MARKET EFFICIENCY IMPACTED BY GOVERNMENT PRICING POLICY FOR GASOHOL CONSUMPTION: A CASE OF THAILAND

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ABSTRACT

Title of Dissertation	Market Efficiency Impacted by Government Pricing Policy for Gasohol Consumption: A Case of Thailand
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The aim of the dissertation is to examine the market efficiency of gasohol consumption in Thailand impacted by government pricing policies (a tax and subsidy regime managed via the Oil Fund) for 2004-2013. The deadweight losses in gasohol are estimated through the changes in consumer and producer surplus applying the Johansen cointegration method and the Vector Error Correction Model.

Consequently, the elasticity estimates indicate that the consumption of gasohol 91, E20, and E85 are elastic to their own prices in the long run. But gasohol 95 consumption is elastic to its own price in the short run. Besides, the total long run deadweight losses in gasohol 91, 95, E20, and E85 are 2937.63, 35611.81, 349.99, and 673.90 million baht for 2004-2013 and become 2348.09, 22861.09, 348.99, and 673.90 million baht for 2009-2013, respectively. Conspicuously, gasohol 95 causes the highest total deadweight loss, whereas gasohol E85 results in the maximum per unit deadweight loss (3.57 baht per liter). In comparison, the per unit deadweight losses in gasohol 91, 95, and E20 are rather small as 0.25, 1.21, and 0.19 baht per liter, respectively.

Thus, the government pricing policies are practical as a pricing strategy for achieving the objectives of gasohol usage promotion, but it creates market inefficiency. In addition, since taxation and subsidy of the Oil Fund generate the deadweight losses, the government should take advantage of the downtrend in global crude oil prices by abolishing the oil fund taxes (subsidies) on gasohol 91 and 95, reducing the oil fund taxes on gasoline (sustaining its prices beyond gasohol prices), and decreasing the oil fund subsidies on gasohol E20 and E85 in order to diminish the market inefficiency.

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SYMBOLS AND ABBREVIATIONS

Symbols	Equivalence
P_c	Price of Complementary Goods
P_i	Price of Inputs
P_r	Price of Related Goods
P_s	Price of Substitute Goods
P_x	Price of Good x
Δ	Change in

Abbreviations	Equivalence
ADF	Augmented Dickey-Fuller
AIC	Akaike Information Criteria
C_{HSD}	Consumption of High Speed Diesel
C_{G91E10}	Gasohol 91 Consumption
C_{G95E10}	Gasohol 95 Consumption
C_{G95E20}	Gasohol E20 Consumption
C_{G95E85}	Gasohol E85 Consumption
C_{UGR91}	Gasoline 91 Consumption
C_{ULG95}	Gasoline 95 Consumption
DDGs	Dried Distillers Grains with Solubles
DEDE	Department of Alternative Energy Development and Efficiency
DOEB	Department of Energy Business
ECM	Error Correction Model
FFV	Flex-Fuel Vehicle

G91E10	Gasohol 91 (10 Percent Ethanol with 90 Percent Gasoline 91)
G95E10	Gasohol 95 (10 Percent Ethanol with 90 Percent Gasoline 95)
G95E20	Gasohol E20 (20 Percent Ethanol with 80 Percent Gasoline 95)
G95E85	Gasohol E85 (85 Percent Ethanol with 15 Percent Gasoline 95)
GDP	Gross Domestic Product
HFCS	High Fructose Corn Syrup
HSD	High Speed Diesel
LPG	Liquefied Petroleum Gas
M1	Narrow Money Supply
M2	Broad Money Supply
M3	Broadest Money Supply
OECD	Organization for Economic Co-operation and Development
P_E	Ethanol Price
P_{HSD}	High Speed Diesel Price
P_{G91E10}	Gasohol 91 Price
P_{G95E10}	Gasohol 95 Price
P_{G95E20}	Gasohol E20 Price
P_{G95E85}	Gasohol E85 Price
P_{UGR91}	Gasoline 91 Price
P_{ULG95}	Gasoline 95 Price
Q_0	Equilibrium Quantity of Consumption
Q_S	Quantity of Consumption at Subsidized Price
Q_T	Quantity of Consumption at Taxed Price
S_E	Ethanol Supply
S_G	Gasohol Supply
S_U	Gasoline Supply

UGR91	Gasoline 91 (Unleaded Regular Gasoline Octane 91)
ULG95	Gasoline 95 (Premium Unleaded Gasoline or Benzene octane 95)
VAR	Vector Autoregression
VECM	Vector Error Correction Model

CHAPTER 1

INTRODUCTION

1.1 Background and Motivation

Crude oil is an essential resource for economic development in all countries. In the past, world crude oil consumption rapidly increased, whereas the supply relatively dropped. So, as a crude oil importer, Thailand was only a price taker in the international markets. It was inevitably impacted by world oil price fluctuations and volatility. Under these circumstances, in 1973 Thai government established the Oil Fund as an instrument to maintain domestic retail fuel prices at a set ceiling in times by taxation and subsidy on the fuel prices during world oil price volatility. Furthermore, the government launched an Alternative Energy Development Plan (AEDP 2008-2022) which aims to reduce crude oil imports, increase domestic alternative energy use, and build energy security. For this reason, gasohol consumption is stimulated by taxation and subsidy on fuel prices via the Oil Fund to replace the use of gasoline 91 and 95.

Nevertheless, taxation and subsidy on fuel prices primarily generate price distortions and market inefficiency. So, this dissertation targets to examine the effects of government pricing policies on the market efficiency of gasohol, which the gasohol prices are taxed and subsidized by the Oil Fund.

Accordingly, the dissertation's scope covers all types of gasohol currently sold in Thailand. Econometric models are applied as a tool for investigating the demand and supply price elasticities of gasohol, and the deadweight losses in gasohol consumption. Finally, the valuable outcome will provide indications to the pricing policy makers with regard to fuel price stabilization, the promotion of gasohol consumption, and market efficiency.

1.2 Objectives

The objectives of the dissertation are to examine the market efficiency of gasohol consumption in Thailand impacted by the government pricing policies (a tax and subsidy scheme manipulated through the Oil Fund), applying econometric models to obtain demand and supply elasticities and the changes in consumer and producer surplus for deadweight loss calculation. Appropriate indications pertaining to the market efficiency will be revealed to the pricing policy makers.

1.3 Expected Benefit

The expected benefit of the dissertation includes the discernment of government pricing policies through deadweight loss estimates, the apprehension of consumer and producer behavior on gasohol consumption influenced by the changes in fuel prices, and obtaining the alternative approaches of fuel price stabilization.

1.4 Scope of the Study

The dissertation emphasize on the scrutiny of deadweight losses in the consumption of gasohol 91, 95, E20, and E85 in Thailand caused by government pricing policies via the Oil Fund. The deadweight loss estimates are executed using monthly data. The period of the study is 2004-2013, which the data of gasohol 91, 95, E20, and E85 covers the period 2005-2013, 2004-2013, 2008-2013, and 2009-2013, respectively.

CHAPTER 2

LITERATURE REVIEW, THEORY AND CONCEPTUAL FRAMEWORK

2.1 History of Renewable Energy in Thailand

In 1985, His Majesty King Bhumibol Adulyadej requested the study of ethanol produced from sugarcane as an alternative fuel and facilities for the study were opened in Chitralada Palace. In 1992, Thai government introduced the legal and financial support structures to increase renewable energy use and reduce energy imports, as well as the Energy Conservation Promotion Act and Energy Conservation Fund was established. In 1994, the Royal Chitralada project disclosed that ten percent ethanol fuel could be used in existing automobile engines. Two years later, Her Royal Highness Princess Maha Chakri Sirindhorn opened the first gasohol E10 filling station in the Palace. Also in 1994, the Energy Conservation Program was launched as guidelines, criteria, and conditions for the fund allocation. Further, in 1999 Dr. Dennis Shuetzel, Ford Motor company director, discussed a collaborative effort with the Minister of Science and Technology, regarding the research of gasohol E10 for light trucks. In 2001, the National Ethanol Committee was appointed. And a year later, the government defined the commercial specifications of gasohol. However, in 2005 the National Ethanol Committee was canceled, while the National Biofuel Development and Promotion Committee was appointed by the Cabinet. Furthermore, the National Energy Policy Council endorsed a 15 year Alternative Energy Development Plan (AEDP 2008-2022) to increase the domestic alternative energy use and replace fuel imports at 20 percent of the country's total energy demand. To achieve the plan, only the cancellation of gasoline 91 and the promotion of gasohol E20 use would be inadequate. The government might deliver more ethanol promotion strategies, such as the termination of gasoline 95 and an increase in gasohol subsidies (Suthin Wianwiwat, 2011).

Nevertheless, in 2011 the 15 year plan was revised to the ten year plan (AEDP 2012-2021) by targeting the domestic alternative energy use from 20 to 25 percent and increasing ethanol consumption to nine million liters per day, by 2021. Thus, the government created strategies and incentives to boost the demand and supply. As a consequence, at present, the ethanol supply increases due to (1) the expansion of cassava and sugarcane production, (2) the promotion of alternative feedstock supply, and (3) the permission of BOI privileges for fuel ethanol plants. Similarly, the ethanol demand arises due to (1) the dissolution of gasoline 91, (2) the subsidy of gasohol E20 by the Oil Fund, (3) the expansion of gasohol E20 service stations, (4) the public campaigns, and (5) a decrease in excise tax on gasohol E85 vehicles and eco-cars (gasohol E20 vehicles). As far as the renewable energy is concerned, a clear policy and a strong signal from the government are necessary to disseminate information through public campaigns to build a strong public confidence on renewable energy technologies (Boonrod Sajjakulnukit and Suteera Prasertsan, 2006).

2.2 Consumption of Gasohol

The types of gasohol (a mixture of ethanol and gasoline) available in Thailand are categorized as gasohol 91, 95, E20, and E85. In 2003, gasohol 95 (a mixture of ten percent ethanol and 90 percent gasoline 95) was launched in the market. Gasohol 91 (a mixture of ten percent ethanol and 90 percent gasoline 91) was sold in 2005. And three years later, gasohol E20 (a mixture of 20 percent ethanol and 80 percent gasoline 95) and gasohol E85 (a mixture of 85 percent ethanol and 15 percent gasoline 95) was released.

Furthermore, the government anticipated to increase gasohol consumption via tax incentives and subsidies. In this case, ethanol producers reaped the benefits of partial excise tax exemption, and gasohol refiners were subsidized by the Oil Fund. The government also reduced excise tax on gasohol E85 vehicle manufacturers and lowered import duties on flex-fuel vehicles (FFVs) from 80 to 60 percent. (Ponnarong Prasertsri and Sakchai Preechajarn, 2009). As a result, the retail prices of gasohol 91 and 95 dropped below gasoline prices about 22 to 26 percent, while gasohol E85 prices fell below the prices of gasohol 91 and 95 approximately 30 percent. Gasohol consumption increased from 0.16 million liters per day in 2004 to 9.27 million liters per day in 2008 (Ministry of Energy. Department of Alternative Energy Development and Efficiency [DEDE], 2012b). Besides, Santhiti Thongchuang and Srisuda Thungsuwan (2010) revealed that the gasohol E20 usage promotion led to an increase in the production quantity and sales volume of gasohol E20, for 2008-2009. In 2013, gasohol consumption raised to 7,470 million liters (20 million liters per day) greater than in 2012 (12 million liters per day). Particularly, gasohol E20 and E85 consumption significantly rose due to an increase in eco-cars and flex-fuel vehicles. In the first four months of 2014, gasohol consumption increased up to 21 million liters per day, while gasoline 95 consumption decreased to 1.4 million liters per day (from 1.7 million liters per day in 2013). In 2014, the prices of gasohol E20 and E85 were approximately 27 and 50 percent below gasoline 95 price, respectively. Moreover, in May 2014 gasohol E85 service stations expanded to 385 stations and were expected to be 500 stations by the end of the year. Besides, gasohol consumption was probably 95 percent of gasoline consumption by 2014 (Ponnarong Prasertsri and Sakchai Preechajarn, 2014). Nevertheless, without continued government subsidies, gasohol could not be in a major role as a vehicle fuel (Rask, 1998).

2.3 Aspects of Ethanol

2.3.1 Demand and Supply of Ethanol

With the abundance of agricultural resources, Thai government promoted the ethanol use which aims to reduce fuel imports. For 2002-2003, 47.8 million tons of crop and wood residues were sufficient for producing biofuel to replace gasoline—1.3 times the gasoline consumption or 17 percent of crude oil imports (Asia-Pacific Economic Cooperation [APEC], 2008). In 2012, domestic demand for gasoline was approximately 30 million liters per day, however the ethanol supply was adequate for gasohol production to meet the demand. In 2013, fuel ethanol consumption significantly increased to 2.6 million liters per day caused by the dissolution of gasoline 91. In 2014, fuel ethanol consumption escalated to 2.9 million liters per day due to a growth in gasohol E20 and E85 consumption effected by (1) the oil fund subsidies, (2) a rise in eco-cars and flex-fuel vehicles, and (3) the expansion of gasohol E20 and E85 service stations. Moreover, fuel ethanol consumption probably becomes 3.5 million liters per day in 2015 (Ponnarong Prasertsri and Sakchai Preechajarn, 2014).

In addition, Thailand is the Asia's largest producer of cassava (20 million tons per year) where positions to be the leading ethanol producer in Asia (Gonsalves, 2006). The production of ethanol was 192.8 million liters (0.53 million liters per day) in 2007 (Maysa Kunasirirat, Ponnarong Prasertsri and Sakchai Preechajarn, 2007). However, in 2011 ethanol production could not achieve the target of three million liters per day. Its actual production was only 1.43 million liters per day. Under these circumstances, the government has planned to (1) enhance the average yield of sugarcane above 15 tons per rai (105 million tons per year) and above five tons per rai (35 million tons per year) of cassava by 2021, (2) subsidize gasohol E20 prices to stay at three baht per liter below gasohol 95 prices, (3) increase the marketing margin of gasohol E20 at 0.50 baht per liter above that of the gasoline 91, (4) reduce excise tax on eco-car and flex-fuel vehicle manufacturers, and (5) terminate gasoline 91 (Ponnarong Prasertsri and Sakchai Preechajarn, 2012). Nevertheless, Ackom, Kumar, Salam and Shrestha (2013) assessed that the quantity of ethanol produced from agricultural residues is 1.14-3.12 billion liters per year in 2011, sufficient to offset 25.10-68.50 percent of domestic consumption of gasoline. Instead, Ponnarong Prasertsri and Sakchai Preechajarn, (2014) found that the actual ethanol production was 613.2 million liters per year in 2011. In 2014, ethanol production approximately increased to 1,100 million liters (three million liters per day) and was expected to be 1,280 million liters (3.5 million liters per day) in 2015, while the number of ethanol plants would be 23, and the total production capacity is 5.4 million liters per day (Ponnarong Prasertsri, 2014).

As for a lot of excess ethanol supply in the market (Wanida Norasethasopon, 2010), Thailand also exported ethanol, which 14.9 million liters of ethanol were exported to Australia, Chinese Taipei, Europe, Singapore, and the Philippines in 2007. In 2008, 65.8 million liters of ethanol were exported to other countries, such as Australia, EU, Singapore, and the Philippines (Ministry of Energy. DEDE, 2012a). The export volume significantly increased to 304 million liters in 2012, but dropped to 64 million liters in 2013 to supply domestically. It causes an increase in domestic ethanol stocks to 43 million liters. The export volume fell to ten million liters in 2014 due to an increase in domestic demand. Likewise, in 2015 ethanol stocks become around 35-40 million liters, while the exports are limited due to high domestic demand for gasohol E20 and E85 (Ponnarong Prasertsri and Sakchai Preechajarn, 2014).

2.3.2 Ethanol Price

The domestic ethanol price was initially determined by the ethanol price in Brazil market plus the costs of freight, insurance, losses, and survey. Thai government regulated the domestic ethanol price consistent with the gasoline price in the world market and attempted to impose a ceiling price on the local ethanol supply, but it was opposed by the ethanol producers (Chumnong Sorapipatana and Suthamma Yoosin, 2007). Subsequently, the ethanol price formula was defined for ethanol producers and oil traders as

$$P_{Eth,t} = [(Q_{Mol,t-2} \times P_{Mol,t}) + (Q_{Css,t-2} \times P_{Css,t})] \div Q_{Total,t-2} \qquad (1)$$

where $P_{Eth,t}$ is the ethanol price in month t, $P_{Mol,t}$ is the molasses-based ethanol price in month t, $P_{Css,t}$ is the cassava-based ethanol price in month t, $Q_{Mol,t-2}$ is the molasses-based ethanol production quantity in month t-2, $Q_{Css,t-2}$ is the cassava-based ethanol production quantity in month t-2, and $Q_{Total,t-2}$ is the total ethanol production quantity in month t-2 (Ministry of Energy. Energy Policy and Planning Office [EPPO], 2009). Further, in 2012, the new ethanol price formula was defined (Ministry of Energy. EPPO, 2012b) by

$$P_{Eth,t} = (0.62 \times P_{Mol,t}) + (0.38 \times P_{Css,t}). \qquad (2)$$

If so, the ethanol price highly correlates to the prices of its feedstocks (molasses and cassava), given by the proportion of 0.62:0.38.

2.3.3 Relationship between Ethanol and Gasoline

In analyzing literature, Eidman (2005), O'Brien and Woolverton (2009), and Pokrivcak and Rajcaniova (2011) found that the price of ethanol has a robust positive correlation with the price of gasoline. Similarly, Bryant, Higgins, Outlaw and Richardson (2006) discovered a cointegrating relationship between the ethanol and gasoline price in the U.S. Besides, Duffield, Vedenov and Wetzstein (2006) applied a continuous time option pricing method to examine the decision threshold of switching from gasoline to ethanol and revealed that (1) blending ethanol into gasoline leads to the lower volatility of gasoline price, and (2) consumers switch from gasoline to gasohol E10 and E85. In addition, Elobeid and Tokgoz (2007) exposed that the impacts of an increase in gasoline price on ethanol in the U.S. and Brazil are quite different. In the U.S., vehicles use either gasoline or gasohol E10, so ethanol consumption drops because of a decrease in gasohol E10 consumption. In contrast, most vehicles in Brazil consume gasohol E75, and the number of flex-fuel vehicles enormously rise, so an increase in gasoline price raises ethanol consumption. It indicates that vehicle specifications are the significance factor of complementary and substitute relationships between ethanol and gasoline. Besides, Du and Hayes (2008) examined the effects of ethanol on gasoline in the U.S. and disclosed that (1) an increase in ethanol consumption causes a decrease in gasoline price, (2) ethanol can significantly substitute for gasoline, and (3) the supply of ethanol significantly negative affects the price of gasoline. Identical to Drabik (2011), an increase in ethanol production will lower gasoline price. Nevertheless, Chumnong Sorapipatana and Suthamma Yoosin (2007) investigated the production cost of ethanol for gasoline substitution in Thailand and concluded that the key factors to make ethanol competitive with gasoline are the prices of sugarcane and cassava.

Particularly, De Gorter and Just (2008) described the relationship between the prices of ethanol and gasoline that the perfect substitutes occur at the same prices of ethanol (P_E) and gasoline (P_G), but one gallon of ethanol has a lower energy content than one gallon of gasoline, for example, a vehicle can travel 0.7 miles per gallon of ethanol, but one mile per gallon of gasoline. Thus, in terms of energy, P_E is equal to kP_G, where k is a constant (0.70) obtained from the ratio of miles per gallon of ethanol to miles per gallon of gasoline, so the ethanol price becomes 70 percent of the gasoline price. De Gorter and Just (2009) also explicated the conceptual framework of demand and supply curve of an ethanol-gasoline mixture (see figure 2.1). In a competitive market, the domestic supply curves of ethanol and gasoline are S_E and S_G, respectively. The domestic demand curve of the ethanol-gasoline mixture is D_F. Ethanol and gasoline

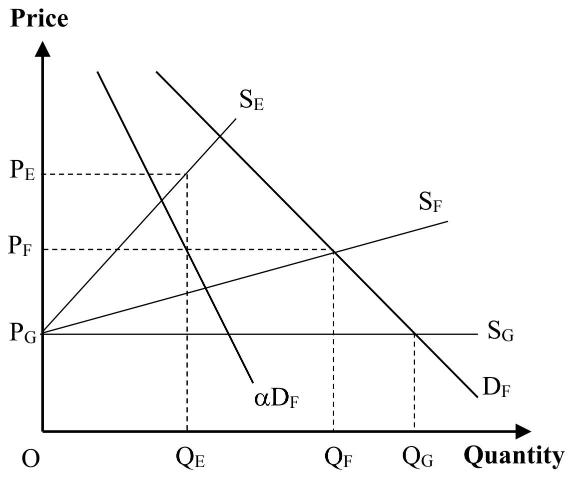


Figure 2.1 Demand and Supply of Ethanol-Gasoline Mixture
Source: De Gorter and Just, 2009: 740.

are assumed to be perfect substitutes. And for ease of exposition, the intercept of the ethanol supply curve is arbitrarily set to coincide with the gasoline price (P_G), and also the intercept of the ethanol-gasoline mixture supply curve (S_F) follows the S_E curve in the proportion of α (the proportion of ethanol in an ethanol-gasoline mixture), which drives up the price of ethanol (P_E), causing the deviation of the market prices of ethanol and gasoline. After the ethanol-gasoline mixture is introduced into the market, the supply curve of the ethanol-gasoline mixture becomes S_F, while the equilibrium price and demand of the ethanol-gasoline mixture are at P_F and Q_F, respectively. The price of the ethanol-gasoline mixture (P_F) is given by the weighted average price of ethanol and gasoline, where the weights are formed by the proportion of ethanol (α) in the ethanol-gasoline mixture. That is,

$$P_F = \alpha P_E + (1 - \alpha)\, P_G. \tag{3}$$

The market equilibrium price (P_F) is determined by allowing the supply of the ethanol-gasoline mixture equal to its demand. And the deviation of the ethanol-gasoline mixture supply curve (S_F) is determined by the component supply curves S_E and S_G. The equilibrium condition for P_F is defined as

$$S_F(P_F) = D_F(P_F) \tag{4}$$

and the equilibrium price of ethanol (P_E) can be derived from

$$S_E(P_E) = \alpha D_F(P_F). \tag{5}$$

Consequently, evaluating the αD_F curve at price P_F can obtain the ethanol quantity (Q_E), and then appraising the ethanol supply curve (S_E) at the quantity (Q_E) can attain the equilibrium market price of ethanol (P_E).

2.3.4 Ethanol Feedstocks

Thailand, as the supplier of ethanol feedstocks (sugarcane, molasses, and cassava), is the leading exporter of sugar and molasses, and also the largest sugarcane producer in Southeast Asia. Yet, the sugar supply tremendously exceeds domestic demand. So, a portion of the sugarcane is allocated to ethanol production with the expected growth of ethanol production capacity. In 2006, molasses was anticipated to increase up to three million tons, while cassava production was 22.5 million tons and expected to rise in line with the expansion of cassava-based ethanol plants. In 2008, 90 percent of ethanol was produced from molasses, and ten percent from cassava (Maysa Kunasirirat, Ponnarong Prasertsri and Sakchai Preechajarn, 2007). In 2011, the ethanol production was 75 percent from molasses, 18 percent from cassava, and seven percent from sugarcane juice (Apichart Jongsakul, 2012). And in 2013, it became 66 percent (629 million liters) from molasses, 28 percent (263 million liters) from cassava, and six percent (57 million liters) from sugarcane juice (Apiradee Thammanomai, 2014). Above all, in 2014 it was anticipated to be 670 million liters from molasses and 30 percent from cassava. And in 2015, molasses-based ethanol was expected to be 720 million liters. In that case, molasses-based ethanol still dominates at 70-80 percent of fuel ethanol production in Thailand (Ponnarong Prasertsri, 2014).

2.4 The Oil Fund

As a fuel importer, Thailand cannot determine a domestic fuel price. The domestic fuel price is volatile in line with the world oil price. The Emergency Decree on Remedy and Prevention of Shortage of Fuel Oils, B.E. 2516 (1973) gave the Prime Minister authority to resolve and prevent the shortages of fuels and to maintain the retail prices of fuels in the country when the world oil price increases. The Prime Minister's Instruction 2/2003 defined key mechanisms to solve and prevent fuel shortages, including the establishment of the Committee on Energy Policy and the Oil Fund. The Oil Fund functions as an instrument to maintain the retail price levels of domestic fuels at the set ceiling in times by taxation and subsidy in accordance with the rates determined by the Executive Committee, which can minimize the impacts of world oil price fluctuations on the economy.

Nevertheless, taxation and subsidy on fuels via the Oil Fund distort the market prices. During an unceasingly increase in world oil price, diesel prices were subsidized, but gasoline prices were taxed. For this reason, it caused a widening gap between the prices of diesel and gasoline. Subsequently, the demand for diesel rose, and the consumers switched from gasoline to diesel vehicles. Diesel vehicles increased 9.3 percent for 2002-2003, 11.7 percent for 2003-2004, and 0.3 percent for 2004-2005. However, the diesel subsidy ended in July 2005, and then its consumption obviously fell. The gasoline consumption also dropped 5.3 percent in 2005, while liquefied petroleum gas (LPG) was permanently subsidized, which led to 8.2 percent growth of LPG consumption compared with 2.4 percent in 2003, and 1.4 percent in 2004. Moreover, during the first quarter of 2006, the gasoline and diesel consumption dropped 2.8 and 7.5 percent respectively, while the consumption of LPG increased 9.4 percent.

