the ethanol policy largely caused a decrease in the households' disposable income, except the poorest household, whose disposable income increased. Conversely, the biodiesel policy increased the primary factor price and households' disposable income. Furthermore, the biodiesel policy increased the prices of the consumption goods: food, nonfood, beverage, transportation and service commodities, while the ethanol policy decreased them. Thus, the biodiesel policy stimulated inflation, while the ethanol policy caused deflation. Therefore, both policies increased the households' expenditure.

The compensating variation showed that both policies had different effects on consumer welfare. The biodiesel policy had a negative effect on each income group, while the ethanol policy showed a positive effect. Although the biodiesel policy stimulated the disposable income, households had higher expenditure for the same amount of goods due to the commodity price increase. Compared to the high-income groups, the compensating variation change was higher than in low-income groups. The ethanol policy had a comparable effect on the compensating variation of the income groups as the biodiesel policy. Both policies made the lower-income households worse off than the higher-income households.

Summary and Policy Implications

The objectives of the biofuel policy include the increase in prices of agricultural commodities, reduction of poverty, and decrease of trade deficit. The results indicated that in the long run, both the ethanol and biodiesel policies increased real GDP and agricultural GDP. However, both policies had a different effect on agricultural prices. While the biodiesel policy stimulated the price of oil palm, the ethanol policy lowered the prices of cassava and sugarcane. Moreover, both policies increased the real wage and rent in the factor market, which led to an increase in households' real expenditure. The effect of both policies on the expenditure of each income group was different. The third income group was impacted more by both policies compared to the other groups. The appreciation of the baht led to a deficit of trade balance. Both policies had the same effect on the export value, especially on agricultural and agro-industrial products. The compensating variation indicated that the richer income groups benefited more from the biofuel policy than the poorest.

Although the biofuel policy could stimulate the GDP growth rate in the economy, the government should also take into account its effects on other sectors, including households, agriculture, and export. The increase in biodiesel proportion from 7% to 10% increased the palm oil price, whereas the increase in ethanol blend to 85% ethanol did not increase the cassava and sugarcane prices. Under the managed floating exchange rate system, a stronger exchange rate could directly affect the export price and lead to a loss of competitiveness. Thus, the ethanol policy would appreciate the exchange rate and deteriorate the trade balance.

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Appendix

Table 7 Variable description

Variables	Description
P_c^{1C} and X_c^{1C}	Price and quantity of intermediate commodities c
X_i^{1TOT}	Output of industry i
P_i^{1EF} and X_i^{1EF}	Price and quantity of primary goods
$P_i^{1L} and\ X_i^{1L}$	Price and quantity of labor
$P_i^{1K} and\ X_i^{1K}$	Price and quantity of capital.
$P_c^{0Com}\ and\ X_c^{0com}$	Price and total output of commodity c
$P_c^{0Dom}\ and\ X_c^{0Dom}$	Domestic price and total domestic output of commodity c
$P_c^{0Exp}\ and\ X_c^{4C}$	Export price and total export output of commodity c
$P_c^{3C}\ and\ X_c^{3C}$	Price and quantity of commodity c for household
$P_{cs}^{3C}\ and\ X_{cs}^{3C}$	Domestic and import commodity's price and Domestic and import commodity's quantity for household
$p_c^{2C}\ and\ X_c^{2C}$	Price and quantity of commodity c for investment
$P_{cs}^{2C}\ and\ X_{cs}^{2C}$	Domestic and import commodity's price and Domestic and import commodity's quantity for investment
$p_{ci}^{4C}\ and\ X_{ci}^{4C}$	Price and quantity of commodity c for export
$p_c^{5C}\ and\ X_c^{5C}$	Price and quantity of commodity c for government
$P_{cs}^{5C}\ and\ X_{cs}^{5C}$	Domestic and import commodity's price and commodity's Domestic and import quantity for government
x_c^{0DOM}	Supply of domestic commodity c
x_c^{0imp}	Supply of imported commodity c
$\sigma_c^{1c}, \sigma_c^{3c}\ \sigma_c^{5c}$	CES Elasticity of substitution between domestic and imported commodities c
σ_1^{1EF}	CES Elasticity of substitution between labor and capital factor