In that case, the oil fund subsidy on LPG caused its widespread use, especially in a transportation sector (Ministry of Energy. EPPO, 2008). The Oil Fund largely bore the financial burden of the fuel price subsidies, which was financed by short term bank loans. In 2005, the government permitted to issue oil bonds at attractive rates, which was anticipated to finance through the future fuel taxes, whereas the oil fund taxes on gasoline and diesel still rose. Yet, the government reduced the oil fund taxes on diesel from 2.50 to 0.95 baht per liter to lower the impacts of high prices of diesel on the economy. Consequently, the retail prices of diesel were below gasoline prices, though the ex-refinery prices of diesel were above that of gasoline (Bacon and Kojima, 2006).

Accordingly, the some obvious problems of stabilizing fuel prices via the Oil Fund were as follows: (1) the large scale and long period of the price rise caused the unmanageable short term financial cost of subsidies, and also an increase in borrowing to cover the deficit; and (2) the lower prices of diesel, in comparison with international diesel prices and domestic gasoline prices, led to an increase in diesel consumption and subsidy costs. Besides, during 2006 world oil price peaked and the Oil Fund still bore the huge financial burden, so the government had to accept the higher prices of fuels (Bacon and Kojima, 2006).

Therefore, taxation and subsidy via the Oil Fund are considered as the tool of the government to stabilize fuel prices. A number of studies have examined the roles of the Oil Fund and the pricing policies, for example, Thiraphong Vikitset (2014) studied the role of the Oil Fund as a fuel price stabilization instrument in the case of one way price stabilization. It was suggested as a method to stabilize oil prices in accordance with the initial intention of the Emergency Decree 1973, instead of cross subsidies.

2.5 Roles and Effects of Taxes and Subsidies

A tax is a fee levied on a taxpayer (an individual or legal entity) imposed by a government to finance government's activities, whereas a subsidy is a benefit given by a government to an economic sector (or institution, business, or individual) normally with the aim of promoting social and economic policy in the form of a cash payment or tax reduction. Therefore, plenty of literature examined taxation and subsidy in different aspects, countries, and periods of time. Hughes (1986) discovered that using a fuel tax as a method to achieve social or economic objectives is not suitable, but it should be set to lower energy consumption, which generates a negative externality, especially in a transportation sector. Besides, a general tax on petroleum products very slightly induces an economic loss, so it may be desirable as the method of increasing government revenue. Hope and Singh (1995) studied the energy prices in developing countries (Colombia, Ghana, Indonesia, Malaysia, Turkey, and Zimbabwe) and disclosed that an increase in energy prices impacts households in various income classes, depending on the energy share in the household and the price elasticity of demand. Also, the energy consumption greatly increases with income, so an increase in energy tax modestly affects the industries, which are flexible to substitute when energy prices rise, but it largely impacts nonpoor urban households; however, an increase in energy tax can significantly reduce the drain on public resources. Bacon (2001) proposed that goods which receive a larger share of budgets for the rich should be taxed more greatly, and goods which cause larger negative externalities should be taxed at higher rates to reduce their consumption and social detriment. Johansson and Schipper (1997) discovered that an increase in fuel taxes in 12 OECD countries causes a decrease in fuel consumption in the long run. Nonetheless, Hossain (2003) examined taxation on petroleum products in Nigeria, which exposed that most gasoline vehicles are owned by the richer and demand for gasoline is quite inelastic, so the government may impose a tax on gasoline by the consideration of equity and revenue.

In Thailand, Sompong Jirapapaisarn (2007) investigated the dominant factors of gasohol consumption for 2005-2007 and revealed that the pricing policy on gasohol influences consumer behavior. The consumers switch from gasoline (higher price) to gasohol (lower price), and the cross (gasoline) price elasticity of gasohol consumption is 6.52. In addition, Thiraphong Vikitset (2010) examined the retail pricing policy of gasoline and high speed diesel characterized by the cross price subsidy and the vehicle tax policy, for 2002-2005. The results indicate that the pricing policy causes the under consumption of gasoline and the over consumption of high speed diesel, which generate welfare losses in the form of consumer surplus. And the vehicle tax policy leads to the over consumption of gasoline and the under consumption of high speed diesel. However, the welfare losses are produced by the vehicle tax policy greater than by the pricing policy. Furthermore, Jirath Chenphuengpawn (2012) showed that the cross price subsidy between high speed diesel and biodiesel B5 generates the deadweight loss of 11,497 million baht within a four year period, and the highest deadweight loss arises in high speed diesel market.

In contrast to Thailand, Brunei, as a petroleum producer and exporter, highly subsidized the energy prices below the production cost, which had no change for over twenty years. The consumers did not recognize the true cost of energy and had little incentive to conserve energy, as well as the producers had no motivation to explore new petroleum reserves. Hence, the subsidy on energy prices causes the inefficient consumption of energy and also the welfare loss (Lawrey and Pillarisetti, 2011).

2.6 Demand and Supply Models of Fuels

2.6.1 Determinants of Fuel Demand

The fuel demand is typically influenced by several factors, such as fuel price, gross domestic product (GDP), taxes, population, income, and expectation. Dahl and Sterner (1990) exposed that income (*Y*) and price (*P*) are the dominant explanatory variables in determining demand. Consistently, Bacon and Kojima (2006) discovered that the two significant factors that impact demand for any goods consist of its own price and GDP. Numerous past studies applied price and income as explanatory variables to demand models such as Dahl (1993); Somsak Kitsamrej (1993); Samimi (1995); Cooper (2003); Basso and Oum (2007); Flood, Islam and Sterner (2007); Hagman and Tekin (2007); Sterner (2007); Hughes, Knittel and Sperling (2008); Faria and Santos (2012). Another popular alternative demand modeling is the presence of a vehicle stock (V) in the model. A simple vehicle model is given by

$$G = f(P, Y, V) \tag{6}$$

where *G* is fuel demand, *P* is fuel price, and *Y* is income. Similarly, Dahl and Sterner (1991) included vehicle efficiency presented by vehicle characteristics (*CHAR*) to capture the long run adjustment of the vehicle stock, as

$$G = f(P, Y, V, CHAR). \tag{7}$$

Espey (1998) compared previous findings with the variations caused by structural changes in the road transport sector. The results indicate that vehicle ownership is certainly a significant explanatory variable for the gasoline demand. If the vehicle ownership variable was excluded from the demand models, it would cause the higher values of price and income elasticities of gasoline demand. Sterner (2007) also mentioned that models which include vehicle numbers and characteristics contribute the intermediate value of price elasticity of gasoline demand. In addition, Braathen (2000) suggested that another way to capture the difference between the short and long run effects in the demand function is including more explanatory variables in the function, such as adding vehicle ownership in gasoline demand functions. Accordingly, Johansson and Schipper (1994) estimated the demand for car fuel in the long run using vehicle stock, mean fuel intensity, and distance driven per car separately as the functions of income, fuel price, and other variables in 9 OECD countries, focusing on the lagged endogenous model. Johansson and Schipper (1997) examined vehicle stock, fuel consumption per kilometer driven (fuel intensity), and average annual driving distance as the three most important determinants of fuel demand in 12 OECD countries, for 1973-1992. The results indicate that fuel intensity is an important factor affecting gasoline demand elasticity in the long run, and the total fuel consumption in the long run is impacted by the fuel taxes much greater than by the car ownership tax. Besides, Baltagi, Bresson, Griffin and Pirotte (2003) estimated dynamic gasoline demand models in French which the explanatory variables are composed of the gasoline price, income, the lagged consumption, and the number of cars per capita. Graham and Gleister (2004) focused on the demand elasticity of traffic, the costs of car ownership, and freight. The results show that the long run price elasticity of kilometers driven is -0.26 greater (in absolute value) than the elasticity of car trips (-0.19) because the consumers may adjust the average trip length. Pock (2007) exposed that the demand for gasoline is inelastic to its own price. The dynamic model is defined as

$$GAS_t = \alpha Y_t^{\gamma} PG_t^{\beta} CARG_t^{\delta} CARD_t^{\theta} GAS_{t-1}^{\lambda} \qquad (8)$$

where *GAS* is gasoline consumption per passenger car, *Y* is real income per capita, *PG* is real gasoline price, *CARG* is gasoline fueled passenger cars per drivers, and *CARD* is diesel fueled passenger cars per drivers. In addition, Thiraphong Vikitset (2010) examined the policies on gasoline and high speed diesel prices, and vehicle taxes in Thailand for 2002-2005 by modeling (in the log linear form) fuel consumption per vehicle as the function of real per capita income, real gasoline and diesel price, and the stocks of vehicles per capita.

2.6.2 Determinants of Fuel Supply

The fuel supply can be affected by many factors, such as fuel price, input price, technology, and the expectation of future price. In this case, Krichene (2007) analyzed world oil and gas markets by modeling the crude oil supply as

$$Q = f(P, ORSV, DUMO) \tag{9}$$

where *P* is crude oil price, *ORSV* is crude oil proven reserves, and *DUMO* is dummy variable for large changes in oil price. Also, the natural gas supply is defined by

$$G = f(PG, P, GRSV, DUMG) \tag{10}$$

where *PG* is natural gas price, *P* is nominal crude oil price, *GRSV* is natural gas proven reserves, and *DUMG* is dummy variable for large changes in natural gas price. Ardakani (2009) examined the effect of U.S. government policies on ethanol supply by modeling ethanol production as the function of ethanol price, domestic HFCS price, domestic corn price, national gas price, interest rate, corn oil price, DDGs price, gluten feed price, and gluten meal price. Ponce and Neumann (2014) studied the elasticity of natural gas supply in the U.S. by modeling natural gas supply as the function of natural gas price, the price of a substitute, working gas in storages, drilling activity, and the season of the year. Thiraphong Vikitset (2014) studied the role of the Oil Fund in Thailand and proposed the one way price stabilization for vehicle fuels to improve social welfare without the account deficit of the Oil Fund. The research models the supply of gasohol as the function of gasohol and ethanol prices. For example,

$$S_{E10\_91,t} = \beta_0 + \beta_1 P_{E10\_91,t} + \beta_2 P_{ETH,t} + \varepsilon_t \tag{11}$$

where S_{E10_91} is the supply of gasohol 91, P_{E10_91} is the price of gasohol 91, and P_{ETH} is the price of ethanol.

2.7 Proxy Variables of GDP

According to the macroeconomic theory, an increase in money supply leads to a lower interest rate, a rise in consumption, and the extension of borrowing, which correlate with the GDP growth. Numerous researches applied money supply as a proxy variable of GDP, income, or output. In different countries and periods of study, the appropriate proxy variables might be different, such as narrow money supply (M1) and broad money supply (M2). This conflicted evidence is exposed in Ramachandra (1986), Miller (1991), Friedman and Kuttner (1992), Stock and Watson (1993), Breuer and Lippert (1996), Jamie (2005), Herwartz and Reimers (2006), Abdul Majid (2007), Korap and Saatcioglu (2008). These studies disclose the relationship between money supply and economic activities in theoretical and empirical aspects in developed and developing countries for different sample periods. In this case, Sims (1972) examined the causal relationship between money and income, in the U.S. and found unidirectional causality from money to income. In contrast, Goodhart, Gowland and Williams (1976) confirmed unidirectional causality from income to money, in the UK. Similarly, Abbas and Husain (2006) found unidirectional causality from income to money, in Pakistan. Moreover, King and Levine (1993) revealed that the level of financial development is the good predictor of economic growth in over 80 countries. However, Bannett and Barth (1974) discovered bidirectional causality between money and income, in Canada. Dyreyes, Starleaf and Wang (1980) detected bidirectional causality between money and income, in the U.S. Lee and Li (1983) discerned bidirectional causality between money and income, in Singapore. K. Joshi and S. Joshi (1985) found bidirectional causality between money and income, in India. And, Abbas (1991) revealed bidirectional causality between money and income, in Pakistan, Malaysia, and Thailand. Nevertheless, Morimune and Zhao (1997) disclosed that nominal income caused money, but not vice versa, in Japan for 1960-1990. In addition, Feldstein and Stock (1994) indicated that causal relationship from M2 to nominal GDP growth may exist. Miyao (2004) argued that M2 cannot predict future economic activity from the late 1990s. Above all, Macri and Sinha (2001) found (1) bidirectional causality relationship between income and financial variables, in India and Malaysia, (2) unidirectional causality from financial variables to income, in Japan and Thailand, and (3) unidirectional causality from income to financial variables, in Korea, Pakistan, and the Philippines. Furthermore, Hossain (2005) showed that M1 or M2 exists cointegration with real permanent income, in Indonesia. Similar to Tsen (2005) that found the cointegration of financial development and economic growth, in Malaysia, which indicates that the financial development significantly impacts economic growth. Conversely, Hassan and Islam (2005) did not find any causal relationship between financial development and GDP, in Bangladesh. In particular, Jirawan Jitthavech, Thiraphong Vikitset, Vichit Lorchirachoonkul and Watchareeporn Chaimongkol (2006) examined the relationship between M1 and GDP using Thailand's data for 1991-2003 and discovered that M1 can be applied as a proxy variable of GDP. Likewise, Thiraphong Vikitset (2008, 2010) confirmed a strong relationship between M1 and GDP, in Thailand, and also applied M1 as a proxy variable of GDP to the studies. Besides, Abdul Majid (2007) found bidirectional causality between output and monetary aggregates, M2, and M3, in Malaysia. Soukhakian (2007) indicated the long run equilibrium relationship between financial development and GDP, in Japan, which M2 is a proxy variable of financial development. Benar, Kahyalar and Katircioglu (2007) revealed the long run equilibrium relationship between financial development and real income growth, which indicates bidirectional causality between M2 and real income growth, in India. Yucel (2009) exposed bidirectional causality between financial development and GDP, in Turkey. Jenkins and Katircioglu (2010) found that GDP growth stimulates the long run money supply, in Cyprus. Chimobi (2010) revealed the long run cointegration between economic growth and financial development, in Nigeria, and the causality from economic growth to financial development, but not vice versa. Further, Chimobi and Ugwuanyi (2010) demonstrated that M2 has a strong causal effect on the real output, in Nigeria. Hatekar, Kumar and Sharma (2010) indicated that output does not cause money supply. But, Mehrara and Musai (2011) presented the strong unidirectional effect of prices and GDP on money supply, in Iran. Abdulkheir (2013) found the long run cointegration between M2 and its explanatory variables (interest rate, real exchange rate, and inflation rate), but not between M2 and real GDP, in Saudi Arabia for 1987-2009. In Thailand, monthly M1 based on available evidence was applied as a possible proxy variable of monthly GDP in many studies, such as Sompong Jirapapaisarn (2007), Thiraphong Vikitset (2008, 2010, 2014) and Jirath Chenphuengpawn (2012).

2.8 Consideration of Demand and Supply Models

The dissertation generates the models of fuel consumption and ethanol supply to capture the price elasticity values for deadweight loss estimates. The essential variables that affect the fuel consumption are selected, including the prices of fuels and narrow money supply (a possible proxy variable of GDP). Thus, the consumption function of fuel *x* is defined as

$$C_x = f(M1, P_x, P_s, P_c) \tag{12}$$

where *M1* is narrow money supply, P_x is the price of fuel x, P_s is the price of substitute fuel, and P_c is the price of complementary fuel. Likewise, the ethanol supply (S_E) is impacted by the selected dominant factors, including the ethanol price (P_E) and the price of related fuels (P_r). So, the supply function of ethanol is given by

$$S_E = f(P_E, P_r). \tag{13}$$

Nonetheless, various econometric approaches for estimating price and income elasticities appear in plenty of literature. These are the essential guidance for the model selection in the dissertation.

With regard to the model selection, in static model, the price elasticity of gasoline demand is more elastic than the short run price elasticity in the dynamic model, but less elastic than the long run price elasticity in the dynamic model (Espey, 1998). For this reason, the elasticity value in a static model should be considered as the intermediate run (Dahl, 2012). A static demand model generally cannot capture the complex process of adaptation to changes in prices and income (Sterner, 2006). But, a dynamic model approach is the elegant combination of the short and long run elasticities within one equation that makes it popular (Dahl and Sterner, 1991). It is the popular technique for separating out the short and long run effects of demand elasticity by adding a lagged endogenous variable to the model. The advantages of a dynamic model consist of (1) a simple and flexible use with an intuitively appealing lag shape, (2) obtaining the short and long run estimates immediately and reasonably (Franzen, 1994; Johansson and Schipper, 1994), and (3) the easiest interpretation of the dominant elasticity values (Basso and Oum, 2007). Conversely, a disadvantage is a fairly restrictive shape for the lag constrained equally for all variables (Dahl, 1993). However, it is more appropriate than a static model for elasticity estimates in the long run (Braathen, 2000).

An early and widely used model representing dynamic behavior is the partial adjustment model (PAM). For example,

$$lnG_{it} = c + \alpha lnP_{it} + \beta lnY_{it} + \lambda lnG_{it-1} + \mu_{it} \qquad (14)$$

where G is fuel demand, P is fuel price, and Y is income. The short run elasticities are given by α and β. The long run elasticities are defined by $\alpha \div (1\text{-}\lambda)$ and $\beta \div (1\text{-}\lambda)$, where $(1\text{-}\lambda)$ is the speed of adjustment to the long run equilibrium. The PAM can capture the limited capability of consumers to adjust immediately to the long run equilibrium of consumption in response to price, income, population, and other factors (Dahl and Sterner, 1992; Al-faris, 1997; Banaszak, Chakravorty and Leung, 1999; Hensher, Li and Rose, 2010). The lagged endogenous model is easy to interpret and not over demanding in terms of data requirements, which the lag length represents the inertia of economic behavior (Bohi and Zimmerman, 1984).

Nevertheless, there is no a single right approach for modeling energy demand because an approach might be applicable in one setting, but inapplicable in another, such as a PAM, an autoregressive distributed lag (ARDL) model, and a structural time series model (Plourde and Ryan, 2008). Thus, Cuddington and Dagher (2011) proposed four popular approaches for dynamic modeling to estimate the short and long run price and income elasticity as follows: (a) the long run demand function with an AR(1) error process, (b) a PAM, (c) an Error Correction Model (ECM), and (d) an ARDL model. It was argued that the ARDL or corresponding ECM should be applied in practice rather than using the AR or PAM specifications. Nevertheless, price elasticity become more homogeneous when the different approaches are applied (Sterner, 1991).

Many studies in the past applied the dynamic model with a lagged endogenous variable to estimate elasticity, for example, Somsak Kitsamrej (1993) used both static and dynamic models to estimate demand for gasoline in Thailand as follows:

$$Q_{gt} = f\,(P_{gt},\ Y_t) \tag{15}$$

$$Q_{gt} = f\,(P_{gt},\ Y_t,\ Q_{gt-1}) \tag{16}$$

where Q_g is demand for gasoline, P_g is gasoline price, and Y is income. Likewise, Cooper (2003) applied the adaptation of Nerlove's partial adjustment model (Nerlove, 1956) to estimate the short and long run elasticities of demand in 23 countries such that

$$lnD_t = \alpha + \beta lnP_t + \gamma lnY_t + \delta lnD_{t-1} + \varepsilon_t \tag{17}$$

where D is oil demand, P is oil price, and Y is income. Similarly, Hagman and Tekin (2007) applied the Cooper (2003)'s model to examine oil dependency and effects on the oil demand of Peak Oil in 6 countries. Flood et al. (2007) studied the effect of politically determined tax levels on gasoline demand elasticity, using the dynamic model with a lagged endogenous variable. Jirath Chenphuengpawn (2012) applied a PAM to estimate the deadweight loss caused by the cross price subsidy between high speed diesel and biodiesel B5, in Thailand. Otherwise, Cernat-Gruici and Constantin (2010) studied the relationship between international oil prices (WTI and Brent) and international energy sector index (MSCI) applying cointegration tests and Vector Error Correction Models (VECMs). Supanee Harnphattananusorn (2012) investigated the relationship between real exchange rate and real oil price, in Thailand, using a cointegration test to capture the long run relationship, and a VECM to describe the short run relationship and the speed of adjustment to the long run equilibrium. The ECM is

$$\begin{aligned}\Delta REER_t = {} & \alpha(REER_{t-1}+\beta_1 IPI_{t-1}+\beta_2 CPI_{t-1}+\beta_3 ROIL_{t-1}+\gamma) \\ & +\lambda_1\Delta REER_{t-1}+\lambda_2\Delta REER_{t-2}+\lambda_3\Delta REER_{t-3}+\lambda_4\Delta IPI_{t-1} \\ & +\lambda_5\Delta IPI_{t-2}+\lambda_6\Delta IPI_{t-3}+\lambda_7\Delta CPI_{t-1}+\lambda_8\Delta CPI_{t-2}+\lambda_9\Delta CPI_{t-3} \\ & +\lambda_{10}\Delta ROIL_{t-1}+\lambda_{11}\Delta ROIL_{t-2}+\lambda_{12}\Delta ROIL_{t-3}\end{aligned} \tag{18}$$

where *REER* is real exchange rate, *IPI* is industrial production index, *CPI* is consumer price index, and *ROIL* is real oil price. Chervachidze, Nechayev, and Wheaton (2014) estimated supply elasticities in 68 US metropolitan statistical areas (MSA) housing with non-stationary data applying a VECM, which allows to distinguish between the short and long run elasticities, as

$$\Delta S_t = \alpha_0[S_{t-1} - (\beta_1 + \beta_2 P_{t-1})] + \sum_{i=1}^{n} \lambda_i \Delta P_{t-i} + \sum_{i=1}^{n} \alpha_i \Delta S_{t-i} \tag{19}$$

where *S* is the stock of housing, and *P* is house price. In addition, Hung-Pin (2014) investigated the short and long run relationship between renewable energy consumption (*RE*) and economic growth (*Y*) in nine OECD countries using the ARDL bounds testing approach of cointegration test and the VECM. The ECM of the ARDL model is expressed as

$$\Delta Y_t = \beta_1 + \sum_{i=1}^{m1} \theta_{1i} \Delta Y_{t-i} + \sum_{j=0}^{n1} \delta_{1j} \Delta RE_{t-j} + \gamma_1 Y_{t-1} + \gamma_2 RE_{t-1} + \mu_t. \tag{20}$$

Turning to the demand and supply models of ethanol, few researches investigated on these aspects, for example, Ardakani (2009) examined the effect of U.S. government policies on the ethanol market using an econometric model as

$$\begin{aligned} &\textit{Ethanol Production} = f\,(\textit{ethanol price, domestic HFCS price,} \\ &\quad \textit{domestic corn price, national gas price, interest rate, corn} \\ &\quad \textit{oil price, DDGs price, gluten feed price, gluten meal price).} \end{aligned} \tag{21}$$

The results indicate that corn is the major feedstock of ethanol, and domestic corn prices negatively affect the ethanol production. Faria and Santos (2012) estimated the price and income elasticities of gasoline and ethanol in the fuel market for light vehicles in Brazil, using spatial panel data models as

$$lnG_{it} = \beta_0 + \beta_1 lnP_{G(it)} + \beta_2 lnP_{E(it)} + \beta_3 lnGDP_{it} + \varepsilon_{it} \tag{22}$$

$$lnE_{it} = \beta_0 + \beta_1 lnP_{G(it)} + \beta_2 lnP_{E(it)} + \beta_3 lnGDP_{it} + \varepsilon_{it} \tag{23}$$

where G is the per capita consumption of gasoline, P_G is gasoline price, P_E is real ethanol price, *GDP* is per capita gross domestic product, and E is the per capita consumption of ethanol. As for the supply side, Krichene (2007) analyzed world oil and gas markets using ARDL models in the logarithm form. The crude oil supply function is given by

$$Q = f\,(P,\ ORSV,\ DUMO) \tag{24}$$

where P is crude oil price, *ORSV* is crude oil proven reserves, and *DUMO* is dummy variable for large changes in oil price. Likewise, the natural gas supply function is given by

$$G = f\,(PG,\ P,\ GRSV,\ DUMG) \tag{25}$$

where *PG* is natural gas price, P is nominal crude oil price, *GRSV* is natural gas proven reserves, and *DUMG* is dummy variable for large changes in natural gas price. Ponce and Neumann (2014) studied the elasticity of natural gas supply in the U.S. using an ARDL model (in the logarithm form) to obtain the short and long run elasticities. The natural gas supply function is defined by

$$q = f\,(PG,\ PS,\ S,\ D,\ season) \tag{26}$$

where *PG* is natural gas price, *PS* is the price of a substitute, S is working gas in storages, D is drilling activity, and *season* is the season of the year.

2.9 Review of Some Empirical Results of Estimates

A great quantity of literature investigated the demand elasticities of energy, crude oil, gasoline, or natural gas, but few studies focused on the demand and supply elasticities of gasohol, especially the supply elasticity. Anderson (2006) examined the demand for gasohol E85, in Minnesota (U.S.), impacted by the retail prices of gasohol E85 and gasoline, for 1997-2006. The results show that the price elasticity of gasohol

E85 demand is -13, and the cross (gasoline) price elasticity is 16. The demand for gasohol E85 is highly sensitive to the change in prices of gasohol E85 and gasoline, which implies that the small price changes induce the fuel switching between gasohol E85 and gasoline. Sompong Jirapapaisarn (2007) studied the demand for gasohol 95 in Thailand for 2005-2007 and found that the present demand for gasohol 95 is elastic to its own price lagged four months at -6.31. Besides, Santhiti Thongchuang and Srisuda Thungsuwan (2010) analyzed the price and cross price elasticity of gasohol E20 consumption in Thailand, for 2008-2009. The results indicate that gasohol E20 consumption is inelastic to its own price, the price of gasoline 91, and the price of gasoline 95 at -0.23, 0.07, and 0.09 respectively, but it is elastic to the prices of gasohol 91 and 95 at -1.15 and 1.31, respectively.

As for the elasticities of gasoline, Dahl and Sterner (1991) surveyed in the various studies on gasoline demand elasticities in different countries. The results indicate that the short and long run price elasticities of the gasoline demand become -0.24 and -0.80 on average, respectively. The long run income elasticity is greater than one, whereas the short run income elasticity is lower than one. Brons, Nijkamp, Pels and Rietveld (2008) used a meta-analysis to examine the price elasticities of gasoline estimated by 43 primary studies. The results show that the short run price elasticity values are between -1.36 and 0.37 (mean = -0.34) and the long run price elasticity values are between -2.04 and -0.12 (mean = -0.84).

Numerous researches investigated the demand and supply elasticities using U.S. data. For example, Dahl (1992) applied a cross section time series for 1970-1978 to a flow adjustment in log linear model. The model variables include the per capita gasoline consumption, the per capita income, and the per capita stock of vehicles. The results indicate that the demand for gasoline is inelastic to its own price, the income, and the vehicle stock at -0.2, 0.11, and 0.12 in the short run and -0.98, 0.50, and 0.57 in the long run, respectively. Likewise, Hausman and Newey (1993) compared the parametric and nonparametric regression models of the gasoline tax, for 1979-1981. The results show that the income and price elasticities are 0.37 and -0.80, respectively. Espey (1996, 1998) applied meta-analysis in different countries, for 1966-1997 covering 1929-1993. The results reveal that the short run price elasticity of gasoline in the U.S. is -0.26 on average lower than that in other western countries, and the long run price elasticity is -0.58 on average. Surprisingly, Greening and Puller (1999) found that the price elasticity of gasoline in the short run is higher than that in the long run, for 1980-1990. However, Dahl (2007) discovered that the price elasticities of gasoline demand are inelastic at -0.3 for 1975-1980 and -0.04 for 2001-2006. Hughes et al. (2008) applied a PAM and a basic model in the log linear form to examine the short run price and income elasticities using the monthly data of per capita gasoline consumption, personal disposable income, and the retail price of gasoline. The results indicate that the short run price elasticities of gasoline demand for 2001-2006 are more inelastic than that for 1975-1980, which range from -0.034 to -0.077 and -0.24 to -0.34, respectively. Graham, Noland and Wadud (2010) examined the household gasoline demand for 1997-2002 and exposed that (1) the price and income elasticities of gasoline are influenced by the number of vehicles owned, the number of wage earners, and the household location; (2) the households with multiple vehicles are more price elastic; (3) the multiple wage earners have higher price elasticity than the single wage earners; and (4) the rural households consume more gasoline, but less respond to the price change. Levin, Lewis and Wolak (2013) estimated the price elasticities of gasoline demand in 243 U.S. cities, for 2006-2009. The results show that the price elasticities range from -0.29 to -0.61, besides adding more aggregated data causes more inelastic estimates of gasoline demand.

In Europe, Guntensperger and Wasserfallen (1988) applied a partial equilibrium model to explain the gasoline demand and the total stock of motor vehicles in Switzerland for 1962-1985, using annual data. The results indicate that the short run price elasticities of gasoline demand are between -0.3 and -0.45. Additionally, Schleiniger (1995) approximated the demand for gasoline in Switzerland for 1967-1994 using cointegration techniques and found that the price of gasoline does not affect the demand. Banfi, Filippini and Hunt (2005) studied the demand for gasoline in the Swiss border regions, and revealed that the price elasticity of gasoline demand is -1.5 greater than all other estimates because the vehicles can easily be refueled in a neighboring country. However, Axhausen and Erath (2010) surveyed in Switzerland and found that gasoline price elasticities are between -0.04 and -0.17 in the short run and -0.34 in the long run. Moreover, Baranzini and Weber (2013) applied cointegration techniques, in Switzerland for 1970-2008, and exposed that price elasticities of gasoline demand are

-0.09 in the short run and -0.3 in the long run. Sterner (1991) disclosed that gasoline price elasticities in Northern Europe are -0.2 in the short run and -1.28 in the long run, higher than that in Europe as a whole (-0.15 in the short run and -1.24 in the long run). Sterner (2007) examined the effects of gasoline tax on global carbon emissions in European countries and discovered that the gasoline consumption is highly elastic to price in the long run, but quite inelastic in the short run, implying that the gasoline tax restrain the demand growth. Baltagi et al. (2003) estimated dynamic gasoline demand models in French and revealed that the demand is inelastic to price. Christina and Matthew (2014) examined the gasoline demand impacted by GDP, gasoline price, and registered vehicle quantity in six main districts of Greece for 2006-2012. The results indicate that the price and income elasticities of demand for unleaded 100 RON are quite high, while the income elasticity of demand for unleaded 95 RON is moderate.

In African, Hossain (2003) studied taxation and pricing of petroleum products in Nigeria and exposed that the demand for gasoline is quite inelastic. Similarly, Omisakin and Oyinlola (2012) investigated the cointegration status of gasoline demand models in Nigeria for 1977-2008 and detected that the gasoline demand is inelastic to price and income, in the short and long run.

In Asia, Akhani (1999) estimated the demand for transportation fuels in the transportation sector in Iran for 1974-1995 and revealed that income and price elasticities of gasoline demand are very low. Eghdami and Khataie (2006) found a weak relationship between the demand and the price of gasoline in Iran for 1980-2002. Ahmadian, Chitnis and Hunt (2007) also found that the demand for gasoline is inelastic to price in the short and long run, for 1968-2002 in Iran. In contrast, Ahmadi and Mehrara (2011) found that the price elasticity of gasoline demand is -1.01, for 1997-2008 in Iran.

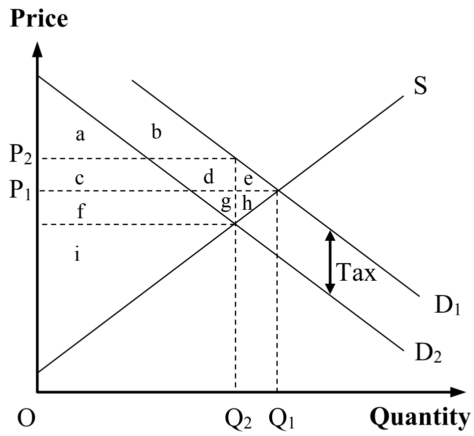
In Thailand, Ratana Sivanunwong (1987) estimated gasoline demand for 1979-1985 (using quarterly data) and revealed that the demand for gasoline is inelastic to price similar to Somsak Kitsamrej (1993) using annual data for 1970-1989. Naowarat Pathawintharanon (1995) studied the demand for gasoline and found that the price elasticities of demand are -0.13 and -0.96 in the short and long run, respectively.

Few researches examined the supply price elasticity of gasoline. However, Ahmadian, Chitnis and Hunt (2007) described about the gasoline supply in Iran that the petroleum product industry is operated by public refinery companies and the gasoline price is determined yearly by Iranian government. The government also controls the crude oil quantity for producing petroleum products. Therefore, the gasoline supply in Iran is assumed to be perfectly inelastic to price. In contrast, Thiraphong Vikitset (2008, 2010) revealed that the supplies of gasoline and high speed diesel in Thailand are perfectly elastic because the ex-refinery prices depend on the import parity principle. As Singapore is the fuel supplier of Thailand, the import prices of gasoline and high speed diesel are equal to the Singapore ex-refinery prices plus the costs of transportation, insurance, and quality adjustment. Besides, Thailand, a relatively small country, can import all required fuels at the import prices without the effects on world oil prices. And, Thai government determines the local ex-refinery prices of gasoline and high speed diesel equal to the import prices. Under these circumstances, the supplies of gasoline and high speed diesel in Thailand can be considered as perfectly elastic at local ex-refinery prices.

Very few studies discussed on the supply of ethanol. For example, Elobeid and Tokgoz (2007) found that a decrease in the world ethanol supply causes an increase in the world ethanol price. Besides, McPhail (2011) studied the ethanol demand and supply shocks in the U.S. using a structural VAR model and discovered that the expansion of ethanol supply does not influence the real oil prices.

2.10 Estimate of Deadweight Losses

Taxation and subsidy on prices theoretically create a price distortion and a deadweight loss. The deadweight loss arises when prices are not equal to the marginal costs. Regarding a fuel tax, a fuel becomes less attractive after imposing the tax. The consumers reduce the fuel consumption, and then the deadweight loss occurs. The deadweight loss from the fuel tax (subsidy) relies on the amount of the fuel tax (subsidy) combined with the changes of consumption and production quantities of the fuel. Thus, the deadweight losses from taxation and subsidy on fuels are illustrated in Figure 2.2 and 2.3 respectively.



Original

Consumer Surplus = a + b + c + d + e

Producer Surplus = f + g +h + i

Total Surplus = a + b + c + d + e + f + g + h + i

After Taxation

Consumer Surplus = a + b

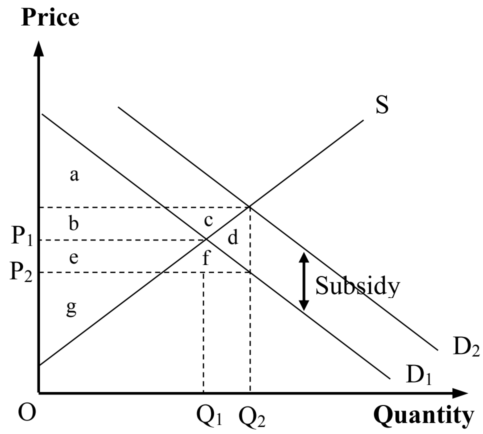
Producer Surplus = i

Government Surplus = c + d + f + g

Total Surplus = a + b + c + d + f + g + i

Deadweight Loss = e + h

Figure 2.2 Deadweight Loss from Taxation



Original

Consumer Surplus = a + b

Producer Surplus = e + g

Total Surplus = a + b + e + g

After Subsidy

Consumer Surplus = a + b + e + f

Producer Surplus = b + c + e + g

Government Surplus = – (b + c + d + e + f)

Total Surplus = a + b – d + e + g

Deadweight Loss = d

Figure 2.3 Deadweight Loss from Subsidy

The dissertation estimates the deadweight losses via the losses in consumer and producer surplus consistent with lots of literature. This approach is employed through the demand and supply elasticity estimates. Willig (1976) investigated the consumer surplus controversy and inferred that the Marshallian measure of consumer surplus is the very good approximation of appropriate welfare measure. However, Hausman (1981), Rosen and Small (1981) argued that the approximation may often do well for the consumer surplus measure, but do poorly in the measure of deadweight loss. Varian (1982, 1983) proposed a nonparametric model as an alternative method based on the revealed preference ideas of Samuelson (1948) and Afriat (1967, 1973), however it can only estimate the upper and lower bounds on the welfare measures. Moreover, Vartia (1983) suggested a variety of numerical algorithms to estimate consumer surplus and deadweight loss, which can be applied to a wider range of situations. Larsen and Shah (1992) used a range of price elasticities to estimate the welfare losses caused by the world fossil price subsidies and global carbon emissions. In addition, Hausman and Newey (1993) compared the parametric and nonparametric regression models and created demand curves to estimate the consumer surpluses and the deadweight losses caused by the gasoline tax in the U.S. The results indicate that the deadweight losses estimated by both models are totally different. Goolsbee (2006) also used the consumer and producer surplus approach to estimate the deadweight loss of taxation on broadband internet access in the U.S. Ahmadian, Chitnis and Hunt (2007) discovered the impact of gasoline pricing policy on social welfare through a structural time series model in Iran during 1968-2002, and also estimated the changes in social welfare affected by the high price of gasoline in 2003 and 2004. Depro, Jones, Patil, Tom and Wood (2007) estimated the welfare effects of controlling toxic air pollutants in the gasoline distribution industry area by means of a consumer and producer surplus approach via the price elasticities of demand and supply. In the same way, Jirath Chenphuengpawn (2012) evaluated the economic losses caused by the cross price subsidy between high speed diesel and biodiesel B5 in Thailand, applying the consumer and producer surplus through the demand and supply price elasticities. In particular, Thiraphong Vikitset (2014) examined the role of the Oil Fund in Thailand and proposed the one way price stabilization for vehicle fuels that aims to improve social welfare without the Oil Fund's account deficit. The one way price stabilization is executed using a consumer and producer surplus approach by modeling demand and supply equations. The demand and supply models with monthly data in the case of gasohol 91, for instance, are defined by

$$D_{E10\_91,\,t} = \alpha_0 + \alpha_1 P_{E10\_91,\,t} + \alpha_2 P_{BEN91,\,t} + \alpha_3 M1_t + \varepsilon_t \qquad (27)$$

$$S_{E10\_91,\,t} = \beta_0 + \beta_1 P_{E10\_91,\,t} + \beta_2 P_{ETH,\,t} + \varepsilon_t \qquad (28)$$

where D_{E10_91} is the demand for gasohol 91, P_{E10_91} is the price of gasohol 91, P_{BEN91} is the price of gasoline, $M1$ is narrow money supply, S_{E10_91} is gasohol 91 supply, and P_{ETH} is the price of ethanol.

2.11 Retail Price Structure of Fuels

Since the deregulation of oil price in Thailand began in 1991, the government has manipulated the retail fuel price structure via taxation, such as oil fund tax and energy conservation promotion fund tax. The rates of municipal tax, excise tax, and energy conservation promotion fund tax have not changed for many years, so the government controls the retail prices of fuels through the Oil Fund's taxation.

Table 2.1 Retail Price Structure of Fuels in Bangkok (1 October 2012)

(Unit: baht/liter)

	Gasoline 91	Gasoline 95	Gasohol 91	Gasohol 95	Gasohol E20	Gasohol E85
(1) Ex-refinery Gate Price	25.29	25.72	25.11	25.32	24.84	20.83
(2) Excise Tax (T_1)	7.00	7.00	6.30	6.30	5.60	1.05
(3) Municipal Tax (T_2)	0.70	0.70	0.63	0.63	0.56	0.10
(4) Oil Fund Tax	6.10	7.40	-0.60	1.70	-0.90	-11.80
(5) Energy Conservation Promotion Fund Tax	0.25	0.25	0.25	0.25	0.25	0.25
(6) Wholesale Price (1)+(2)+(3)+(4)+(5)	39.34	41.07	31.69	34.20	30.35	10.44
(7) VAT_1	2.75	2.88	2.22	2.39	2.12	0.73
(8) Wholesale Price + VAT_1	42.09	43.95	33.90	36.60	32.47	11.17
(9) Marketing Margin	1.46	3.69	1.75	1.53	2.16	10.38
(10) VAT_2	0.10	0.26	0.12	0.11	0.15	0.73
(11) Retail Price (8)+(9)+(10)	43.65	47.90	35.78	38.23	34.78	22.28
(12) Economic Cost (1)+(5)+(9)	26.99	29.67	27.11	27.10	27.24	31.47

Source: Ministry of Energy. EPPO, 2012a.

Note: VAT_1 is value added tax 1 and VAT_2 is value added tax 2

Accordingly, the retail price structure of fuels is exhibited in Table 2.1, which can be derived as follows:

Ex-refinery gate price = Crude oil price + Cross refining margin

Wholesale price = Ex-refinery gate price + Excise tax + Municipal tax + Oil fund tax + Energy conservation promotion fund tax

Marketing margin = Storage costs + Transportation costs + Marketing costs + Retail margin

Retail price = Wholesale price + VAT_1 *+ Marketing margin +* VAT_2

2.12 Conceptual Framework

Thai government establishes the Oil Fund to stabilize the domestic fuel price at a set ceiling in times by means of taxation and subsidy. The Oil Fund subsidizes the domestic fuel price when the world oil price upsurge, and imposes tax when the domestic fuel price drops below the set ceiling price. On the other hand, the alternative energy development plan is one of the government policies that aims to reduce oil imports and build energy security. Thus, gasohol consumption is stimulated through the pricing policies, which targets to replace gasoline. Theoretically, a decrease in price of gasohol encourages the consumers to use more gasohol and reduce gasoline, known as substitution effects. However, the gasohol usage promotion by taxation and subsidy generates a price distortion and market inefficiency.

In that case, the dissertation examines the impacts of the pricing policies (taxation and subsidy via the Oil Fund) on gasohol consumption concerning market efficiency. The econometric approaches are utilized to examine the cointegrating relationship between gasohol consumption and the dominant variables. The VECMs are estimated to describe the short run dynamics and the speed of adjustment of cointegrated variables towards their equilibrium values. In the models, gasohol consumption is influenced by its own price, the prices of substitute fuels, and money supply M1 (a proxy variable of GDP). Moreover, the supply of gasohol is determined by the combination of ethanol and gasoline supplies (De Gorter and Just, 2009). As ethanol is a feedstock of gasohol, the supply of ethanol depends not only on its own price, but also on the prices of gasohol and gasoline due to the expectation of future ethanol price. An increase in the price of gasohol will encourage ethanol producers to expect a profit of an increasing price of ethanol in the future. So, the ethanol firms desire to increase the supply to serve the increasing production volume of gasohol. In contrast, an increase in gasoline price (an input cost of gasohol) causes the lower production volume of gasohol. The ethanol firms anticipate that the ethanol price trends to reduce, so the firms prefer to decrease the ethanol production.

Turning to the models, the long run price and income elasticities are given by the normalized cointegrating coefficients, while the short run price and income elasticities are derived from the ECMs. The deadweight losses in gasohol consumption can be approximated using a consumer and producer surplus method. Eventually, the market efficiency of gasohol consumption could be perceived and pricing policy options could be proposed. Under these circumstances, the conceptual framework is illustrated as Figure 2.4.

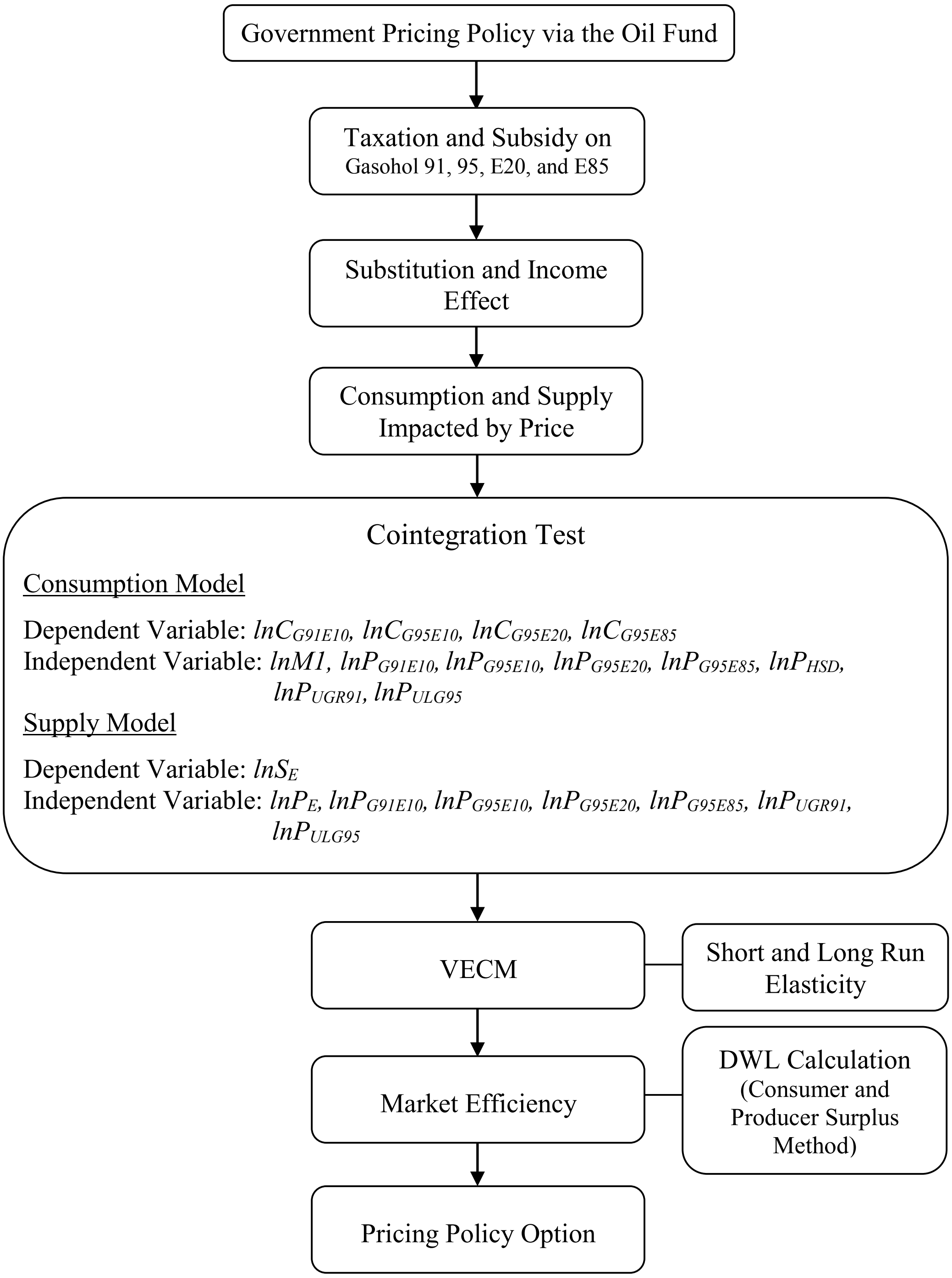


Figure 2.4 Conceptual Framework

CHAPTER 3

OIL FUND TAX POLICIES ON GASOHOL

3.1 Fuel Consumption and Oil Fund Taxes in the Past

Table 3.1 Fuel Consumption

(Unit: million liter)

Year	Gasohol 91	Gasohol 95	Gasohol E20	Gasohol E85	Gasoline 91	Gasoline 95	HSD	Total
2004	-	59.62	-	-	4631.25	2969.80	19535.60	27196.26
	-	*0.22%*	-	-	*17.03%*	*10.92%*	*71.83%*	*100%*
2005	29.20	645.75	-	-	4332.87	2240.29	19509.97	26758.06
	0.11%	*2.41%*	-	-	*16.19%*	*8.37%*	*72.91%*	*100%*
2006	94.48	1184.82	-	-	4464.37	1471.46	18213.76	25428.89
	0.37%	*4.66%*	-	-	*17.56%*	*5.79%*	*71.63%*	*100%*
2007	244.25	1518.51	-	-	4467.32	1106.70	18046.82	25383.61
	0.96%	*5.98%*	-	-	*17.60%*	*4.36%*	*71.10%*	*100%*
2008	923.50	2439.18	29.03	-	3387.93	340.73	13572.29	20692.66
	4.46%	*11.79%*	*0.14%*	-	*16.37%*	*1.65%*	*65.59%*	*100%*
2009	1414.53	2972.11	83.35	0.25	2877.02	177.10	9980.31	17504.67
	8.08%	*16.98%*	*0.48%*	*0.001%*	*16.44%*	*1.01%*	*57.02%*	*100%*
2010	1551.62	2691.43	137.35	2.11	2957.57	76.61	11049.09	18465.78
	8.40%	*14.58%*	*0.74%*	*0.01%*	*16.02%*	*0.41%*	*59.84%*	*100%*
2011	1859.84	2121.94	221.65	9.10	3077.01	41.62	18070.05	25401.19
	7.32%	*8.35%*	*0.87%*	*0.04%*	*12.11%*	*0.16%*	*71.14%*	*100%*
2012	2120.87	1931.46	366.65	35.74	3208.04	42.19	20021.82	27726.77
	7.65%	*6.97%*	*1.32%*	*0.13%*	*11.57%*	*0.15%*	*72.21%*	*100%*
2013	3337.03	3029.57	962.73	139.84	108.77	616.22	20404.53	28598.68
	11.67%	*10.59%*	*3.37%*	*0.49%*	*0.38%*	*2.15%*	*71.35%*	*100%*
Total	**11575.32**	**18594.38**	**1800.76**	**187.03**	**33512.14**	**9082.71**	**168404.22**	**243156.56**
	4.76%	***7.65%***	***0.74%***	***0.08%***	***13.78%***	***3.74%***	***69.26%***	***100%***

Source: Ministry of Energy. Department of Energy Business [DOEB], 2013.
Note: The Data are Calculated Using Daily Consumption Obtained

Fuel consumption ratios in Thailand for 2004-2013 are exhibited in Table 3.1. It indicates that the consumption of gasohol 95 and 91 are the third and fourth highest levels, respectively. In contrast, gasohol E20 and E85 are consumed considerably smaller than the other fuels. In particular, the consumption of gasoline 95, gasohol 91, and gasohol 95 improve in 2013 after the sell volume of gasoline 91 drops due to the promotion policy of gasohol consumption and the termination of gasoline 91. Obviously, gasohol consumption trends to escalate in the future.

Table 3.2 Percentages of Oil Fund Tax Value of Fuels

(Unit: million baht)

Year	Gasohol 91	Gasohol 95	Gasohol E20	Gasohol E85	Gasoline 91	Gasoline 95	HSD	Total
2004	-	13.82	-	-	-2867.10	-1225.60	-44504.32	-48583.20
	-	*0.03%*	-	-	*-5.90%*	*-2.52%*	*-91.60%*	*-100.00%*
2005	4.67	118.84	-	-	4415.96	2677.58	-20464.91	-13247.85
	0.04%	*0.90%*	-	-	*33.33%*	*20.21%*	*-154.48%*	*-100.00%*
2006	81.65	1000.57	-	-	11229.22	3953.26	27117.51	43382.21
	0.19%	*2.31%*	-	-	*25.88%*	*9.11%*	*62.51%*	*100.00%*
2007	87.65	1199.08	-	-	15043.06	4026.66	25207.46	45563.90
	0.19%	*2.63%*	-	-	*33.02%*	*8.84%*	*55.32%*	*100.00%*
2008	438.36	2136.94	-5.11	-	11093.86	1247.50	4618.36	19529.90
	2.24%	*10.94%*	*-0.03%*	-	*56.80%*	*6.39%*	*23.65%*	*100.00%*
2009	1691.71	5328.12	-61.29	-2.21	15246.80	1218.97	8080.74	31502.85
	5.37%	*16.91%*	*-0.19%*	*-0.01%*	*48.40%*	*3.87%*	*25.65%*	*100.00%*
2010	2212.91	7378.34	-55.66	-23.14	19665.93	574.54	7159.98	36912.91
	5.99%	*19.99%*	*-0.15%*	*-0.06%*	*53.28%*	*1.56%*	*19.40%*	*100.00%*
2011	-707.34	4273.59	-398.35	-122.78	12298.40	191.75	-10607.01	4928.26
	-14.35%	*86.72%*	*-8.08%*	*-2.49%*	*249.55%*	*3.89%*	*-215.23%*	*100.00%*
2012	337.35	3950.92	-521.28	-436.74	14936.37	212.44	14061.12	32540.18
	1.04%	*12.14%*	*-1.60%*	*-1.34%*	*45.90%*	*0.65%*	*43.21%*	*100.00%*
2013	4270.50	10371.12	-1036.79	-1604.12	769.81	5919.62	30769.72	49459.87
	8.63%	*20.97%*	*-2.10%*	*-3.24%*	*1.56%*	*11.97%*	*62.21%*	*100.00%*
Total	**8417.46**	**35771.35**	**-2078.47**	**-2188.99**	**101832.31**	**18796.73**	**41438.64**	**201989.03**
	4.17%	***17.71%***	***-1.03%***	***-1.08%***	***50.41%***	***9.31%***	***20.52%***	***100.00%***

Source: Ministry of Energy. DOEB, 2013; EPPO, 2014.

Note: The percentages of the oil fund tax value of fuels are derived from the oil fund tax value of each fuel divided by the summation of the oil fund tax value of all fuels (the percentage of the oil fund tax value of fuel x_i = the oil fund tax value of fuel $x_i \div \sum_{j=1}^{7}$ the oil fund tax value of fuel x_j; i = 1 to 7)

The percentages of the oil fund tax value of fuels in Thailand during 2004-2013 are exhibited in Table 3.2. It indicates the yearly oil fund tax values of fuels, which the Oil Fund levies as per liter of sell multiplied by the consumption quantity in a given period of time: $T_x = \sum_{i=1}^{12} (R_i \times C_i)$, where T_x is the yearly oil fund tax value of fuel x, R_i

is an oil fund tax rate in month i (baht per liter), and C_i is the consumption quantity in month i. Mainly, the oil fund tax values of gasohol 95 and 91 are levied at the third and fifth highest level respectively, and indicate the increasing trend of tax values. On the contrary, gasohol E20 and E85 are primarily subsidized and also show the rising trend of subsidy values. Furthermore, gasohol E85 are apparently subsidized the same amount as gasohol E20, but the per unit subsidy of gasohol E85 is noticeably higher. For this reason, the total subsidy values between gasohol E20 and E85 are not much different because of a large difference in per unit subsidy, though the consumption of gasohol E20 is substantially greater than that of gasohol E85.

3.2 Key Pricing Policies of the Oil Fund in the Past

The key pricing policies of the Oil Fund for 2009-2013 are exhibited in Table 3.3. These policies were enforced by the Committee on Energy Policy Administration (CEPA) Act in accordance with the energy situation at that time. Interestingly, the CEPA Act No. 121/2011 had reduced oil fund taxes on gasoline 91, gasoline 95, and high speed diesel to be zero baht per liter since 27 August 2011. However, these taxes had been levied again since 16 January 2012.

As far as a zero oil fund tax is concerned, the advantages, disadvantages, and implications of a zero oil fund tax are discussed in Section 6.2.

3.3 Present Policies of the EFAI toward the Oil Fund

In the fiscal year 2013-2014, as world energy prices greatly fluctuated, the Energy Fund Administration Institute (EFAI) monitored the world energy prices closely. The EFAI analyzed the Oil Fund’s situation which was inevitably affected by the volatility of the global fuel prices. However, the government managed domestic energy prices to moderate the burden of living costs, and the torments of people and entrepreneurs. Furthermore, the EFAI controlled the financial liquidity of the Oil Fund for the domestic fuel price stabilization, compliant with the government pricing policies.

Table 3.3 Key Pricing Policies of the Oil Fund for 2009-2013

Active Date	CEPA Act No.	Key Pricing Policy
14 August 2009	66/2009	**Gasoline 91:** raising taxes from 5.70 THB/L to 6.20 THB/L
		Gasoline 95: raising taxes from 7.00 THB/L to 7.50 THB/L
		HSD: reducing taxes from 1.70 THB/L to 0.53 THB/L
25 September 2009	79/2009	**Gasohol E85:** raising taxes from 7.13 THB/L to 10.3 THB/L
4 December 2009	152/2009	**Gasohol E20:** raising subsidies from 0.40 THB/L to 1.30 THB/L
		Gasohol E85: raising subsidies from 11.00 THB/L to 13.50 THB/L
17 December 2010	158/2010	**HSD:** switching from taxes 0.15 THB/L to subsidies 0.35 THB/L
12 April 2011	54/2011	**HSD:** raising subsidies from 5.90 THB/L to 6.40 THB/L
7 June 2011	67/2011	**HSD:** switching from subsidy 0.1645 THB/L to 0.3355 THB/L taxation
27 August 2011	121/2011	**Gasoline 91:** reducing taxes from 6.70 THB/L to zero
		Gasoline 95: reducing taxes from 7.5 THB/L to zero
		HSD: reducing taxes from 1.9 THB/L to zero
31 August 2011	123/2011	**Gasohol 91:** switching from taxes 0.10 THB/L to subsidies 1.40 THB/L
		Gasohol 95: reducing taxes from 2.40 THB/L to 1.40 THB/L
		Gasohol E20: raising subsidies from 1.30 THB/L to 2.80 THB/L
16 January 2012	8/2012	**Gasoline 91 and 95:** raising taxes from zero to 1.00 THB/L
		Gasohol 91: reducing subsidies from 1.40 THB/L to 0.40 THB/L
		Gasohol 95: raising taxes from 0.20 THB/L to 1.20 THB/L
		(taxes/subsidies will increase/decrease about 1.00 THB/L monthly)
16 February 2012	25/2012	**Gasohol E20:** reducing subsidies from 1.80 THB/L to 0.80 THB/L
		Gasohol E85: reducing subsidies from 13.60 THB/L to 12.60 THB/L
		HSD: taxes 0.60 THB/L
22 April 2012	87/2012	**Gasohol 91:** raising taxes from 1.40 THB/L to 1.70 THB/L
		Gasohol 95: raising taxes from 3.00 THB/L to 3.30 THB/L
		Gasohol E20: reducing subsidies from 0.50 THB/L to 0.20 THB/L
23 April 2012	88/2012	**Gasoline 91 and 95:** raising taxes from 6.70 THB/L to 7.10 THB/L
		HSD: raising taxes from 2.40 THB/L to 2.80 THB/L
18 August 2012	116/2012	**Gasohol 91:** switching from tax 1.30 THB/L to subsidy 1.50 THB/L
		Gasohol 95: reducing taxes from 1.30 THB/L to 0.80 THB/L
		Gasohol E20: raising subsidies from 1.30 THB/L to 1.80 THB/L
12 December 2012	173/2012	**Gasohol 91:** subsidy 0.50 THB/L
		Gasohol 95: raising taxes from 2.30 THB/L to 2.80 THB/L
5 March 2013	30/2013	**Gasoline 91:** raising taxes from 7.90 THB/L to 8.40 THB/L
		Gasoline 95: raising taxes from 9.20 THB/L to 9.70 THB/L
		Gasohol E85: reducing subsidies from 11.10 THB/L to 10.90 THB/L
		Gasohol E20: reducing subsidies from 0.90 THB/L to 0.40 THB/L
18 April 2013	48/2013	**Gasohol 91:** raising taxes from 1.90 THB/L to 2.40 THB/L
		Gasohol 95: raising taxes from 4.00 THB/L to 4.50 THB/L
24 April 2013	53/2013	**HSD:** raising taxes from 4.40 THB/L to 4.90 THB/L
29 May 2013	69/2013	**Gasohol E20:** raising subsidies from 0.40 THB/L to 0.90 THB/L
4 December 2013	158/2013	**HSD:** subsidies 0.60 THB/L

Source: Ministry of Energy. EPPO, 2013.

Recently, in the fiscal year 2015, the world oil prices have severely dropped since September 2014. For this reason, the government increases oil fund taxes on domestic fuel prices to improve the financial stability of the Oil Fund, and reforms the structures of domestic energy prices and excise tax rates. Besides, the roles of the Oil Fund are developed to eschew the financial burden, and to achieve the equality of fuel consumption for all sectors. In addition, the EFAI establishes agencies to accommodate an energy price structure reform policy, and to monitor the energy price situation and the financial liquidity of the Oil Fund (The Energy Fund Administration Institute [EFAI], 2015a).

Annual Strategic plans for the Oil Fund management 2015 (EFAI, 2015a) are aimed to:

1) Monitor and evaluate the situation of domestic and international energy prices, and domestic energy consumption, pertaining to the financial liquidity of the Oil Fund.
2) Assess the satisfaction of corporate governance and organizational development.
3) Manage the deposits, loans, and cash flow of the Oil Fund.
4) Compensate oil fund taxes for the fuel entrepreneurs within the time limit.
5) Improve the Oil Fund disbursement system for the projects approved by the CEPA.
6) Check the accuracy of disbursement, and the financial statements of the EFAI and Oil Fund.
7) Establish human resource agencies to deal with human resource activities.
8) Provide training and assessment for officers consecutively.

3.4 Oil Fund Taxes at Present and Trend

Oil fund taxes on fuels for 2014-2015 are illustrated in Figure 3.1. It indicates that, the oil fund tax rates of gasoline 95 are considerably higher than that of the other fuels. Likewise, the oil fund tax rates of gasohol 95 are greater than that of the other types of gasohol, whereas gasohol E85 is mainly subsidized at high rates. The linear trend lines show that the oil fund taxes and subsidies decline consistent with a decrease in world oil prices, which were lower than $80 a barrel during the fourth quarter of 2014 and below $40 a barrel during the third quarter of 2015 (as of NYMEX crude oil).

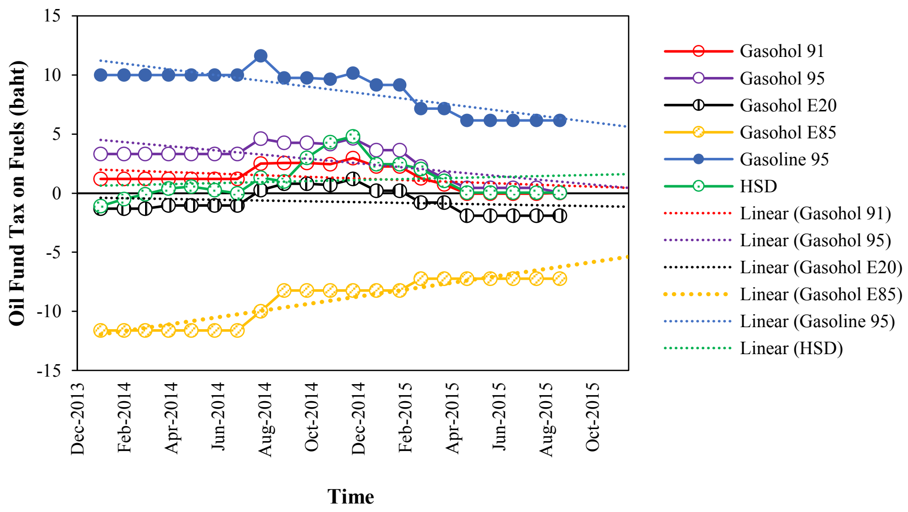


Figure 3.1 Oil Fund Taxes on Fuels at Present and Trend

CHAPTER 4

METHODOLOGY

4.1 Approach to the Study

The approach to the study is to analyze the long run relationship between the consumption of gasohol (91, 95, E20, and E85) and dominant factors. With reference to the review of literature, such as Dahl (1993), Somsak Kitsamrej (1993), Samimi (1995), Cooper (2003), Sterner (2007), Basso and Oum (2007), Hagman and Tekin (2007), Flood et al. (2007) and Hughes et al. (2008), the dominant factors of gasohol consumption are judiciously chosen, including the gasohol prices, the prices of substitute and complementary fuels, and M1—a proxy variable of GDP (Sompong Jirapapaisarn, 2007; Thiraphong Vikitset, 2008, 2010, 2014; Jirath Chenphuengpawn, 2012). However a vehicle factor is omitted, though it is proved to be a significant factor in Dahl and Sterner (1991), Johansson and Schipper (1994, 1997), Espey (1998), Pock (2007), Sterner (2007) and Thiraphong Vikitset (2010). Moreover, a long run relationship between ethanol supply (the feedstock of gasohol) and dominant factors is examined. Consistent with several researches: Krichene (2007), Ponce and Neumann (2014), and Thiraphong Vikitset (2014), the dominant factors of ethanol supply are rationally selected comprising an ethanol price, gasohol prices, and gasoline prices. But the prices of molasses and cassava (the input prices of ethanol) are excluded in order to inhibit a multicollinearity problem caused by the high correlation between ethanol price and the prices of molasses and cassava. Still, the input prices of ethanol are exposed as an important factor in some literature, such as Ardakani (2009).

In that case, the dissertation applies a Johansen cointegration approach to analyze the long run relationship in the consumption model of gasohol and the supply model of ethanol. The approach is suitable for a multivariate framework and allows to realize more than one cointegrating vector. Besides, it can incorporate non-stationary data with the long run relationships and the short run dynamics.

The time series data of the dissertation are verified by the Augmented Dickey-Fuller (ADF) test for the presence of a unit root. That is,

$$\Delta y_t = \alpha + \beta y_{t-1} + \sum_{i=1}^{k} \gamma_i \Delta y_{t-i} + \varepsilon_t \qquad (29)$$

where Δy denotes the first difference of the series y, α is a constant term, ε is a residual term, and k is the lagged values of Δy_t. The optimal lag length is obtained from the Akaike Information Criteria (AIC). The time series data should be non-stationary in level and integrated of order one (stationary after the first difference).

With regard to the cointegration models, the coefficients of dependent variables in the cointegrating equations are normalized to be one to capture the coefficient values of independent variables.

Furthermore, VECMs are applied to examine the short run dynamics and the long run relationships between gasohol consumption and its dominant variables. Then, an ECM of fuel x consumption is given by

$$\begin{aligned} \Delta lnC_{x,t} = {} & \pi (lnC_{x,t-1} - \beta_1 lnM1_{t-1} - \beta_2 lnP_{x,t-1} - \beta_3 lnP_{s,t-1} - \beta_4 lnP_{c,t-1} - \beta_5) \\ & + \sum_{i=1}^{k} \alpha_i \Delta lnC_{x,t-i} + \sum_{i=1}^{k} \lambda_i \Delta lnP_{x,t-i} + \sum_{i=1}^{k} \gamma_i \Delta lnP_{s,t-i} \\ & + \sum_{i=1}^{k} \delta_i \Delta lnP_{c,t-i} \end{aligned} \qquad (30)$$

where C_x is the consumption of fuel x, $M1$ is narrow money supply, P_x is the price of fuel x, P_s is the price of substitute fuels, and P_c is the price of complementary fuels. Likewise, an ECM of ethanol supply is defined as

$$\begin{aligned} \Delta lnS_{E,t} = {} & \pi (lnS_{E,t-1} - \beta_1 lnP_{E,t-1} - \beta_2 lnP_{r,t-1} - \beta_3) + \sum_{i=1}^{k} \alpha_i \Delta lnS_{E,t-i} \\ & + \sum_{i=1}^{k} \lambda_i \Delta lnP_{E,t-i} + \sum_{i=1}^{k} \gamma_i \Delta lnP_{r,t-i} \end{aligned} \qquad (31)$$

where S_E is the ethanol supply, P_E is the ethanol price, P_r is the price of related fuels, and k is the optimal lag length. Also, the coefficients of the error correction terms (β_i) indicate the long run elasticity estimates. The cointegration equation coefficients (π)

show the speed of adjustment in the long run of the variables. And the other coefficients ($\alpha_i, \lambda_i, \gamma_i, and\ \delta_i$) indicate the short run elasticity estimates.

Consequently, the price elasticities of gasohol consumption and ethanol supply, in the short and long run, can be obtained from the models. Next, the price elasticity of gasohol supply is derived from the proportion of the supply elasticity values of ethanol and gasoline (De Gorter and Just, 2009). Furthermore, the demand and supply price elasticities of gasohol are applied to a consumer and producer surplus approach so as to calculate the deadweight losses by integrating the area under the demand and supply curves deviated from market equilibrium (caused by taxation and subsidy through the Oil Fund), which are discussed in Section 5.4.

4.2 Data

The dissertation utilizes the monthly data of (1) the per capita consumption of gasohol 91, 95, E20, and E85, (2) the per capita supply of ethanol, (3) the prices of gasohol 91, 95, E20, and E85, (4) the prices of gasoline 91 and 95, (5) a high speed diesel price, (6) an ethanol price, and (7) per capita M1, for 2004-2013. Particularly, M1 is applied as a possible proxy variable of GDP. The domestic fuel data are obtained from the Ministry of Energy of Thailand. Thailand GDP is collected from Office of the National Economic and Social Development Board (2013). And, M1 is obtained from Bank of Thailand (2013). Then, the data charts are illustrated in Figure 4.1 and 4.4.

Correspondingly, the descriptive statistics and correlation matrix of the logarithmic series of fuel consumption, the fuel prices, the M1, and the supply and price of ethanol are exhibited in Appendix A. Also, in Table A.1.1-A.1.2 the positive (negative) values of skewness indicate that the series' distributions are skewed to the right (left). The kurtosis values of most variables are close to three, which indicate that their peak is near normal distribution. And, Jarque–Bera tests reject the normal distribution of lnC_{G91E10}, lnC_{G95E10}, lnC_{HSD}, lnC_{UGR91}, lnC_{ULG95}, lnP_{G95E20}, lnP_{G95E85}, lnP_{HSD}, and lnP_{ULG95} at the one percent level.

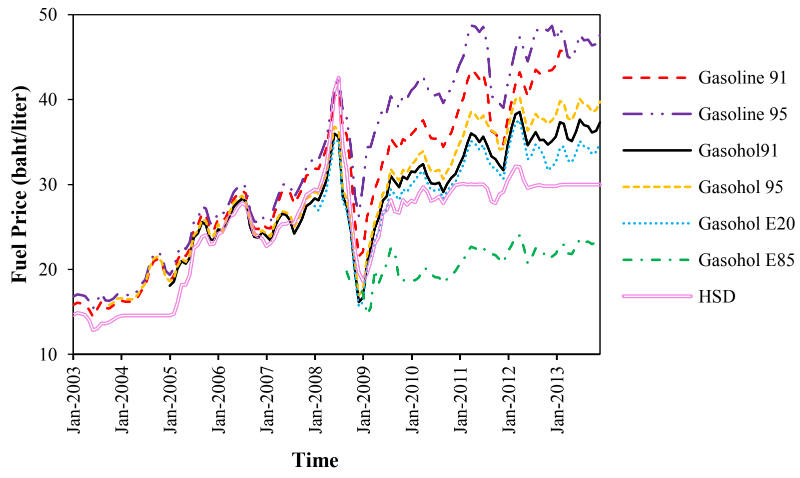


Figure 4.1 The Retail Prices of Fuels in Bangkok

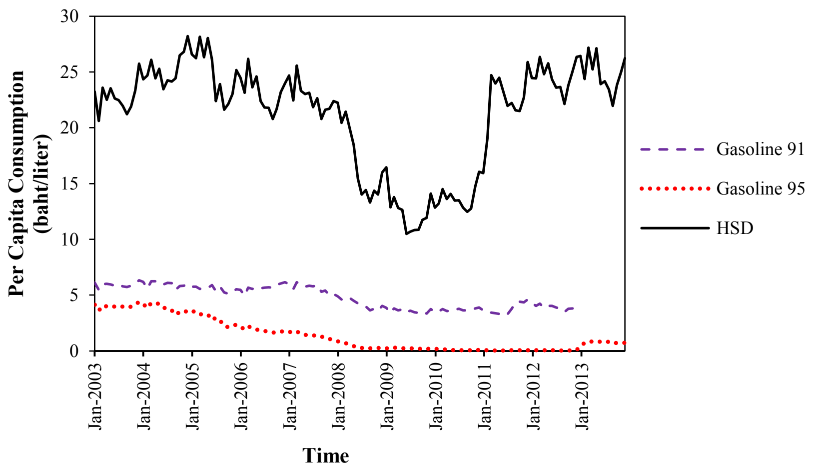


Figure 4.2 Per Capita Consumption of Gasoline and High Speed Diesel

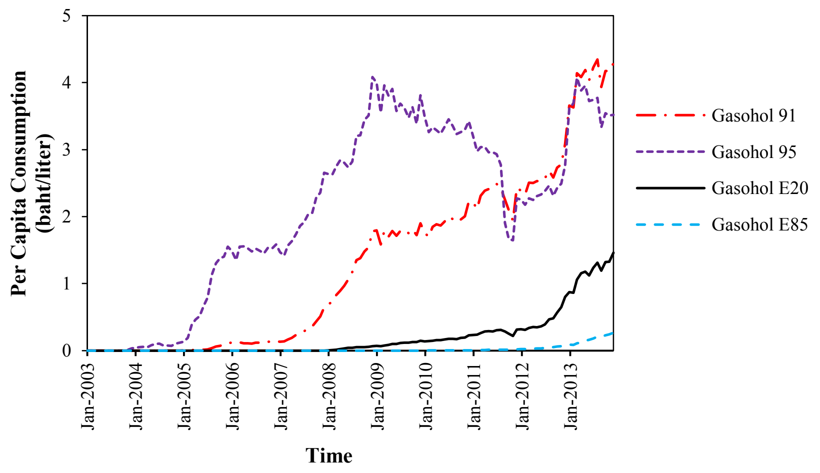


Figure 4.3 Per Capita Consumption of Gasohol

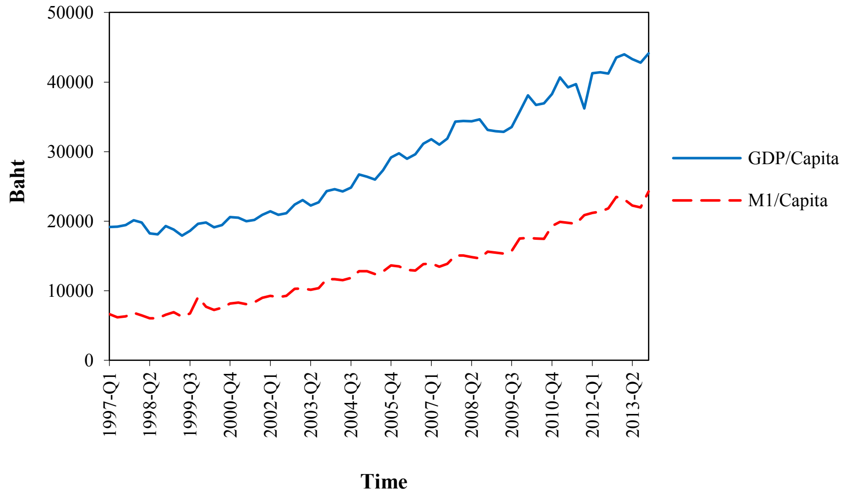


Figure 4.4 Per Capita GDP and Per Capita M1

CHAPTER 5

RESULTS

5.1 Augmented Dickey-Fuller Test Results

Table 5.1 exhibits the Augmented Dickey-Fuller (ADF) test results of the time series data. It reveals that most series fail to reject the null hypothesis in level (the presence of the unit root of the series). However, after taking the first difference of the series, the all series are stationary, indicating the integration of the series of the same order $I(1)$.

Table 5.1 Augmented Dickey-Fuller Test Results

Variable		ADF (level)	ADF (1st diff)	1% CV	5% CV
lnC_{G91E10}	(Gasohol 91 Consumption)	-2.19 (8)	-3.96** (2)	-3.49	-2.89
lnC_{G95E10}	(Gasohol 95 Consumption)	-5.34** (13)	-3.08* (14)	-3.49	-2.89
lnC_{G95E20}	(Gasohol E20 Consumption)	-0.44 (6)	-3.79** (6)	-3.54	-2.91
lnC_{G95E85}	(Gasohol E85 Consumption)	-1.7 (6)	-3.04* (5)	-3.55	-2.91
lnC_{HSD}	(High Speed Diesel Consumption)	-1.29 (9)	-6.45** (5)	-3.48	-2.88
lnC_{UGR91}	(Gasoline 91 Consumption)	-1.12** (9)	-3.70** (10)	-3.49	-2.89
lnC_{ULG95}	(Gasoline 95 Consumption)	-0.40 (3)	-5.07** (2)	-3.49	-2.89
lnP_{G91E10}	(Gasohol 91 Price)	-1.16** (8)	-5.71** (7)	-3.50	-2.89
lnP_{G95E10}	(Gasohol 95 Price)	-2.03 (2)	-6.04** (4)	-3.49	-2.89
lnP_{G95E20}	(Gasohol E20 Price)	-1.60 (9)	-5.01** (11)	-3.55	-2.91
lnP_{G95E85}	(Gasohol E85 Price)	-2.28 (6)	-6.46** (5)	-3.55	-2.91
lnP_{HSD}	(High Speed Diesel Price)	-2.30** (5)	-6.22** (4)	-3.48	-2.88
lnP_{UGR91}	(Gasoline 91 Price)	-1.68 (5)	-6.34** (4)	-3.49	-2.89
lnP_{ULG95}	(Gasoline 95 Price)	-2.08 (8)	-6.99** (4)	-3.48	-2.88
lnP_E	(Ethanol Price)	-1.23 (12)	-3.23** (11)	-3.51	-2.90
lnS_E	(Ethanol Supply)	-1.48 (11)	-5.46** (10)	-3.51	-2.90
$lnM1$	(Narrow Money Supply)	0.19 (11)	-3.65** (11)	-3.49	-2.89

Note: ADF tests include intercept but not trend. ** and * denote statistical significance at the one and five percent level, respectively. The numbers in parentheses indicate the optimal lag length obtained from Akaike Information Criteria

5.2 Johansen Cointegration Test Results

The Johansen cointegration test results are exhibited in Table 5.2. The Trace and Max-Eigen statistics verify the cointegrating relationship between gasohol consumption and its dominant variables in all cases. However, the cointegrating relationship between ethanol supply and its dominant variables are solely confirmed by Trace statistics. As a consequence, it can be inferred that at least one linear combination exists among the variables (the variables are cointegrated), which confirms the long run relationship, though it deviates from equilibrium in the short run.

Table 5.2 Johansen Cointegration Test Results

Dependent Variable	Independent Variable	Trace Statistic	5% CV	Prob.	Rank	Max-Eigen Statistic	5% CV	Prob.	Rank
lnC_{G91E10}	$lnM1$ lnP_{G91E10} lnP_{UGR91}	43.45	42.92	0.04	2	25.51	25.82	0.06	2
lnC_{G95E10}	$lnM1$ lnP_{G91E10} lnP_{G95E10}	34.60	29.80	0.01	2	21.80	21.13	0.04	2
lnC_{G95E20}	lnP_{G95E10} lnP_{G95E20}	32.27	25.87	0.01	2	23.47	19.39	0.01	2
lnC_{G95E85}	lnP_{G91E10} lnP_{G95E10} lnP_{G95E20} lnP_{G95E85}	44.02	42.92	0.04	3	27.49	25.82	0.03	3
lnS_{E}	lnP_{E} lnP_{G95E10} lnP_{G95E20} lnP_{ULG95}	74.15	69.82	0.02	1	29.38	33.88	0.16	0

Furthermore, the coefficients of dependent variables in the cointegrating equations are normalized to be one to capture the coefficient values of independent variables. Correspondingly, the analysis of the normalized cointegrating coefficients allows to understand the speed of adjustment in the long run of the variables.

Consequently, the results of the normalized cointegrating coefficients are exhibited in Table 5.3. It firstly presents the case of gasohol 91 consumption such that: (1) P_{G91E10} has the expected sign and is statistically significant. Its coefficient indicates that a one percent increase in gasohol 91 price leads to a 6.46 percent decrease in gasohol 91 consumption in the long run. (2) P_{UGR91} has the expected sign and is statistically significant. Its coefficient shows that a one percent increase in gasoline 91 price causes a 12.99 percent increase in gasohol 91 consumption in the long run. (3) M1 has the unexpected positive sign (equivalent to the negative sign in a demand function) and is statistically significant. It implies that gasohol 91 is an inferior good (when income increases, the consumers switch from gasohol 91 to gasohol 95). Also, its coefficient indicates that a one percent increase in M1 results in a 12.98 percent decrease in gasohol 91 consumption in the long run.

Table 5.3 Normalized Cointegrating Coefficients

Normalized Cointegrating Coefficient					
Gasohol 91 Consumption					
lnC_{G91E10}	lnM1	lnP_{G91E10}	lnP_{UGR91}	Trend	
1.0000	12.9754	6.4576	-12.9945	-0.0786	
	[4.6621]**	[3.2015]**	[-5.4354]**	[-3.6086]**	
Gasohol 95 Consumption					
lnC_{G95E10}	lnM1	lnP_{G91E10}	lnP_{G95E10}		
1.0000	-3.5604	-2.9453	6.0612		
	[-2.6363]*	[-0.3151]	[0.6301]		
Gasohol E20 Consumption					
lnC_{G95E20}	lnP_{G95E10}	lnP_{G95E20}	Trend		
1.0000	-11.9781	12.0375	-0.0349		
	[-4.3243]**	[4.5787]**	[-6.6671]**		
Gasohol E85 Consumption					
lnC_{G95E85}	lnP_{G91E10}	lnP_{G95E10}	lnP_{G95E20}	lnP_{G95E85}	Trend
1.0000	18.3699	-11.7706	-9.0723	4.7046	-0.1338
	[19.4974]**	[-23.5798]**	[-14.9843]**	[25.7712]**	[-80.7093]**
Ethanol Supply					
lnS_E	lnP_E	lnP_{G95E10}	lnP_{G95E20}	lnP_{ULG95}	
1.0000	-0.2124	-16.7680	15.4146	2.4047	
	[-0.4692]	[-6.6551]**	[6.7537]**	[1.9387]	

Note: t-statistics are in [ ]. ** and * denote statistical significance at the one and five percent level, respectively

Second, the case of gasohol 95 consumption, it discloses that M1 has the expected sign and is statistically significant. Its coefficient indicates that a one percent increase in M1 leads to a 3.56 percent increase in gasohol 95 consumption in the long run. Nevertheless, P_{G91E10} and P_{G95E10} have the expected signs, but are statistically insignificant. Thus, it cannot be presumed that the prices of gasohol 91 and 95 influence gasohol 95 consumption in the long run.

Third, the case of gasohol E20, P_{G95E10} has the expected sign and is statistically significant. Its coefficient confirms that a one percent increase in gasohol 95 price causes an 11.98 percent increase in gasohol E20 consumption in the long run. Moreover, P_{G95E20} has the expected sign and is statistically significant. Its coefficient proves that a one percent increase in gasohol E20 price leads to a 12.04 percent decrease in gasohol E20 consumption in the long run.

Fourth, the consumption of gasohol E85, P_{G95E10}, P_{G95E20}, and P_{G95E85} have the expected sign and are statistically significant. The coefficients indicate that a one percent increase in the prices of gasohol 95 and E20 lead to an 11.77 and 9.07 percent increase in gasohol E85 consumption in the long run, respectively. Instead, a one percent increase in gasohol E85 price causes a 4.70 percent decrease in gasohol E85 consumption in the long run.

Lastly, the ethanol supply, P_E has the expected sign, but is statistically insignificant. So, it cannot be deduced that the ethanol price affects its consumption. On the contrary, P_{G95E10} has the expected sign and is statistically significant. Its coefficient indicates that a one percent increase in gasohol 95 price causes a 16.77 percent increase in ethanol supply in the long run.

5.3 Error Correction Models

The error correction models (ECMs) exhibited in Table 5.4-5.8 describes the short run dynamics and the speed of adjustment of cointegrated variables towards their equilibrium values. Table 5.4 illustrates the ECM of gasohol 91 consumption. The speed of adjustment has a negative sign and is statistically significant of at the five percent level. The negative sign indicates that the movement of the variables in any period deviated from the long run equilibrium is corrected. Besides, the value close to zero (-0.0481) indicates the slow speed of adjustment to the long run equilibrium. In other words, when the price of gasohol 91 drops one percent in any period, its consumption increases 4.81 percent until it turns out to equal 6.46 percent (a long run price elasticity estimates) and then remains unchanged. In brief, 4.81 percent of the disequilibrium is corrected. Nevertheless, P_{G91E10} is statistically insignificant, so it cannot be ascertained that the price of gasohol 91 influences its consumption in the short run.

Table 5.4 An Error Correction Model of Gasohol 91 Consumption

Error Correction: ΔlnC_{G91E10}	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
Cointegrating Equation	-0.0481	0.0211	-2.2796	0.0293*
$\Delta lnC_{G91E10(-1)}$	0.3330	0.0936	3.5576	0.0007**
$\Delta lnC_{G91E10(-2)}$	0.1029	0.0919	1.1197	0.2320
$\Delta lnM1_{(-1)}$	0.6664	0.4627	1.4402	0.1732
$\Delta lnM1_{(-2)}$	-0.3131	0.4487	-0.6978	0.4416
$\Delta lnP_{G91E10(-1)}$	0.7783	0.6533	1.1913	0.2403
$\Delta lnP_{G91E10(-2)}$	-0.1115	0.6911	-0.1614	0.8244
$\Delta lnP_{UGR91(-1)}$	-0.5906	0.7342	-0.8044	0.4335
$\Delta lnP_{UGR91(-2)}$	0.1378	0.8144	0.1692	0.8311
C	0.0309	0.0128	2.4181	0.0207**
$R^2 = 0.35$ DW = 1.94 LM = 0.68 Normality = 0.01 Heteroskedasticity = 0.10				

Note: ** and * denote statistical significance at the one and five percent level, respectively

Similarly, the ECM of gasohol 95 consumption exhibited in Table 5.5 discloses that the speed of adjustment has a negative sign and is statistically significant at the one percent level. As a consequence, 8.64 percent of the divergence from the long run equilibrium of the variables is corrected in any period. Besides, P_{G95E10} is statistically significant at the five percent level. Its coefficient verifies that a one percent increase in gasohol 95 price leads to a 2.58 percent decrease in its consumption in the short run.

Table 5.5 An Error Correction Model of Gasohol 95 Consumption

Error Correction: ΔlnC_{G95E10}	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
Cointegrating Equation	-0.0864	0.0170	-5.0861	0.0000**
$\Delta lnC_{G95E10(-1)}$	0.1544	0.0885	1.7450	0.0841
$\Delta lnM1_{(-1)}$	0.0223	0.3315	0.0673	0.9465
$\Delta lnP_{G91E10(-1)}$	2.5758	1.0571	2.4366	0.0166*
$\Delta lnP_{G95E10(-1)}$	-2.5771	1.1004	-2.3420	0.0212*
C	0.0236	0.0095	2.4830	0.0147*
$R^2 = 0.39$ DW = 1.92 LM = 0.47 Normality = 0.00 Heteroskedasticity = 0.02				

Note: ** and * denote statistical significance at the one and five percent level, respectively

Correspondingly, Table 5.6 exhibits the ECM of gasohol E20 consumption. The speed of adjustment has a negative sign and is statistically significant at the one percent level. 23.60 percent of the divergence from the long run equilibrium of the variables is corrected in any period. Nonetheless, P_{G95E20} is statistically insignificant, so it cannot be conjectured that gasohol E20 price affects its consumption in the short run.

Table 5.6 An Error Correction Model of Gasohol E20 Consumption

Error Correction: ΔlnC_{G95E20}	Coefficient	Std. Error	t-Statistic	Prob.
Cointegrating Equation	-0.2360	0.0542	-4.3551	0.0001**
$\Delta lnC_{G95E20(-1)}$	0.0281	0.1173	0.2392	0.8117
$\Delta lnC_{G95E20(-2)}$	0.0893	0.1064	0.8394	0.4045
$\Delta lnP_{G95E10(-1)}$	-2.2990	1.1883	-1.9347	0.0577
$\Delta lnP_{G95E10(-2)}$	-1.0880	1.1893	-0.9149	0.3639
$\Delta lnP_{G95E20(-1)}$	2.0844	1.1139	1.8712	0.0661
$\Delta lnP_{G95E20(-2)}$	1.3782	1.1051	1.2472	0.2171
C	0.0664	1.4562	0.0456	0.0001**
$R^2 = 0.41$ DW = 2.07 LM = 0.06 Normality = 0.00 Heteroskedasticity = 0.01				

Note: ** and * denote statistical significance at the one and five percent level, respectively

Likewise, Table 5.7 exhibits the ECM of gasohol E85 consumption. The speed of adjustment has a negative sign and is statistically significant at the one percent level. 71.18 percent of the divergence from the long run equilibrium of the variables is corrected in any period. Yet, P_{G95E85} does not have the expected sign in accord with the economic theory, although it is statistically significant. Thus, it cannot be deduced that gasohol E85 price induces its consumption in the short run.

Above all, Table 5.8 exhibits the ECM of ethanol supply. The speed of adjustment has a negative sign and is statistically significant at the one percent level. 47.69 percent of the disequilibrium is corrected. But, P_E is statistically insignificant, so it cannot be deemed that ethanol price causes its supply in the short run.

Turning to Table 5.9, it summarizes the price and cross price elasticities of gasohol consumption and ethanol supply. It lucidly displayed that: (1) The price elasticity of gasohol 91 consumption is equal to -6.46 in the long run, but statistically insignificant in the short run. (2) The price elasticity of gasohol 95 consumption is -2.58 in the short run, but the long run price elasticity is statistically insignificant, -6.06. (3) The price elasticity of gasohol E20 consumption is -12.04 in the long run, but statistically insignificant in the short run. (4) The price elasticity of gasohol E85 consumption is equal to -4.70 in the long run. (5) Ethanol price does not affect its supply both in the short and long run, but the supply is impacted by gasohol 95 price in the long run. It implies that an increase in gasohol 95 price leads to an increase in gasohol 95 supply and also the demand for ethanol (as a gasohol feedstock), so ethanol supply is encouraged to increase in the long run.

Table 5.7 An Error Correction Model of Gasohol E85 Consumption

Error Correction: ΔlnC_{G95E85}	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
Cointegrating Equation	-0.7118	0.1272	-5.5943	0.0000**
$\Delta lnC_{G95E85(-1)}$	0.1851	0.1305	1.4183	0.1645
$\Delta lnC_{G95E85(-2)}$	1.0200	0.1858	5.4906	0.0000**
$\Delta lnC_{G95E85(-3)}$	0.7564	0.1792	4.2205	0.0002**
$\Delta lnC_{G95E85(-4)}$	0.8188	0.1818	4.5048	0.0001**
$\Delta lnC_{G95E85(-5)}$	0.5318	0.1291	4.1192	0.0002**
$\Delta lnP_{G91E10(-1)}$	10.1778	2.0331	5.0061	0.0000**
$\Delta lnP_{G91E10(-2)}$	16.5906	2.8674	5.7859	0.0000**
$\Delta lnP_{G91E10(-5)}$	4.2669	1.9353	2.2048	0.0338*
$\Delta lnP_{G95E10(-1)}$	-10.4209	2.1748	-4.7916	0.0000**
$\Delta lnP_{G95E10(-2)}$	-12.8915	2.1079	-6.1157	0.0000**
$\Delta lnP_{G95E10(-3)}$	-2.9906	1.6723	-1.7883	0.0819
$\Delta lnP_{G95E20(-2)}$	-7.0941	2.2107	-3.2090	0.0028**
$\Delta lnP_{G95E20(-3)}$	1.6091	1.4400	1.1175	0.2710
$\Delta lnP_{G95E20(-4)}$	-1.6623	0.5935	-2.8007	0.0081**
$\Delta lnP_{G95E20(-5)}$	-4.2446	1.9046	-2.2287	0.0320*
$\Delta lnP_{G95E85(-2)}$	3.3156	0.7059	4.6971	0.0000**
$\Delta lnP_{G95E85(-3)}$	1.4436	0.6035	2.3919	0.0220*
$\Delta lnP_{G95E85(-4)}$	1.9965	0.6458	3.0917	0.0038**
$\Delta lnP_{G95E85(-5)}$	0.9730	0.5666	1.7173	0.0943
C	-0.2860	0.0702	-4.0760	0.0002**
$R^2 = 0.81$ DW = 1.52 LM = 0.09 Normality = 0.00 Heteroskedasticity = 0.37				

Note: ** and * denote statistical significance at the one and five percent level, respectively.

Table 5.8 An Error Correction Model of Ethanol Supply

Error Correction: ΔlnS_E	Coefficient	Std. Error	t-Statistic	Prob.
Cointegrating Equation	-0.4769	0.1131	-4.2159	0.0001**
$\Delta lnS_{E(-1)}$	-0.3119	0.1264	-2.4680	0.0166*
$\Delta lnS_{E(-2)}$	-0.1288	0.1380	-0.9331	0.3547
$\Delta lnP_{E(-1)}$	0.3251	0.3992	0.8143	0.4189
$\Delta lnP_{E(-2)}$	0.2222	0.4143	0.5363	0.5938
$\Delta lnP_{G95E10(-1)}$	-5.1815	3.0183	-1.7167	0.0915
$\Delta lnP_{G95E10(-2)}$	-2.1004	2.9669	-0.7079	0.4819
$\Delta lnP_{G95E20(-1)}$	3.5287	2.8791	1.2256	0.2254
$\Delta lnP_{G95E20(-2)}$	-0.3449	2.8378	-0.1215	0.9037
$\Delta lnP_{ULG95(-1)}$	2.7479	1.3115	2.0952	0.0406
$\Delta lnP_{ULG95(-2)}$	3.7132	1.3700	2.7104	0.0089*
C	0.0009	0.0287	0.0313	0.9752
$R^2 = 0.46$ DW = 2.02 LM = 0.22 Normality = 0.00 Heteroskedasticity = 0.68				

Note: ** and * denote statistical significance at the one and five percent level, respectively.

Table 5.9 Summary of Price Elasticities of Gasohol Consumption and Ethanol Supply

Type	Independent Factor	Price and Cross Price Elasticities in the Short Run	Price and Cross Price Elasticities in the Long Run
Gasohol 91 Consumption (C_{G91E10})	Gasohol 91 Price (P_{G91E10})	-	**-6.46****
	Gasoline 91 Price (P_{UGR91})	-	12.99**
Gasohol 95 Consumption (C_{G95E10})	Gasohol 91 Price (P_{G91E10})	2.58*	2.95
	Gasohol 95 Price (P_{G95E10})	**-2.58***	-6.06
Gasohol E20 Consumption (C_{G95E20})	Gasohol 95 Price (P_{G95E10})	-	11.98**
	Gasohol E20 Price (P_{G95E20})	-	**-12.04****
Gasohol E85 Consumption (C_{G95E85})	Gasohol 95 Price (P_{G95E10})	-	11.77**
	Gasohol E20 Price (P_{G95E20})	-	9.07**
	Gasohol E85 Price (P_{G95E85})	-	**-4.70****
Ethanol Supply (S_E)	Ethanol Price (P_E)	**-**	**0.21**
	Gasohol Price 95 (P_{G95E10})	-	16.77**

Note: ** and * denote statistical significance at the one and five percent level, respectively.

5.4 Deadweight Loss Calculation

With regard to De Gorter and Just (2009), the supply curve of an ethanol-gasoline mixture in figure 2.1 can explain the supply curves of gasohol E10 (91 and 95), a mixture of ten percent ethanol and 90 percent gasoline. The slope of the supply curve of gasohol E10 is prominently influenced by the supply of gasoline as a larger proportion of the gasohol mixture. So, the slope of the supply curve of gasohol E10 should be close to the perfectly elastic supply curve of gasoline. In contrast, gasohol E85 is an 85 percent ethanol and 15 percent gasoline mixture. Its supply curve is mostly influenced by the supply of ethanol as a larger proportion of the mixture. However, the normalized cointegrating coefficient of the ethanol supply model exhibited in Table 5.3 evidently indicates that the ethanol price does not affect its supply. And the consumption quantity of gasohol E10 is considerably higher than that of gasohol E85. Thus, the gasohol supply is assumed to be perfectly elastic compliant with the gasoline supply. Under these circumstances, the long run price elasticity of gasohol consumption and the perfect price elasticity of gasohol supply are applied to estimate the deadweight losses in gasohol through a consumer and producer surplus approach. The deadweight losses in gasohol are calculated by integrating the area under the demand curve of gasohol with respect to the changes in its prices illustrated as Figure 5.1 and 5.2.

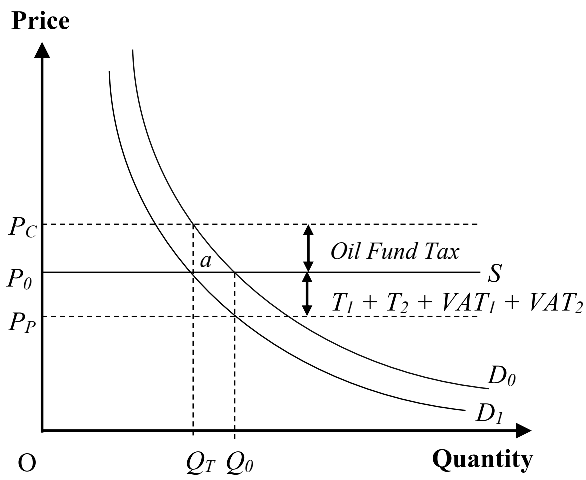


Figure 5.1 Deadweight Loss from Oil Fund Tax

In addition, the deadweight losses from oil fund taxes on gasohol (the area *a* in Figure 5.1) is defined by

$$DWL_T = \int_{P_0}^{P_C} (D(P)_0 - Q_T)\, dP \tag{32}$$

and simplified by assuming a linear relationship, as

$$DWL_T = 0.5\,(Q_0 - Q_T)\,(P_C - P_0) \tag{33}$$

where $D(P)_0$ is the demand function of gasohol before oil fund tax (subsidy), Q_T is the consumption quantity of gasohol after oil fund tax, P_C is consumer price, P_P is producer price, and P_0 is the gasohol price before oil fund tax (subsidy) including T_1, T_2, VAT_1, and VAT_2; while T_1 is excise tax, T_2 is municipal tax, VAT_1 is value added tax 1, and VAT_2 is value added tax 2.

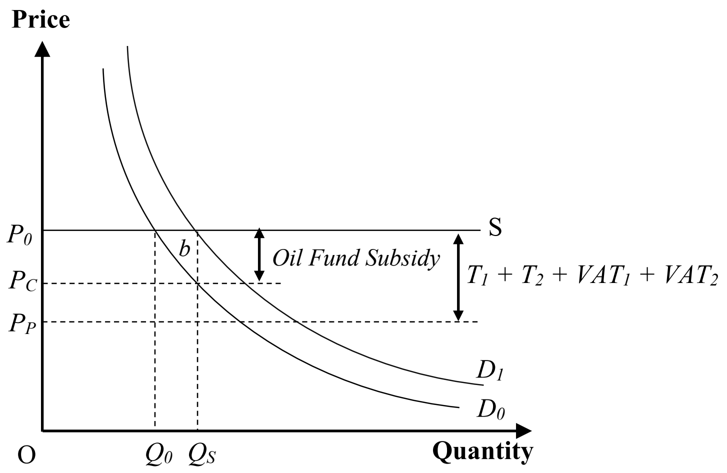


Figure 5.2 Deadweight Loss from Oil Fund Subsidy

In the same way, the deadweight losses from oil fund subsidies on gasohol (the area *b* in Figure 5.2) is given by

$$DWL_S = \int_{P_C}^{P_0} (Q_S - D(P)_0)\, dP \tag{34}$$

and simplified by assuming a linear relationship, then

$$DWL_S = 0.5\ (Q_S - Q_0)\ (P_0 - P_C) \qquad (35)$$

where Q_S is the consumption quantity of gasohol after oil fund subsidy.

In that case, the calculation results of the deadweight losses from the oil fund taxes and subsidies on gasohol are exhibited in Table 5.10-5.13. The deadweight losses impacted by the oil fund taxes and subsidies on gasohol 91 for 2005-2013 are exhibited in Table 5.10. The deadweight loss in gasohol 91 consumption is maximum at 820.17 million baht in 2009, and the total deadweight loss is 2937.63 million baht.

Table 5.10 Deadweight Losses in Gasohol 91 Consumption

(Unit: million baht)

Month	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
January	0.0010	1.2456	4.9721	0.3813	324.6239	55.6521	0.1530	9.9182	6.3001
February	0.0013	1.2147	5.3142	0.3259	13.9102	39.3753	0.1418	0.0965	16.7333
March	0.0024	1.2718	3.6501	0.3576	51.5917	36.3685	0.1479	5.8438	117.4714
April	0.0028	0.3059	2.1987	0.3689	95.3214	36.5240	0.1476	5.7912	198.4438
May	0.0035	0.2859	1.3237	0.3694	12.5306	38.4836	0.1506	6.2125	113.4759
June	0.0039	0.2727	0.9195	0.3752	0.1351	41.5736	0.1549	32.4930	67.6311
July	0.0042	0.2982	0.1734	0.4204	21.2639	43.4629	0.1557	46.3945	67.1560
August	0.0091	0.2994	0.2550	0.2720	58.7358	42.3322	0.0413	3.4695	61.5405
September	0.0140	0.3604	0.5620	2.2519	59.1687	43.7528	22.0586	13.5298	13.8725
October	0.0161	1.8774	0.1519	20.9704	63.4892	42.5415	20.6515	4.4502	42.4760
November	0.0219	5.0804	0.0860	149.5423	56.2916	42.0488	19.4678	0.0000	48.5107
December	0.0272	4.8967	0.1875	376.5960	63.1041	45.7015	24.7570	2.1212	48.1483
Total	0.1073	17.4091	19.7941	552.2312	820.1662	507.8168	88.0278	130.3203	801.7597
Total deadweight loss = 2937.6324									

Likewise, Table 5.11 exhibits the deadweight losses in gasohol 95 consumption for 2004-2013. Total deadweight loss in gasohol 95 consumption is extensively greater than the other types of gasohol for 2004-2013 (35611.81 million baht). Besides, the deadweight loss is extremely high in December 2008 (11216.31 million baht) because of a massive increase in the oil fund tax (16.04 percent of gasohol 95 price), while the oil fund tax on gasohol 95 price is 4.90 percent on average during the period of study.

Table 5.11 Deadweight Losses in Gasohol 95 Consumption

(Unit: million baht)

Month	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
January	0.0413	0.0382	13.8842	48.4542	0.9278	4766.2320	225.1526	211.9158	8.9772	318.0232
February	0.0492	0.0032	13.2654	47.8209	1.2157	6.7871	330.9330	186.0475	47.4961	412.8403
March	0.0540	0.0060	14.3331	30.6896	1.2243	295.1106	386.1629	175.6856	92.4021	1108.3982
April	0.0515	0.0069	3.9146	17.0633	1.2083	470.3367	372.2221	166.0540	90.3588	1709.4264
May	0.0739	0.0079	3.6767	9.0559	1.0873	92.5128	403.1974	164.2192	100.3364	1060.1623
June	0.0907	0.0100	3.5057	5.9642	0.9843	23.6764	452.0077	169.9538	232.7698	676.7544
July	0.0901	0.0105	3.5490	6.2312	1.0262	117.8682	468.5588	163.5338	285.0121	617.5886
August	0.0579	0.0147	3.5849	12.7004	2.7746	240.2245	449.2076	156.5001	41.1805	596.8566
September	0.0547	0.0161	3.8513	17.1226	25.7540	241.5433	476.5101	28.9151	27.7734	281.0667
October	0.0519	0.0171	19.2701	10.2280	121.8820	263.4569	442.8649	25.6116	61.2541	486.2494
November	0.0016	0.0580	50.2754	2.2407	967.2168	225.8150	421.7562	1.0876	129.8914	511.9226
December	0.0370	14.8944	50.8847	1.8102	11216.3062	259.3701	393.9621	0.5690	205.7213	483.0683
Total	0.6538	15.0829	183.9952	209.3811	12341.6074	7002.9337	4822.5354	1450.0932	1323.1731	8262.3571
Total deadweight loss = 35611.8129										

Furthermore, Table 5.12 exhibits the deadweight losses in gasohol E20 consumption for 2008-2013. The deadweight loss increases annually and reaches 160.03 million baht in 2013, rising almost twice as many as the previous year. And the total deadweight loss is 349.99 million baht.

Table 5.12 Deadweight Losses in Gasohol E20 Consumption

(Unit: million baht)

Month	2008	2009	2010	2011	2012	2013
January	0.0056	0.1288	0.3264	3.2861	10.7827	20.7164
February	0.0084	3.1518	0.2754	3.2854	4.1620	14.4347
March	0.0154	0.2862	0.2620	3.5182	1.8544	1.2903
April	0.0245	0.1097	0.2733	3.7546	1.9120	0.0014
May	0.0306	1.2680	0.2835	3.8464	1.9930	2.0499
June	0.0371	2.1094	0.3147	3.8646	0.8045	8.2028
July	0.0398	1.0029	0.3295	4.0753	0.1779	8.7799
August	0.0288	0.2822	0.3305	4.5065	7.7692	17.9258
September	0.0556	0.2928	0.3337	13.2879	6.6229	29.4463
October	0.0705	0.3208	0.3559	11.8645	13.7105	19.3457
November	0.0290	0.3079	0.3583	10.3549	22.7270	18.1953
December	0.6481	0.3567	0.4185	15.0452	22.2783	19.6405
Total	0.9933	9.6172	3.8618	80.6895	94.7944	160.0290
Total deadweight loss = 349.9852						

Next, Table 5.13 exhibits the deadweight losses in gasohol E85 consumption for 2009-2013. The annual deadweight loss in gasohol E85 consumption enormously increases, especially in 2013. It becomes 489.60 million baht, increasing greater than three times as many as in 2012. Also, the total deadweight loss is 673.90 million baht.

Table 5.13 Deadweight Losses in Gasohol E85 Consumption

(Unit: million baht)

Month	2009	2010	2011	2012	2013
January	-	0.2448	1.7095	6.1640	22.3723
February	0.0146	0.3245	1.7389	6.4942	20.4491
March	0.0200	0.4488	2.3376	7.4346	24.8252
April	0.0090	0.4158	2.2534	7.7732	28.4531
May	0.0238	0.4331	3.1890	8.6598	33.4333
June	0.0314	0.5161	3.3698	9.0731	38.5669
July	0.0279	0.5946	3.8334	10.9771	42.5596
August	0.0368	0.6649	4.0461	13.9256	49.6137
September	0.0372	0.7153	3.9955	13.5933	51.7105
October	0.1056	0.8683	3.9873	15.0358	55.4566
November	0.1604	0.9270	3.5103	16.5331	58.5354
December	0.1983	1.1444	5.5105	21.1955	63.6196
Total	0.6649	7.2976	39.4813	136.8591	489.5953
Total deadweight loss = 673.8982					

Turning to Table 5.14, it exhibits the per unit deadweight losses in gasohol consumption for the given periods. The per unit deadweight loss in gasohol 91 consumption is highest at 0.60 baht per liter, in 2008. The per unit deadweight loss in gasohol 95 consumption is vastly excessive up to 5.06 baht per liter in 2008, because of an enormous increase in the oil fund tax. Besides, the per unit deadweight loss in gasohol E20 consumption is highest at 0.36 baht per liter, in 2011. Remarkably, the per unit deadweight loss in gasohol E85 consumption is considerably greater than that in the other types of gasohol, which its maximum value is 4.34 baht per liter in 2011. For 2009-2013, the deadweight losses per liter in the consumption of gasohol 91, 95, E20, and E85 become 0.25, 1.21, 0.18, and 3.57 baht per liter on average, respectively.

Table 5.14 Per Unit Deadweight Losses in Gasohol Consumption

(Unit: baht/liter)

Year	Gasohol 91	Gasohol 95	Gasohol E20	Gasohol E85
2004	-	0.0110	-	-
2005	0.0037	0.0234	-	-
2006	0.1843	0.1553	-	-
2007	0.0810	0.1379	-	-
2008	0.5980	5.0597	0.0342	-
2009	0.5798	2.3562	0.1154	2.7078
2010	0.3273	1.7918	0.0281	3.4586
2011	0.0473	0.6834	0.3640	4.3410
2012	0.0614	0.2023	0.2585	3.8293
2013	0.2403	0.5846	0.1662	3.5012
2009-2013	0.2512	1.2111	0.1864	3.5676
The Entire Period of Study	0.2359	1.5160	0.1611	3.5676

In particular, Table 5.15 exhibits the total and per unit deadweight losses in gasohol consumption relative to the price elasticities, the total consumption, and the total oil fund taxes, for 2009-2013. It can be inferred that (1) the price elasticity of gasohol consumption positively relates to a per unit deadweight loss in the consumption, and (2) the consumption quantity and the oil fund tax value are typically significant factors to best describe the total deadweight loss. Additionally, for 2009-2013 the total deadweight loss in gasohol 95 consumption is prominently high compared with the others, because gasohol 95 is used at the highest quantity and it is collected tax at the greatest amount by the Oil Fund. But, the total deadweight loss in gasohol E20 consumption is lowest, although its total consumption is higher than that of gasohol E85 because the per unit deadweight loss of gasohol E85 is greater.

Table 5.15 Deadweight Losses in Gasohol Consumption and Related Factors

Types of Gasohol	Total Deadweight Loss (million baht)	Per Unit Deadweight Loss (baht)	Price Elasticity	Total Consumption (million liter)	Total Oil Fund Tax (million baht)
Gasohol 91	2348.09	0.2512	-6.46	10283.89	7805.14
Gasohol 95	22861.09	1.2111	-6.06	12746.52	31302.10
Gasohol E20	348.99	0.1864	-12.04	1771.73	-2073.36
Gasohol E85	673.90	3.5676	-4.70	187.03	-2188.99

Note: The data are calculated for 2009-2013

CHAPTER 6

PRICING POLICY SCENARIO ANALYSIS AND IMPLICATIONS

6.1 Pricing Policy Scenario Analysis

The dissertation demonstrates scenario analysis to examine the impacts of the alteration in oil fund taxes and subsidies on the total deadweight losses in gasohol consumption. Consequently, the alternative possible pricing policies are recommended by allowing the consideration of outcomes and implications.

Thus, the first scenario analyzes the impact of a decrease in oil fund taxes (subsidies) on the deadweight losses in gasohol 91 consumption exhibited in Table 6.1 and Figure 6.1. It indicates that (1) a decrease in the oil fund taxes (subsidies) on gasohol 91 undoubtedly leads to a decrease in the deadweight losses, (2) the speed of the percent decrease in the deadweight losses to the percent decrease in the oil fund taxes (subsidies) is slow down (a decreasing positive slope, see Figure 6.1), (3) in early stage the percent decrease in the deadweight losses are higher than the percent decrease in the oil fund taxes (subsidies), but unit the percent decrease in the oil fund taxes (subsidies) exceed 68.56 percent, the percent decrease in the deadweight losses are lower, and (4) the deadweight loss elasticity to the oil fund tax (subsidy) is about 0.60.

Scenario 1: A Decrease in Oil Fund Taxes (Subsidies) on Gasohol 91 by Holding the Prices of the Other Fuels Constant.

Table 6.1 Deadweight Loss Elasticity to Oil Fund Tax (Subsidy): for Gasohol 91

A Decrease in Oil Fund Tax (Subsidy) (%)	10	20	30	40	50	60	68.56	70	80	90
A Decrease in DWL (%)	21.63	36.34	47.07	55.13	61.20	65.72	68.56	68.95	71.11	72.32
%Δ DWL to %Δ Oil Fund Tax (Subsidy)	2.16	1.82	1.57	1.38	1.22	1.10	1.00	0.99	0.89	0.80

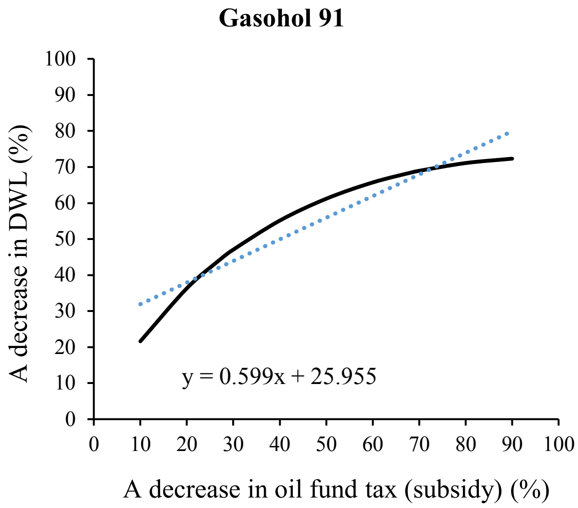


Figure 6.1 Deadweight Loss Elasticity to Oil Fund Tax (Subsidy): for Gasohol 91

Correspondingly, the second scenario analyzes the impact of a decrease in oil fund taxes (subsidies) on the deadweight losses in gasohol 95 consumption exhibited in Table 6.2 and Figure 6.2. It shows that (1) a decrease in the oil fund taxes (subsidies), of course, leads to a decrease in deadweight losses, (2) the speed of the percent decrease in the deadweight losses to the percent decrease in the oil fund taxes (subsidies) is slow down (a decreasing positive slope, see Figure 6.2), (3) the percent decrease in the deadweight losses are always greater than the percent decrease in the oil fund taxes (subsidies), for example, a ten percent decrease in the oil fund tax (subsidy) on gasohol 95 causes a 52.90 percent decrease in the deadweight loss, and (4) the deadweight loss elasticity to the oil fund tax (subsidy) is approximately 0.53.

Scenario 2: A Decrease in Oil Fund Taxes (Subsidies) on Gasohol 95 by Holding the Prices of the Other Fuels Constant.

Table 6.2 Deadweight Loss Elasticity to Oil Fund Tax (Subsidy): for Gasohol 95

A Decrease in Oil Fund Tax (Subsidy) (%)	10	20	30	40	50	60	70	80	90
A Decrease in DWL (%)	52.90	69.40	79.62	86.63	91.58	95.06	97.43	98.94	99.75
%Δ DWL to %Δ Oil Fund Tax (Subsidy)	5.29	3.47	2.65	2.17	1.83	1.58	1.39	1.24	1.11

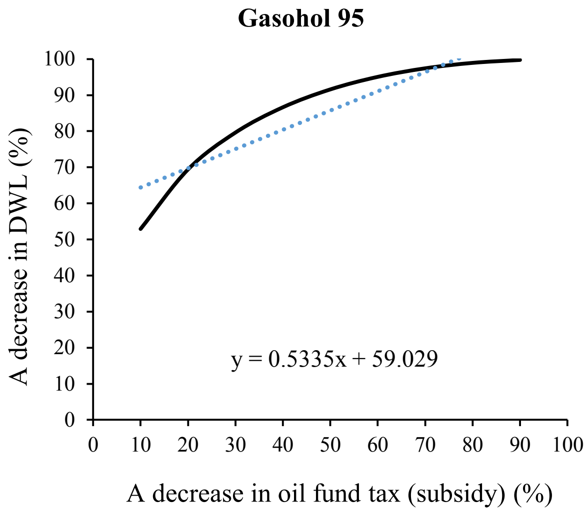


Figure 6.2 Deadweight Loss Elasticity to Oil Fund Tax (Subsidy): for Gasohol 95

Likewise, the third scenario analyzes the impact of a decrease in oil fund taxes (subsidies) on the deadweight losses in gasohol E20 consumption exhibited in Table 6.3 and Figure 6.3. It reveals that (1) similarly a decrease in the oil fund taxes (subsides) leads to a decrease in deadweight losses, (2) the percent decrease in the deadweight losses and the oil fund taxes (subsidies) are not considerably different, for example, a ten percent decrease in the oil fund tax (subsidy) on gasohol E20 causes a 15.68 percent decrease in the deadweight loss, and (3) the deadweight loss elasticity to the oil fund tax (subsidy) is approximately 1.05.

Scenario 3: A Decrease in Oil Fund Taxes (Subsidies) on Gasohol E20 by Holding the Prices of the Other Fuels Constant.

Table 6.3 Deadweight Loss Elasticity to Oil Fund Tax (Subsidy): for Gasohol E20

A Decrease in Oil Fund Tax (Subsidy) (%)	10	20	30	40	50	60	70	80	90
A Decrease in DWL (%)	15.68	30.51	44.39	57.19	68.77	78.94	87.47	94.09	98.42
%Δ DWL to %Δ Oil Fund Tax (Subsidy)	1.57	1.53	1.48	1.43	1.38	1.32	1.25	1.18	1.09

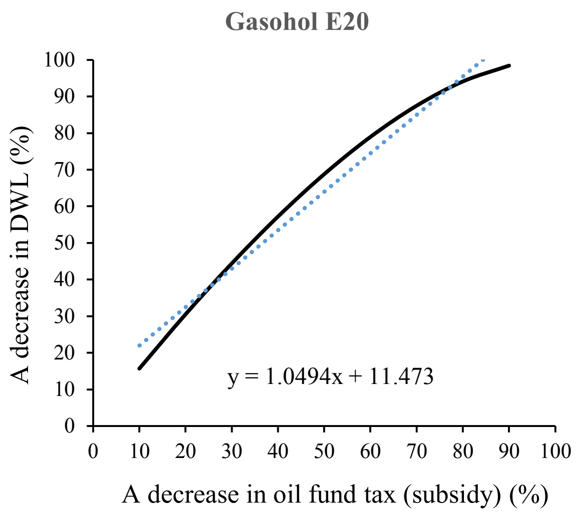


Figure 6.3 Deadweight Loss Elasticity to Oil Fund Tax (Subsidy): for Gasohol E20

Similarly, the fourth scenario analyzes the impact of a decrease in oil fund taxes (subsidies) on the deadweight losses in gasohol E85 consumption exhibited in Table 6.4 and Figure 6.4. It confirms that (1) a decrease in the oil fund taxes (subsidy) leads to a decrease in deadweight losses, (2) the percent decrease in deadweight losses and oil fund taxes (subsidies) are not largely different, for example, a ten percent decrease in oil fund tax (subsidy) on gasohol E85 causes a 12.46 percent decrease in deadweight loss, and (3) the deadweight loss elasticity to the oil fund tax (subsidy) is approximately 1.07.

Scenario 4: A Decrease in Oil Fund Taxes (Subsidies) on Gasohol E85 by Holding the Prices of the Other Fuels Constant.

Table 6.4 Deadweight Loss Elasticity to Oil Fund Tax (Subsidy): for Gasohol E85

A Decrease in Oil Fund Tax (Subsidy) (%)	10	20	30	40	50	60	70	80	90
A Decrease in DWL (%)	12.46	24.76	36.85	48.66	60.10	71.00	81.13	90.06	96.95
%Δ DWL to %Δ Oil Fund Tax (Subsidy)	1.25	1.24	1.23	1.22	1.20	1.18	1.16	1.13	1.08

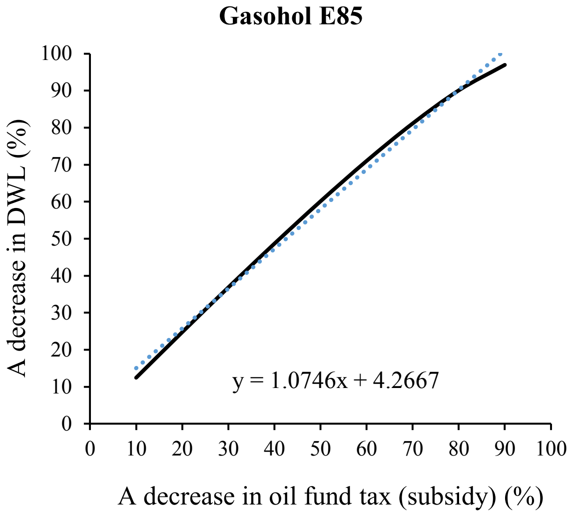


Figure 6.4 Deadweight Loss Elasticity to Oil Fund Tax (Subsidy): for Gasohol E85

6.2 Pricing Policy Implications

Since the chairman of the Ombudsman has proposed the dissolution of the Oil Fund, how the energy structural reform policy of the National Council for Peace and Order (NCPO) should be directed and enforced. The Oil Fund should be completely dissolved or not, as it causes the burden of higher fuel prices and cross price subsidies to the people. In particular, the Oil Fund aims to stabilize the domestic fuel prices impacted by world oil price volatility. But it also compensates for the price of LPG, allowing the domestic price lower than the world price. Moreover, the burden of cross price subsidy is transferred to gasoline users, which generates inequity and the excessive use of subsidized fuels.

In that case, if the Oil Fund is dissolved (as of 31 August 2015), the consequences are predictable as follows: (1) the prices of gasoline 95, gasohol 95, and high speed diesel will drop 6.15, 0.45, and 0.05 baht per liter, respectively; (2) the prices of gasohol 91, E20, and E85 will increase 0.05, 1.90, and 7.23 baht per liter, respectively; (3) the prices of LPG will fall 0.91 baht per kilogram; (4) cassava and sugarcane farmers, and ethanol industry will suffer from a decrease in product prices because of a drop in gasohol consumption; (5) the oil imports will rise due to the escalation of domestic gasoline consumption, as its price goes down; and (6) the fuel price stabilization mechanism will have no budget to subsidize the fuel prices, so the one way price stabilization (Thiraphong Vikitset, 2014) is an option—the method of price stabilization without an account deficit

6.2.1 The Advantages and disadvantages of dissolution of the Oil Fund.

In the dissertation, the advantages and disadvantages of dissolution of the Oil Fund are discussed. For too long, the government misuses the Oil Fund as a fuel price stabilization mechanism. The Oil Fund faces a debt burden which is partially transferred to the public, especially the gasoline users who pay for a cross price subsidy on fuel consumption.

Hence, the advantage of dissolution of the Oil Fund is to stop the added burden to the people. Besides, the gasoline price will decrease, whereas the prices of gasohol 91, E20, and E85 will upsurge. Moreover, the consumers will aware of the true costs of fuels and also consume fuels economically. Eventually, the fuel market will be efficient.

In contrast, the disadvantages of the dissolution can be described. First, the government will have no instruments to stabilize the domestic fuel prices during world oil price fluctuations. Second, a decrease in the gasoline price close to the gasohol prices will lead to a large decrease in gasohol consumption because the production costs of gasohol are more expensive than that of gasoline. And third, the policy of ethanol usage promotion through gasohol consumption will be affected by a huge drop in gasohol consumption.

6.2.2 The essential guidelines concerning the Oil Fund

With regard to the financial status of the Oil Fund, it had been negative for a long time and has just become positive since November 2014. It turns out to be 43,350 million baht in 30 August 2015 (EFAI, 2015b). In particular, the Oil Fund creates the total deadweight loss in domestic gasohol consumption for 2004-2013 at least 39,573.33 million baht. In this case, gasohol 95 consumption causes the highest total deadweight loss, while gasohol 91 consumption causes the second. Instead, the per unit deadweight loss in gasohol E85 consumption is highest, while it is lowest in gasohol E20.

Turning to the pricing policy scenario analysis, it obviously shows that a decrease in taxed or subsidies leads to a larger decrease in deadweight losses. So, the oil fund taxation and subsidy should be restructured to reduce market inefficiency. Besides, the oil fund tax on gasoline should be reduced because the gasoline price is levied at a much higher per unit rate than the gasohol prices and it also causes greater total deadweight loss to the economy. Moreover, the gasoline users should be relieved from the burden of cross price subsidies. However, the gasoline price should be higher than the gasohol prices to avoid the fuel switching from gasohol to gasoline because the energy per liter of gasoline is greater than that of gasohol (De Gorter and Just, 2008), so the vehicles consume more gasohol per kilometer driven than gasoline. In addition, the oil fund taxes (subsidies) on gasohol 91 and 95 should be abolished to make these two markets more efficient. The oil fund subsidies on gasohol E20 and E85 should be reduced to lower per unit deadweight losses, particularly on gasohol E85, which its per unit deadweight loss is up to 3.57 baht per liter. The right prices of gasohol E20 and E85 should be set in respect of the energy per liter per kilometer driven and the policy of gasohol usage promotion, which these aspects are beyond the scope of the dissertation. Above all, the Oil Fund should function as an instrument to stabilize fuel prices without the costs of subsidies and the burden to the public. The one way price stabilization could be as an alternative method to stabilize fuel prices instead of cross price subsidies. Besides, the optimal fuel price structure should be considered by integrating the externality components of fuel consumption, which also generate deadweight losses with price stabilizing components, and revenue generating components (Thiraphong Vikitset, 2014).

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

The dissertation examines the market efficiency of gasohol markets in terms of deadweight losses caused by government pricing policies (price stabilization via the Oil Fund) for 2004-2013. Consequently, the dissertation data are statistically analyzed by conducting the ADF tests. The results indicate that the time series data are non-stationary in levels, but stationary in first difference acceptable for cointegration tests. Thus, the dissertation data can be applied to the Johansen cointegration tests and the VECMs.

Accordingly, the results of cointegration tests indicate the existence of the long run equilibrium relationships between (1) the consumption and price of gasohol in all types, (2) the supply and price of ethanol, and (3) M1 and gasohol 95 consumption. Nevertheless, the normalized cointegrating coefficients and the ECMs display that the estimated price elasticities of ethanol supply are statistically insignificant in the short and long run. Yet, in the long run, a one percent increase in M1 leads to a rise in gasohol 95 consumption up to 3.56 percent, whereas it does not influence the consumption of gasohol 91, E20, and E85.

Similarly, the normalized cointegrating coefficient shows the significant price elasticity of gasohol 91 consumption equal to -6.46 in the long run. But, the ECM discloses the insignificant price elasticity of gasohol 91 consumption in the short run because the previous period consumption of gasohol 91 exists the significantly dominant factor of its current period consumption. Apparently, gasohol 91 users maintain their consumption behavior corresponding to the previous period consumption. Implying that, if the government targets to boost the use of gasohol E20 or E85 by increasing a tax on gasohol 91, the users will leisurely switch from gasohol 91 to gasohol E20 or E85.

In contrast, the normalized cointegrating coefficient indicates the insignificant price elasticity of gasohol 95 consumption (-6.06) in the long run. However the ECM suggests the significant price elasticity of gasohol 95 consumption equal to -2.58 in the short run, implying that gasohol 95 users promptly respond to the change in price of gasohol 95. Furthermore, the previous period consumption of gasohol 95 does not influence its current period consumption. Surely, the government could stimulate the use of gasohol 91, E20, and E85 by raising a tax on gasohol 95. Then, the users are likely to replace gasohol 95 by those products almost immediately.

Turning to gasohol E20, the normalized cointegrating coefficient reveals the price elasticity of gasohol E20 consumption equal to -12.04 in the long run. Nonetheless, the ECM indicates the insignificant price elasticity of gasohol E20 consumption and also no dominant factors affecting the consumption in the short run. So, the users do not hastily substitute the other fuels for gasohol E20 when its price climbs. Yet, they alter their consumption behavior in the long run (24 percent adjustment in each period). As a consequence, augmenting gasohol E20 consumption by the price subsidy is unanticipated as an effective process in the short run. But, once it adjusts to reach the long run, a one percent change in gasohol E20 price could prominently impact a change in consumption up to 12 percent. Thus, the government will be able to implement the price subsidy policy on gasohol E20 to boost its consumption in the long run.

In the same way, gasohol E85 consumption is found to be elastic to its own price of -4.70 in the long run. But, in the short run, the ECM indicates that the price coefficient of gasohol E85 does not have the expected negative sign in accord with the economic theory. When the price of gasohol E85 increases, its consumption also increases because: (1) In theory, gasohol E85 might be a giffen good that people consume more of it as its price rises and vice versa. A giffen good is so strongly an inferior good (being more in demand at lower income) that the net effect of the good's price rise is to increase demand for it. A rise in the price of gasohol E85 might force the poorer consumers to curtail their consumption of the more expensive fuels while gasohol E85 being still the cheapest fuel, which they can get and will take. So, they consume more gasohol E85, and not less of it. However, gasohol E85 is unlikely to be a giffen good because it is commonly used for flex-fuel vehicles which are expensive cars, generally not for the poor. And (2) it is caused by the model specification error from the missing variables of vehicles. The missing error occurs only in the case of gasohol E85 because gasohol E85 is merely used for flex-fuel vehicles which are a small and specific group. Thus, it is possible that the unexpected sign of the coefficient is affected by the specification error of the model. Besides, the price of gasohol 91 in previous period becomes a significant factor that dominates the change in consumption of gasohol E85, so the increase price of gasohol 91 cause gasohol 91 users switching to gasohol E85. In addition, the previous period consumption of gasohol E85 influences its current period consumption. Thus, the decrease price of gasohol E85 does not cause an increase in its consumption in the short run, but in the long run. Consequently, to augment gasohol E85 consumption, the price subsidy policy for gasohol E85 will not affect its consumption in the short run, but it will be effective in the long run. Still, enhancing a tax on gasohol 91 will be certainly effective to gasohol E85 consumption in the short run.

Regarding the substitution effects, in the long run, the results indicate that (1) gasoline 91 can substitute for gasohol 91, (2) gasohol 91 can substitute for gasohol 95, (3) gasohol 95 can replace gasohol E20 and E85, and (4) gasohol E20 can substitute for gasohol E85. Apparently, the cross price subsidy policies enormously impacts gasohol consumption.

In particular, the long run price elasticities of consumption are applied to calculate the deadweight losses in gasohol through a consumer and producer surplus approach. Under the circumstances, the calculation results of deadweight losses expose that: (1) deadweight loss in gasohol 91 consumption is highest at 820.17 million baht in 2009 and its total deadweight loss is 2937.63 million baht for 2005-2013; (2) the total deadweight loss in gasohol 95 consumption is conspicuously greater than the other types of gasohol for 2004-2013 (35611.81 million baht), whereas in 2008 its deadweight loss is dramatically high (12341.61 million baht) due to a huge increase in the oil fund tax (up to 16.04 percent of gasohol 95 price) in December 2008; (3) deadweight loss in gasohol E20 consumption is maximum at 160.03 million baht in 2013, and its total deadweight loss is 349.99 million baht for 2008-2013; and (4) deadweight loss in gasohol E85 consumption is topmost at 489.60 million baht in 2013 (increasing 3.52 times of the previous year), and its total deadweight loss is 673.90

million baht for 2009-2013. Comparatively, for 2009-2013 the total deadweight losses in gasohol 91, 95, E20, and E85 are 2348.09, 22861.09, 348.99, and 673.90 million baht, respectively. However, the per unit deadweight losses demonstrate that gasohol E85 consumption becomes the highest of 3.57 baht per liter while gasohol 91, 95, and E20 become 0.25, 1.21, and 0.19 baht per liter, respectively. In particular, the deadweight loss elasticities to oil fund tax (subsidy) reveal that a one percent change in the oil fund tax (subsidy) on gasohol 91, 95, E20, and E85 causes a change in deadweight losses of 0.60, 0.53, 1.05, and 1.07 percent, respectively.

7.2 Recommendations

The dissertation discloses that gasohol prices are elastic to its own consumption. Hence, the government pricing policy appear to be applicable to encourage gasohol consumption, however it causes market inefficiency. Theoretically, the deadweight loss will indeed escalate when the oil fund tax (subsidy) increases. For this reason, the oil fund tax on gasoline should be lowered because the gasoline price are exceedingly levied by the Oil Fund, while gasoline consumption is considerably greater than the consumption of gasohol, so it generates the remarkably high quantity of total deadweight loss in the fuel market. Also, gasoline users should be relieved from the burden of cross price subsidy. Nevertheless, the gasoline price should be greater than gasohol prices to avoid fuel switching from gasohol to gasoline because energy per liter of gasoline is higher than that of gasohol (De Gorter and Just, 2008), so a vehicle consumes more gasohol per kilometer driven than gasoline. Besides, if the gasoline prices are close to the gasohol prices, the gasohol users will rationally switch to gasoline. Concerning externalities, gasohol vehicles generally produce higher evaporative emissions than gasoline vehicles (Pitstick, 1992; Organization for Economic Co-operation and Development [OECD], 1995), whereas gasohol vehicles emit carbon monoxide, nitrogen oxides, and hydrocarbons less than gasoline vehicles (Branco, Costa, Farah and Szwarc, 1991; Air Quality Improvement Research Program [AQIRP], 1995). Moreover, oil fund taxation and subsidy on the prices of gasohol 91 and 95 should be abolished to make these two markets more efficient. Too, oil fund subsidies on the prices of gasohol E20 and E85 should be reduced to lessen the per unit deadweight losses, especially in gasohol E85, but their prices should be sufficiently attractive to gasohol usage promotion. Furthermore, in accordance with the initial intention of the Emergency Decree (1973), the Oil Fund functions as an instrument to maintain the retail price levels of domestic fuels and minimize the impacts of world oil price fluctuations on the economy. Thus, the Oil Fund should stabilize domestic fuel prices without the costs of subsidies and the burden to the government applying the one way price stabilization method (Thiraphong Vikitset, 2014), the method of price stabilization without an account deficit, instead of cross subsidies.

Nonetheless, the dissertation does not reckon the deadweight losses caused by the pricing policies on the consumption of gasoline, high speed diesel, and LPG, which largely create deadweight losses to the economy. Besides, comparing the deadweight losses affected by oil fund tax and other taxes (excise tax, municipal tax, and value-added tax) could provide relative contribution between the oil fund tax and the others. Above all, externality costs are excluded from the scope of the dissertation but appear to be the important aspect of economic efficiency which should be internalized in a fuel tax, such as the externality costs of local pollution from vehicle emissions containing particulate matter, sulfur dioxide, nitrogen oxide, volatile organic compound, and carbon monoxide (Thiraphong Vikitset, 2010). Including these aspects will be valuable for future study.

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APPENDICES

Appendix A

Descriptive Statistics and Correlation Matrix

Table A.1.1 Descriptive Statistics

Variable	LNCG91E10	LNCG95E10	LNCG95E20	LNCG95E85	LNCHSD	LNCUGR91	LNCULG95	LNPG91E10
Mean	-0.31	0.33	-1.61	-5.10	3.03	1.54	-0.62	3.37
Median	0.57	0.87	-1.50	-4.67	3.12	1.59	-0.08	3.40
Maximum	1.47	1.41	0.38	-1.33	3.34	1.85	1.48	3.65
Minimum	-5.77	-7.74	-5.45	-10.41	2.35	1.19	-3.21	2.78
Std. Dev.	1.72	1.50	1.24	2.56	0.26	0.22	1.71	0.20
Skewness	-1.26	-2.46	-0.60	-0.35	-1.11	-0.16	-0.23	-0.67
Kurtosis	3.82	10.05	3.60	2.04	2.88	1.37	1.44	2.92
Jarque-Bera	31.69	379.14	5.35	3.77	27.33	13.82	13.20	8.08
Probability	0.0000	0.0000	0.0690	0.1517	0.0000	0.0010	0.0014	0.0176
Observation	108	123	72	64	132	120	120	108

Table A.1.2 Descriptive Statistics

Variable	LNPG95E10	LNPG95E20	LNPG95E85	LNPHSD	LNPUGR91	LNPULG95	LNM1	LNSE	LNPE
Mean	3.34	3.41	3.03	3.18	3.35	3.45	9.65	-0.77	3.06
Median	3.37	3.45	3.06	3.30	3.38	3.53	9.62	-0.67	3.07
Maximum	3.70	3.63	3.18	3.75	3.82	3.89	10.10	0.30	3.37
Minimum	2.76	2.75	2.69	2.55	2.67	2.74	9.22	-2.40	2.73
Std. Dev.	0.27	0.17	0.10	0.29	0.33	0.36	0.24	0.63	0.16
Skewness	-0.53	-1.94	-0.96	-0.84	-0.49	-0.53	0.13	-0.58	-0.19
Kurtosis	2.28	7.23	3.96	2.44	2.11	2.01	1.88	2.84	2.16
Jarque-Bera	8.50	98.65	12.27	17.11	9.03	11.51	7.31	5.52	3.36
Probability	0.0143	0.0000	0.0022	0.0002	0.011	0.0032	0.0258	0.0633	0.1864
Observation	123	72	64	132	123	132	132	96	96

Table A.2.1 Correlation Matrix

Variable	LNCG91E10	LNCG95E10	LNCG95E20	LNCG95E85	LNCHSD	LNCUGR91	LNCULG95	LNPG91E10
LNCG91E10	1.00	-0.63	0.96	0.91	0.85	0.30	-0.83	0.69
LNCG95E10	-0.63	1.00	-0.70	-0.78	-0.77	-0.62	0.70	-0.62
LNCG95E20	0.96	-0.70	1.00	0.97	0.79	0.28	-0.87	0.81
LNCG95E85	0.91	-0.78	0.97	1.00	0.81	0.33	-0.91	0.85
LNCHSD	0.85	-0.77	0.79	0.81	1.00	0.47	-0.75	0.54
LNCUGR91	0.30	-0.62	0.28	0.33	0.47	1.00	-0.23	0.06
LNCULG95	-0.83	0.70	-0.87	-0.91	-0.75	-0.23	1.00	-0.74
LNPG91E10	0.69	-0.62	0.81	0.85	0.54	0.06	-0.74	1.00
LNPG95E10	0.73	-0.65	0.84	0.88	0.58	0.09	-0.78	1.00
LNPG95E20	0.67	-0.63	0.79	0.84	0.54	0.06	-0.76	1.00
LNPG95E85	0.70	-0.65	0.72	0.70	0.66	0.18	-0.66	0.78
LNPHSD	0.56	-0.54	0.69	0.75	0.45	0.06	-0.69	0.93
LNPUGR91	0.73	-0.56	0.83	0.85	0.58	-0.05	-0.77	0.97
LNPULG95	0.76	-0.49	0.84	0.85	0.57	-0.11	-0.77	0.94
LNM1	0.94	-0.76	0.96	0.97	0.88	0.36	-0.89	0.77
LNSE	0.70	-0.53	0.68	0.70	0.66	0.21	-0.55	0.61
LNPE	0.21	-0.11	0.28	0.32	0.13	-0.11	-0.44	0.39

Table A.2.2 Correlation Matrix

Variable	LNPG95E10	LNPG95E20	LNPG95E85	LNPHSD	LNPUGR91	LNPULG95	LNM1	LNSE	LNPE
LNCG91E10	0.73	0.67	0.70	0.56	0.73	0.76	0.94	0.70	0.21
LNCG95E10	-0.65	-0.63	-0.65	-0.54	-0.56	-0.49	-0.76	-0.53	-0.11
LNCG95E20	0.84	0.79	0.72	0.69	0.83	0.84	0.96	0.68	0.28
LNCG95E85	0.88	0.84	0.70	0.75	0.85	0.85	0.97	0.70	0.32
LNCHSD	0.58	0.54	0.66	0.45	0.58	0.57	0.88	0.66	0.13
LNCUGR91	0.09	0.06	0.18	0.06	-0.05	-0.11	0.36	0.21	-0.11
LNCULG95	-0.78	-0.76	-0.66	-0.69	-0.77	-0.77	-0.89	-0.55	-0.44
LNPG91E10	1.00	1.00	0.78	0.93	0.97	0.94	0.77	0.61	0.39
LNPG95E10	1.00	0.99	0.79	0.93	0.97	0.95	0.80	0.62	0.41
LNPG95E20	0.99	1.00	0.78	0.94	0.97	0.93	0.76	0.60	0.42
LNPG95E85	0.79	0.78	1.00	0.76	0.77	0.71	0.70	0.50	0.30
LNPHSD	0.93	0.94	0.76	1.00	0.93	0.85	0.66	0.45	0.48
LNPUGR91	0.97	0.97	0.77	0.93	1.00	0.98	0.78	0.61	0.38
LNPULG95	0.95	0.93	0.71	0.85	0.98	1.00	0.79	0.65	0.33
LNM1	0.80	0.76	0.70	0.66	0.78	0.79	1.00	0.69	0.29
LNSE	0.62	0.60	0.50	0.45	0.61	0.65	0.69	1.00	-0.01
LNPE	0.41	0.42	0.30	0.48	0.38	0.33	0.29	-0.01	1.00

Appendix B

Johansen Cointegration Tests

Table B.1 Johansen Cointegration Test of lnRGDP and lnRM1

Sample (adjusted): 1997Q4 2013Q4
Included observations: 65 after adjustments
Trend assumption: Linear deterministic trend
Series: LNRGDP LNRM1
Lags interval (in first differences): 1 to 2

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.234638	18.33121	15.49471	0.0182
At most 1	0.014506	0.949813	3.841466	0.3298

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.234638	17.38140	14.26460	0.0156
At most 1	0.014506	0.949813	3.841466	0.3298

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I):

LNRGDP	LNRM1
-24.82905	14.74927
9.279047	-1.568178

Unrestricted Adjustment Coefficients (alpha):

D(LNRGDP)	0.016879	-0.000204
D(LNRM1)	0.010208	-0.004740

1 Cointegrating Equation(s): Log likelihood 254.4215

Normalized cointegrating coefficients (standard error in parentheses)

LNRGDP	LNRM1
1.000000	-0.594033
	(0.03499)

Adjustment coefficients (standard error in parentheses)

D(LNRGDP)	-0.419101
	(0.09870)
D(LNRM1)	-0.253458
	(0.14048)

Table B.2 Johansen Cointegration Test of $\ln C_{G91E10}$, $\ln M1$, $\ln P_{G91E10}$, $\ln P_{UGR91}$

Date: 01/01/06 Time: 00:18
Sample (adjusted): 2005M04 2013M03
Included observations: 96 after adjustments
Trend assumption: Linear deterministic trend (restricted)
Series: LNCG91E10 LNM1 LNPG91E10 LNPUGR91
Lags interval (in first differences): 1 to 2

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.274425	74.24935	63.87610	0.0053
At most 1 *	0.233332	43.45342	42.91525	0.0441
At most 2	0.112311	17.94612	25.87211	0.3475
At most 3	0.065557	6.509288	12.51798	0.3985

Trace test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.274425	30.79593	32.11832	0.0719
At most 1	0.233332	25.50730	25.82321	0.0550
At most 2	0.112311	11.43683	19.38704	0.4693
At most 3	0.065557	6.509288	12.51798	0.3985

Max-eigenvalue test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I):

LNCG91E10	LNM1	LNPG91E10	LNPUGR91	@TREND(03M02)
2.019769	26.20734	13.04283	-26.24594	-0.158663
-1.526969	4.415895	-18.61636	17.62789	-0.004916
-0.779021	-27.71037	-0.634025	-5.244914	0.267876
-0.255714	-6.843448	19.00288	-19.93287	0.075600

Unrestricted Adjustment Coefficients (alpha):

D(LNCG91E10)	-0.023814	0.032237	0.009015	0.013324
D(LNM1)	-0.002378	-0.004521	0.007911	0.000410
D(LNPG91E10)	0.022742	0.008029	0.003782	-0.000296
D(LNPUGR91)	0.020000	0.003815	0.002934	0.003102

1 Cointegrating Equation(s):	Log likelihood	743.9702

Normalized cointegrating coefficients (standard error in parentheses)

LNCG91E10	LNM1	LNPG91E10	LNPUGR91	@TREND(03M02)
1.000000	12.97542	6.457583	-12.99453	-0.078555
	(2.78315)	(2.01707)	(2.39071)	(0.02177)

Adjustment coefficients (standard error in parentheses)

D(LNCG91E10)	-0.048098
	(0.02110)
D(LNM1)	-0.004802
	(0.00561)
D(LNPG91E10)	0.045934
	(0.00917)
D(LNPUGR91)	0.040395
	(0.00798)

2 Cointegrating Equation(s):	Log likelihood	756.7239

Normalized cointegrating coefficients (standard error in parentheses)

LNCG91E10	LNM1	LNPG91E10	LNPUGR91	@TREND(03M02)
1.000000	0.000000	11.14663	-11.80867	-0.011685
		(2.27187)	(2.76655)	(0.01077)
0.000000	1.000000	-0.361379	-0.091392	-0.005154
		(0.20918)	(0.25473)	(0.00099)

Adjustment coefficients (standard error in parentheses)

D(LNCG91E10)	-0.097323	-0.481733
	(0.02494)	(0.26181)
D(LNM1)	0.002101	-0.082272
	(0.00692)	(0.07261)
D(LNPG91E10)	0.033674	0.631475
	(0.01128)	(0.11844)
D(LNPUGR91)	0.034570	0.540989
	(0.00995)	(0.10447)

3 Cointegrating Equation(s):	Log likelihood	762.4423

Normalized cointegrating coefficients (standard error in parentheses)

LNCG91E10	LNM1	LNPG91E10	LNPUGR91	@TREND(03M02)
1.000000	0.000000	0.000000	-108.1336	0.646299
			(25.8095)	(0.19236)
0.000000	1.000000	0.000000	3.031510	-0.026486
			(0.78750)	(0.00587)
0.000000	0.000000	1.000000	8.641623	-0.059030
			(2.34932)	(0.01751)

Adjustment coefficients (standard error in parentheses)

D(LNCG91E10)	-0.104346	-0.731547	-0.916454
	(0.02597)	(0.37638)	(0.22291)
D(LNM1)	-0.004062	-0.301497	0.048133
	(0.00688)	(0.09965)	(0.05902)
D(LNPG91E10)	0.030728	0.526669	0.144756
	(0.01176)	(0.17039)	(0.10091)
D(LNPUGR91)	0.032284	0.459687	0.187977
	(0.01038)	(0.15043)	(0.08909)

Table B.3 Johansen Cointegration Test of $\ln C_{G95E10}$, $\ln M1$, $\ln P_{G91E10}$, $\ln P_{G95E10}$

Date: 01/01/06 Time: 00:30
Sample (adjusted): 2005M03 2013M12
Included observations: 106 after adjustments
Trend assumption: Linear deterministic trend
Series: LNCG95E10 LNM1 LNPG91E10 LNPG95E10
Lags interval (in first differences): 1 to 1

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.301350	72.61691	47.85613	0.0001
At most 1 *	0.185915	34.60480	29.79707	0.0129
At most 2	0.111180	12.80165	15.49471	0.1223
At most 3	0.002906	0.308462	3.841466	0.5786

Trace test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.301350	38.01211	27.58434	0.0016
At most 1 *	0.185915	21.80314	21.13162	0.0402
At most 2	0.111180	12.49319	14.26460	0.0935
At most 3	0.002906	0.308462	3.841466	0.5786

Max-eigenvalue test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I):

LNCG95E10	LNM1	LNPG91E10	LNPG95E10
1.921119	-6.839907	-5.658270	11.64429
1.329593	-0.121910	-47.85191	42.23319
-0.532713	-14.59680	-107.2374	112.8685
0.886404	-7.232231	-15.45464	15.13294

Unrestricted Adjustment Coefficients (alpha):

D(LNCG95E10)	-0.044968	-0.020572	0.006030	0.001236
D(LNM1)	0.001658	0.002279	0.002753	0.001365
D(LNPG91E10)	-0.012679	0.018156	-0.004831	-0.000265
D(LNPG95E10)	-0.011873	0.016723	-0.006761	-8.07E-05

1 Cointegrating Equation(s): Log likelihood 883.2353

Normalized cointegrating coefficients (standard error in parentheses)

LNCG95E10	LNM1	LNPG91E10	LNPG95E10
1.000000	-3.560376	-2.945299	6.061203
	(1.35050)	(9.34858)	(9.62009)

Adjustment coefficients (standard error in parentheses)

D(LNCG95E10)	-0.086388		
	(0.01699)		
D(LNM1)	0.003184		
	(0.00524)		
D(LNPG91E10)	-0.024359		
	(0.00937)		
D(LNPG95E10)	-0.022810		
	(0.00910)		

2 Cointegrating Equation(s): Log likelihood 894.1368

Normalized cointegrating coefficients (standard error in parentheses)

LNCG95E10	LNM1	LNPG91E10	LNPG95E10
1.000000	0.000000	-36.86337	32.44341
		(10.6758)	(9.92736)
0.000000	1.000000	-9.526541	7.409949
		(3.35697)	(3.12164)

Adjustment coefficients (standard error in parentheses)

D(LNCG95E10)	-0.113741	0.310082	
	(0.02009)	(0.05882)	
D(LNM1)	0.006214	-0.011616	
	(0.00635)	(0.01859)	
D(LNPG91E10)	-0.000219	0.084513	
	(0.01058)	(0.03098)	
D(LNPG95E10)	-0.000575	0.079174	
	(0.01036)	(0.03032)	

3 Cointegrating Equation(s): Log likelihood 900.3834

Normalized cointegrating coefficients (standard error in parentheses)

LNCG95E10	LNM1	LNPG91E10	LNPG95E10
1.000000	0.000000	0.000000	-0.591438
			(0.42974)
0.000000	1.000000	0.000000	-1.127193
			(0.12353)
0.000000	0.000000	1.000000	-0.896143
			(0.01694)

Adjustment coefficients (standard error in parentheses)

D(LNCG95E10)	-0.116954	0.222057	0.592178
	(0.02055)	(0.13827)	(1.00842)
D(LNM1)	0.004747	-0.051802	-0.413650
	(0.00648)	(0.04359)	(0.31787)
D(LNPG91E10)	0.002355	0.155037	-0.278949
	(0.01079)	(0.07258)	(0.52931)
D(LNPG95E10)	0.003027	0.177860	-0.008054
	(0.01050)	(0.07062)	(0.51503)

Table B.4 Johansen Cointegration Test of lnC_{G95E20}, lnP_{G95E10}, lnP_{G95E20}

Date: 01/01/06 Time: 00:42
Sample (adjusted): 2008M04 2013M12
Included observations: 69 after adjustments
Trend assumption: Linear deterministic trend (restricted)
Series: LNCG95E20 LNPG95E10 LNPG95E20
Lags interval (in first differences): 1 to 2

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.337225	60.65567	42.91525	0.0004
At most 1 *	0.288383	32.27466	25.87211	0.0069
At most 2	0.119736	8.799835	12.51798	0.1930

Trace test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.337225	28.38101	25.82321	0.0225
At most 1 *	0.288383	23.47483	19.38704	0.0120
At most 2	0.119736	8.799835	12.51798	0.1930

Max-eigenvalue test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I):

LNCG95E20	LNPG95E10	LNPG95E20	@TREND(03M02)
-5.118981	61.31570	-61.61955	0.178490
0.251827	44.51307	-34.50901	-0.133929
1.887945	45.18828	-46.69294	-0.131566

Unrestricted Adjustment Coefficients (alpha):

D(LNCG95E20)	0.046106	-0.013443	-0.015598
D(LNPG95E10)	0.003217	-0.018577	0.012960
D(LNPG95E20)	0.004103	-0.015432	0.015985

1 Cointegrating Equation(s):	Log likelihood	410.3525

Normalized cointegrating coefficients (standard error in parentheses)

LNCG95E20	LNPG95E10	LNPG95E20	@TREND(03M02)
1.000000	-11.97811	12.03746	-0.034868
	(2.76994)	(2.62901)	(0.00523)

Adjustment coefficients (standard error in parentheses)

D(LNCG95E20)	-0.236017		
	(0.05419)		
D(LNPG95E10)	-0.016470		
	(0.03355)		
D(LNPG95E20)	-0.021001		
	(0.03586)		

2 Cointegrating Equation(s):		Log likelihood	422.0899

Normalized cointegrating coefficients (standard error in parentheses)

LNCG95E20	LNPG95E10	LNPG95E20	@TREND(03M02)
1.000000	0.000000	2.576755	-0.066407
		(0.54872)	(0.00473)
0.000000	1.000000	-0.789833	-0.002633
		(0.03848)	(0.00033)

Adjustment coefficients (standard error in parentheses)

D(LNCG95E20)	-0.239403	2.228650
	(0.05354)	(0.79147)
D(LNPG95E10)	-0.021148	-0.629618
	(0.03130)	(0.46270)
D(LNPG95E20)	-0.024887	-0.435366
	(0.03444)	(0.50918)

Table B.5 Johansen Cointegration Test of $\ln C_{G95E85}$, $\ln P_{G91E10}$, $\ln P_{G95E10}$, $\ln P_{G95E20}$, $\ln P_{G95E85}$

Date: 01/01/06 Time: 00:46
Sample (adjusted): 2009M03 2013M12
Included observations: 58 after adjustments
Trend assumption: Linear deterministic trend (restricted)
Series: LNCG95E85 LNPG91E10 LNPG95E10 LNPG95E20 LNPG95E85
Lags interval (in first differences): 1 to 5

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.795066	171.9221	88.80380	0.0000
At most 1 *	0.462119	79.98828	63.87610	0.0012
At most 2 *	0.377491	44.02141	42.91525	0.0386
At most 3	0.183012	16.52954	25.87211	0.4508
At most 4	0.079521	4.805975	12.51798	0.6244

Trace test indicates 3 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.795066	91.93385	38.33101	0.0000
At most 1 *	0.462119	35.96687	32.11832	0.0161
At most 2 *	0.377491	27.49187	25.82321	0.0299
At most 3	0.183012	11.72357	19.38704	0.4413
At most 4	0.079521	4.805975	12.51798	0.6244

Max-eigenvalue test indicates 3 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I):

LNCG95E85	LNPG91E10	LNPG95E10	LNPG95E20	LNPG95E85	@TREND(03M02)
-25.81870	-474.2873	303.9015	234.2341	-121.4676	3.454635
13.80779	3.947930	-174.1901	65.84168	85.14707	-1.331983
-7.035166	-99.13046	60.13713	38.16738	12.36252	0.825280
3.797096	-67.14874	72.04473	-39.55538	15.18306	-0.423585
-0.773574	43.34980	-49.48722	4.314387	-16.73036	0.146891

Unrestricted Adjustment Coefficients (alpha):

D(LNCG95E85)	0.025586	-0.027403	0.019494	-0.016837	0.012785
D(LNPG91E10)	0.012945	-0.004320	-0.001738	0.005177	0.001236
D(LNPG95E10)	0.011802	-0.002680	-0.003279	0.004223	0.002518
D(LNPG95E20)	0.011016	-0.007030	-0.002946	0.006174	0.001473
D(LNPG95E85)	0.012505	-0.003104	-0.014555	0.006053	0.000118

1 Cointegrating Equation(s):		Log likelihood	855.1409		
Normalized cointegrating coefficients (standard error in parentheses)					
LNCG95E85	LNPG91E10	LNPG95E10	LNPG95E20	LNPG95E85	@TREND(03M02)
1.000000	18.36992	-11.77060	-9.072267	4.704638	-0.133804
	(0.94217)	(0.49918)	(0.60545)	(0.18255)	(0.00166)
Adjustment coefficients (standard error in parentheses)					
D(LNCG95E85)	-0.660587				
	(0.37111)				
D(LNPG91E10)	-0.334229				
	(0.07437)				
D(LNPG95E10)	-0.304716				
	(0.07435)				
D(LNPG95E20)	-0.284418				
	(0.09237)				
D(LNPG95E85)	-0.322867				
	(0.13301)				

2 Cointegrating Equation(s):		Log likelihood	873.1243		
Normalized cointegrating coefficients (standard error in parentheses)					
LNCG95E85	LNPG91E10	LNPG95E10	LNPG95E20	LNPG95E85	@TREND(03M02)
1.000000	0.000000	-12.62870	4.987275	6.189710	-0.095876
		(1.75510)	(1.43580)	(0.70650)	(0.00415)
0.000000	1.000000	0.046712	-0.765357	-0.080843	-0.002065
		(0.09852)	(0.08060)	(0.03966)	(0.00023)
Adjustment coefficients (standard error in parentheses)					
D(LNCG95E85)	-1.038956	-12.24311			
	(0.39541)	(6.40547)			
D(LNPG91E10)	-0.393876	-6.156810			
	(0.08122)	(1.31573)			
D(LNPG95E10)	-0.341716	-5.608193			
	(0.08313)	(1.34664)			
D(LNPG95E20)	-0.381486	-5.252490			
	(0.09801)	(1.58768)			
D(LNPG95E85)	-0.365730	-5.943303			
	(0.14995)	(2.42917)			

3 Cointegrating Equation(s):		Log likelihood	886.8703		
Normalized cointegrating coefficients (standard error in parentheses)					
LNCG95E85	LNPG91E10	LNPG95E10	LNPG95E20	LNPG95E85	@TREND(03M02)
1.000000	0.000000	0.000000	6.359644	-18.93115	-0.067608
			(3.52292)	(5.67080)	(0.01974)
0.000000	1.000000	0.000000	-0.770433	0.012077	-0.002169
			(0.02576)	(0.04146)	(0.00014)
0.000000	0.000000	1.000000	0.108671	-1.989188	0.002238
			(0.28033)	(0.45124)	(0.00157)
Adjustment coefficients (standard error in parentheses)					
D(LNCG95E85)	-1.176096	-14.17551	13.72105		
	(0.39276)	(6.32015)	(4.63568)		
D(LNPG91E10)	-0.381652	-5.984566	4.582056		
	(0.08300)	(1.33563)	(0.97965)		
D(LNPG95E10)	-0.318649	-5.283160	3.856276		
	(0.08364)	(1.34582)	(0.98713)		
D(LNPG95E20)	-0.360762	-4.960478	4.395165		
	(0.09953)	(1.60160)	(1.17474)		

D(LNPG95E85)	-0.263331	-4.500423	3.465757		
	(0.13262)	(2.13401)	(1.56525)		

4 Cointegrating Equation(s):		Log likelihood	892.7321

Normalized cointegrating coefficients (standard error in parentheses)

LNCG95E85	LNPG91E10	LNPG95E10	LNPG95E20	LNPG95E85	@TREND(03M02)
1.000000	0.000000	0.000000	0.000000	-7.003536	-0.092052
				(2.23659)	(0.01028)
0.000000	1.000000	0.000000	0.000000	-1.432882	0.000792
				(0.26019)	(0.00120)
0.000000	0.000000	1.000000	0.000000	-1.785374	0.001821
				(0.30420)	(0.00140)
0.000000	0.000000	0.000000	1.000000	-1.875515	0.003844
				(0.35586)	(0.00164)

Adjustment coefficients (standard error in parentheses)

D(LNCG95E85)	-1.240030	-13.04490	12.50800	5.598816
	(0.38509)	(6.20669)	(4.60108)	(3.16491)
D(LNPG91E10)	-0.361996	-6.332179	4.955014	2.476701
	(0.07876)	(1.26936)	(0.94099)	(0.64727)
D(LNPG95E10)	-0.302614	-5.566720	4.160512	2.295856
	(0.08109)	(1.30705)	(0.96893)	(0.66649)
D(LNPG95E20)	-0.337319	-5.375053	4.839967	1.760811
	(0.09451)	(1.52320)	(1.12917)	(0.77671)
D(LNPG95E85)	-0.240347	-4.906884	3.901854	1.929775
	(0.12953)	(2.08773)	(1.54766)	(1.06458)

Table B.6 Johansen Cointegration Test of lnS_E, lnP_E, lnP_{G95E10}, lnP_{G95E20}, lnP_{ULG95}

Date: 01/01/06 Time: 00:51
Sample (adjusted): 2008M04 2013M12
Included observations: 69 after adjustments
Trend assumption: Linear deterministic trend
Series: LNSE LNPE LNPG95E10 LNPG95E20 LNPULG95
Lags interval (in first differences): 1 to 2

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.346770	74.14623	69.81889	0.0216
At most 1	0.254061	44.76424	47.85613	0.0948
At most 2	0.231436	24.53959	29.79707	0.1786
At most 3	0.075949	6.376593	15.49471	0.6510
At most 4	0.013336	0.926400	3.841466	0.3358

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.346770	29.38199	33.87687	0.1567
At most 1	0.254061	20.22465	27.58434	0.3258
At most 2	0.231436	18.16299	21.13162	0.1239
At most 3	0.075949	5.450193	14.26460	0.6843
At most 4	0.013336	0.926400	3.841466	0.3358

Max-eigenvalue test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I):

LNSE	LNPE	LNPG95E10	LNPG95E20	LNPULG95
4.162903	-0.884120	-69.80354	64.16956	10.01071
3.183550	5.994647	-7.575667	14.85100	-21.71141
1.181462	3.378491	-12.27204	-2.108335	14.46790
-2.079552	7.611465	-12.27160	14.88327	0.389024
-1.587551	-1.541162	-16.18655	10.80292	6.166903

Unrestricted Adjustment Coefficients (alpha):

D(LNSE)	-0.114566	-0.022371	-0.002919	0.026472	0.009045
D(LNPE)	-0.001910	-0.018419	-0.010653	-0.013748	0.000805
D(LNPG95E10)	-0.017837	0.010975	0.009915	-0.006227	-0.000325
D(LNPG95E20)	-0.020325	0.011826	0.007306	-0.006819	-0.000965
D(LNPULG95)	-0.013863	0.015133	0.000225	-0.004283	0.000892

1 Cointegrating Equation(s): Log likelihood 616.8970

Normalized cointegrating coefficients (standard error in parentheses)

LNSE	LNPE	LNPG95E10	LNPG95E20	LNPULG95
1.000000	-0.212381	-16.76800	15.41462	2.404742
	(0.45262)	(2.51957)	(2.28240)	(1.24041)

Adjustment coefficients (standard error in parentheses)

D(LNSE)	-0.476926
	(0.11313)
D(LNPE)	-0.007951
	(0.03645)
D(LNPG95E10)	-0.074254
	(0.02476)
D(LNPG95E20)	-0.084611
	(0.02610)
D(LNPULG95)	-0.057709
	(0.02181)

2 Cointegrating Equation(s): Log likelihood 627.0094

Normalized cointegrating coefficients (standard error in parentheses)

LNSE	LNPE	LNPG95E10	LNPG95E20	LNPULG95
1.000000	0.000000	-15.30964	14.32507	1.469769
		(2.29520)	(2.06416)	(1.07521)
0.000000	1.000000	6.866684	-5.130171	-4.402343
		(2.29493)	(2.06392)	(1.07508)

Adjustment coefficients (standard error in parentheses)

D(LNSE)	-0.548144	-0.032814
	(0.14156)	(0.16368)
D(LNPE)	-0.066590	-0.108729
	(0.04407)	(0.05096)
D(LNPG95E10)	-0.039314	0.081562
	(0.03023)	(0.03495)
D(LNPG95E20)	-0.046962	0.088864
	(0.03182)	(0.03679)
D(LNPULG95)	-0.009531	0.102974
	(0.02537)	(0.02933)

3 Cointegrating Equation(s): Log likelihood 636.0909

Normalized cointegrating coefficients (standard error in parentheses)

LNSE	LNPE	LNPG95E10	LNPG95E20	LNPULG95
1.000000	0.000000	0.000000	15.82282	-22.84196
			(3.80400)	(4.92598)
0.000000	1.000000	0.000000	-5.801945	6.501957
			(1.52180)	(1.97065)
0.000000	0.000000	1.000000	0.097831	-1.588001
			(0.24529)	(0.31763)

Adjustment coefficients (standard error in parentheses)

D(LNSE)	-0.551592	-0.042674	8.202389
	(0.14510)	(0.18739)	(1.92520)
D(LNPE)	-0.079176	-0.144720	0.403595
	(0.04454)	(0.05751)	(0.59089)
D(LNPG95E10)	-0.027600	0.115058	1.040275
	(0.03017)	(0.03896)	(0.40032)
D(LNPG95E20)	-0.038330	0.113547	1.239511
	(0.03220)	(0.04159)	(0.42727)
D(LNPULG95)	-0.009266	0.103733	0.850258
	(0.02601)	(0.03358)	(0.34504)

4 Cointegrating Equation(s):		Log likelihood	638.8160	
Normalized cointegrating coefficients (standard error in parentheses)				
LNSE	LNPE	LNPG95E10	LNPG95E20	LNPULG95
1.000000	0.000000	0.000000	0.000000	-3.122566
				(0.73682)
0.000000	1.000000	0.000000	0.000000	-0.728790
				(0.27880)
0.000000	0.000000	1.000000	0.000000	-1.466078
				(0.11668)
0.000000	0.000000	0.000000	1.000000	-1.246263
				(0.13092)
Adjustment coefficients (standard error in parentheses)				
D(LNSE)	-0.606642	0.158817	7.877535	-7.283718
	(0.15428)	(0.27582)	(1.93699)	(1.80932)
D(LNPE)	-0.050586	-0.249365	0.572310	-0.578273
	(0.04659)	(0.08329)	(0.58494)	(0.54638)
D(LNPG95E10)	-0.014650	0.067658	1.116696	-1.095194
	(0.03200)	(0.05721)	(0.40180)	(0.37532)
D(LNPG95E20)	-0.024150	0.061646	1.323189	-1.245508
	(0.03414)	(0.06103)	(0.42860)	(0.40035)
D(LNPULG95)	-0.000360	0.071136	0.902812	-0.729026
	(0.02769)	(0.04951)	(0.34771)	(0.32479)

Appendix C

Vector Error Correction Models

Table C.1 A Vector Error Correction Model of Gasohol 91

Vector Error Correction Estimates
Date: 01/01/06 Time: 00:58
Sample (adjusted): 2005M04 2013M03
Included observations: 96 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1			
LNCG91E10(-1)	1.000000			
LNM1(-1)	12.97542 (2.78315) [4.66213]			
LNPG91E10(-1)	6.457583 (2.01707) [3.20147]			
LNPUGR91(-1)	-12.99453 (2.39071) [-5.43543]			
@TREND(03M01)	-0.078555 (0.02177) [-3.60856]			
C	-95.95744			
Error Correction:	**D(LNCG91E10)**	**D(LNM1)**	**D(LNPG91E10)**	**D(LNPUGR91)**
CointEq1	-0.048098 (0.02110) [-2.27961]	-0.004802 (0.00561) [-0.85670]	0.045934 (0.00917) [5.00948]	0.040395 (0.00798) [5.06036]
D(LNCG91E10(-1))	0.332969 (0.09359) [3.55763]	0.000144 (0.02486) [0.00577]	0.127437 (0.04067) [3.13308]	0.114790 (0.03541) [3.24175]
D(LNCG91E10(-2))	0.102866 (0.09187) [1.11972]	-0.000153 (0.02441) [-0.00629]	-0.085617 (0.03992) [-2.14444]	-0.080367 (0.03476) [-2.31225]
D(LNM1(-1))	0.666449 (0.46275) [1.44019]	-0.172780 (0.12294) [-1.40543]	-0.346287 (0.20111) [-1.72190]	-0.355232 (0.17508) [-2.02901]

D(LNM1(-2))	-0.313085	-0.178499	-0.163044	-0.153200
	(0.44867)	(0.11920)	(0.19499)	(0.16975)
	[-0.69780]	[-1.49750]	[-0.83616]	[-0.90249]
D(LNPG91E10(-1))	0.778311	0.187863	-0.212769	-0.493400
	(0.65333)	(0.17357)	(0.28393)	(0.24718)
	[1.19129]	[1.08235]	[-0.74936]	[-1.99609]
D(LNPG91E10(-2))	-0.111510	0.095650	-0.087513	-0.023961
	(0.69111)	(0.18361)	(0.30035)	(0.26148)
	[-0.16135]	[0.52095]	[-0.29137]	[-0.09164]
D(LNPUGR91(-1))	-0.590630	-0.225689	0.867292	1.105528
	(0.73425)	(0.19507)	(0.31910)	(0.27780)
	[-0.80440]	[-1.15699]	[2.71794]	[3.97964]
D(LNPUGR91(-2))	0.137788	-0.169936	-0.051559	-0.052475
	(0.81444)	(0.21637)	(0.35395)	(0.30813)
	[0.16918]	[-0.78540]	[-0.14567]	[-0.17030]
C	0.030919	0.009729	0.001580	0.003167
	(0.01279)	(0.00340)	(0.00556)	(0.00484)
	[2.41809]	[2.86404]	[0.28431]	[0.65456]
R-squared	0.346461	0.112558	0.515940	0.528135
Adj. R-squared	0.278067	0.019686	0.465283	0.478753
Sum sq. resids	0.900940	0.063588	0.170161	0.128962
S.E. equation	0.102353	0.027192	0.044482	0.038724
F-statistic	5.065688	1.211967	10.18490	10.69505
Log likelihood	87.87782	215.1268	167.8792	181.1861
Akaike AIC	-1.622455	-4.273476	-3.289150	-3.566377
Schwarz SC	-1.355335	-4.006356	-3.022030	-3.299257
Mean dependent	0.064697	0.006144	0.006420	0.008054
S.D. dependent	0.120462	0.027463	0.060830	0.053636

Determinant resid covariance (dof adj.)	3.39E-12
Determinant resid covariance	2.18E-12
Log likelihood	743.9702
Akaike information criterion	-14.56188
Schwarz criterion	-13.35984

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.688097	Prob. F(32,55)	0.871184
Obs*R-squared	27.73146	Prob. Chi-Square(32)	0.682576

White Heteroskedasticity Test:

F-statistic	1.566549	Prob. F(24,72)	0.074726
Obs*R-squared	33.27573	Prob. Chi-Square(24)	0.098388

Table C.2 A Vector Error Correction Model of Gasohol 95

Vector Error Correction Estimates
Date: 01/01/06 Time: 01:10
Sample (adjusted): 2005M03 2013M12
Included observations: 106 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1
LNCG95E10(-1)	1.000000
LNM1(-1)	-3.560376
	(1.35050)
	[-2.63633]
LNPG91E10(-1)	-2.945299
	(9.34858)
	[-0.31505]
LNPG95E10(-1)	6.061203
	(9.62009)
	[0.63006]
C	23.02850

Error Correction:	D(LNCG95E10)	D(LNM1)	D(LNPG91E10)	D(LNPG95E10)
CointEq1	-0.086388	0.003184	-0.024359	-0.022810
	(0.01699)	(0.00524)	(0.00937)	(0.00910)
	[-5.08605]	[0.60778]	[-2.59903]	[-2.50617]
D(LNCG95E10(-1))	0.154359	-0.008537	0.017747	0.013259
	(0.08846)	(0.02729)	(0.04881)	(0.04740)
	[1.74503]	[-0.31288]	[0.36360]	[0.27973]
D(LNM1(-1))	0.022317	-0.155467	0.164650	0.160744
	(0.33148)	(0.10225)	(0.18291)	(0.17763)
	[0.06733]	[-1.52042]	[0.90018]	[0.90496]
D(LNPG91E10(-1))	2.575759	-0.022605	-0.448720	-0.018236
	(1.05710)	(0.32608)	(0.58329)	(0.56644)
	[2.43663]	[-0.06932]	[-0.76929]	[-0.03219]
D(LNPG95E10(-1))	-2.577046	-0.013484	0.960459	0.486673
	(1.10038)	(0.33943)	(0.60717)	(0.58963)
	[-2.34197]	[-0.03972]	[1.58186]	[0.82538]

C	0.023582	0.007274	0.001426	0.002447
	(0.00950)	(0.00293)	(0.00524)	(0.00509)
	[2.48295]	[2.48289]	[0.27218]	[0.48086]
R-squared	0.388117	0.037947	0.305196	0.288675
Adj. R-squared	0.357523	-0.010155	0.270456	0.253109
Sum sq. resids	0.828599	0.078844	0.252281	0.237918
S.E. equation	0.091027	0.028079	0.050228	0.048777
F-statistic	12.68599	0.788880	8.785103	8.116545
Log likelihood	106.7198	231.3899	169.7471	172.8538
Akaike AIC	-1.900374	-4.252639	-3.089568	-3.148185
Schwarz SC	-1.749613	-4.101879	-2.938807	-2.997424
Mean dependent	0.027609	0.005912	0.006573	0.006991
S.D. dependent	0.113565	0.027938	0.058805	0.056440

Determinant resid covariance (dof adj.)	8.59E-13
Determinant resid covariance	6.80E-13
Log likelihood	883.2353
Akaike information criterion	-16.13651
Schwarz criterion	-15.43296

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.910838	Prob. F(35,65)	0.611064
Obs*R-squared	34.88059	Prob. Chi-Square(35)	0.473879

White Heteroskedasticity Test:

F-statistic	2.117057	Prob. F(35,70)	0.003883
Obs*R-squared	54.50691	Prob. Chi-Square(35)	0.018888

Table C.3 A Vector Error Correction Model of Gasohol E20

Vector Error Correction Estimates
Date: 01/01/06 Time: 01:20
Sample (adjusted): 2008M04 2013M12
Included observations: 69 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1		
LNCG95E20(-1)	1.000000		
LNPG95E10(-1)	-11.97811		
	(2.76994)		
	[-4.32432]		
LNPG95E20(-1)	12.03746		
	(2.62901)		
	[4.57870]		
@TREND(03M01)	-0.034868		
	(0.00523)		
	[-6.66712]		
C	5.830720		
Error Correction:	**D(LNCG95E20)**	**D(LNPG95E10)**	**D(LNPG95E20)**
CointEq1	-0.236017	-0.016470	-0.021001
	(0.05419)	(0.03355)	(0.03586)
	[-4.35514]	[-0.49096]	[-0.58569]
D(LNCG95E20(-1))	0.028070	0.127394	0.151710
	(0.11734)	(0.07264)	(0.07764)
	[0.23922]	[1.75383]	[1.95409]
D(LNCG95E20(-2))	0.089295	-0.079210	-0.091035
	(0.10638)	(0.06585)	(0.07038)
	[0.83943]	[-1.20288]	[-1.29343]
D(LNPG95E10(-1))	-2.299025	0.724987	0.669680
	(1.18830)	(0.73560)	(0.78623)
	[-1.93471]	[0.98557]	[0.85176]
D(LNPG95E10(-2))	-1.088015	0.476250	0.456402
	(1.18928)	(0.73621)	(0.78688)
	[-0.91485]	[0.64690]	[0.58002]
D(LNPG95E20(-1))	2.084366	-0.123456	-0.020561
	(1.11391)	(0.68955)	(0.73701)
	[1.87121]	[-0.17904]	[-0.02790]
D(LNPG95E20(-2))	1.378230	-0.635885	-0.661897
	(1.10508)	(0.68408)	(0.73117)
	[1.24718]	[-0.92954]	[-0.90526]
C	0.061407	-0.001724	-0.003451
	(0.01428)	(0.00884)	(0.00945)

	[4.30058]	[-0.19504]	[-0.36532]
R-squared	0.413292	0.338686	0.350488
Adj. R-squared	0.345965	0.262798	0.275954
Sum sq. resids	0.471732	0.180770	0.206510
S.E. equation	0.087939	0.054437	0.058184
F-statistic	6.138566	4.462952	4.702388
Log likelihood	74.09131	107.1833	102.5905
Akaike AIC	-1.915690	-2.874877	-2.741752
Schwarz SC	-1.656663	-2.615851	-2.482725
Mean dependent	0.067700	0.004068	0.003146
S.D. dependent	0.108738	0.063402	0.068379
Determinant resid covariance (dof adj.)		1.98E-09	
Determinant resid covariance		1.37E-09	
Log likelihood		410.3525	
Akaike information criterion		-11.08268	
Schwarz criterion		-10.17609	

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	1.652457	Prob. F(23,38)	0.083059
Obs*R-squared	34.50296	Prob. Chi-Square(23)	0.058227

White Heteroskedasticity Test:

F-statistic	2.767927	Prob. F(18,50)	0.002348
Obs*R-squared	34.43872	Prob. Chi-Square(18)	0.011112

Table C.4 A Vector Error Correction Model of Gasohol E85

Vector Error Correction Estimates
Date: 01/01/06 Time: 01:26
Sample (adjusted): 2009M03 2013M12
Included observations: 58 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1
LNCG95E85(-1)	1.000000
LNPG91E10(-1)	18.36992
	(0.94217)
	[19.4974]
LNPG95E10(-1)	-11.77060
	(0.49918)
	[-23.5798]
LNPG95E20(-1)	-9.072267
	(0.60545)
	[-14.9843]
LNPG95E85(-1)	4.704638
	(0.18255)
	[25.7712]
@TREND(03M01)	-0.133804
	(0.00166)
	[-80.7093]
C	13.04515

Error Correction:	D(LNCG95E85)	D(LNPG91E10)	D(LNPG95E10)	D(LNPG95E20)	D(LNPG95E85)
CointEq1	-0.660587	-0.334229	-0.304716	-0.284418	-0.322867
	(0.37111)	(0.07437)	(0.07435)	(0.09237)	(0.13301)
	[-1.78001]	[-4.49412]	[-4.09839]	[-3.07915]	[-2.42734]
D(LNCG95E85(-1))	0.151953	0.347459	0.335121	0.315344	0.402061
	(0.38867)	(0.07789)	(0.07787)	(0.09674)	(0.13931)
	[0.39095]	[4.46094]	[4.30369]	[3.25971]	[2.88616]
D(LNCG95E85(-2))	0.909427	0.311792	0.294683	0.248804	0.236874
	(0.43313)	(0.08680)	(0.08677)	(0.10780)	(0.15524)
	[2.09968]	[3.59219]	[3.39598]	[2.30794]	[1.52587]
D(LNCG95E85(-3))	0.687596	0.304089	0.284271	0.248249	0.301706
	(0.41633)	(0.08343)	(0.08341)	(0.10362)	(0.14922)
	[1.65158]	[3.64481]	[3.40819]	[2.39571]	[2.02192]
D(LNCG95E85(-4))	0.825812	0.201268	0.190257	0.174654	0.164956
	(0.38239)	(0.07663)	(0.07661)	(0.09518)	(0.13706)
	[2.15959]	[2.62646]	[2.48345]	[1.83505]	[1.20357]
D(LNCG95E85(-5))	0.435587	0.035958	0.026811	-0.002122	0.051859
	(0.26434)	(0.05297)	(0.05296)	(0.06579)	(0.09474)

	[1.64781]	[0.67880]	[0.50625]	[-0.03225]	[0.54735]
D(LNPG91E10(-1))	7.032388	3.326958	3.126214	2.224399	3.207943
	(5.60519)	(1.12326)	(1.12296)	(1.39511)	(2.00898)
	[1.25462]	[2.96187]	[2.78390]	[1.59442]	[1.59680]
D(LNPG91E10(-2))	17.63120	4.316816	4.513979	4.460145	3.115382
	(5.28275)	(1.05865)	(1.05836)	(1.31486)	(1.89342)
	[3.33750]	[4.07766]	[4.26505]	[3.39211]	[1.64538]
D(LNPG91E10(-3))	-1.947149	2.373700	1.545047	1.532975	2.043831
	(5.69651)	(1.14157)	(1.14126)	(1.41784)	(2.04171)
	[-0.34181]	[2.07934]	[1.35381]	[1.08120]	[1.00104]
D(LNPG91E10(-4))	3.160331	1.509824	1.981998	1.531537	2.093907
	(4.49593)	(0.90097)	(0.90073)	(1.11902)	(1.61141)
	[0.70293]	[1.67577]	[2.20044]	[1.36864]	[1.29943]
D(LNPG91E10(-5))	3.239074	-0.647416	-0.875254	-1.183392	-0.830011
	(4.05161)	(0.81193)	(0.81171)	(1.00843)	(1.45216)
	[0.79945]	[-0.79738]	[-1.07828]	[-1.17350]	[-0.57157]
D(LNPG95E10(-1))	-9.539095	-2.948753	-2.946529	-2.456222	-2.748871
	(4.66627)	(0.93511)	(0.93486)	(1.16142)	(1.67246)
	[-2.04427]	[-3.15339]	[-3.15186]	[-2.11485]	[-1.64361]
D(LNPG95E10(-2))	-11.94715	-3.316581	-2.980497	-2.932968	-2.084420
	(4.18565)	(0.83879)	(0.83857)	(1.04179)	(1.50020)
	[-2.85431]	[-3.95399]	[-3.55428]	[-2.81531]	[-1.38943]
D(LNPG95E10(-3))	-2.927210	-2.317155	-2.131796	-1.902539	-2.129491
	(4.02247)	(0.80609)	(0.80587)	(1.00118)	(1.44171)
	[-0.72771]	[-2.87455]	[-2.64532]	[-1.90030]	[-1.47706]
D(LNPG95E10(-4))	-1.453540	-0.582606	-0.614991	-0.363768	-0.810588
	(3.18430)	(0.63812)	(0.63795)	(0.79256)	(1.14130)
	[-0.45647]	[-0.91300]	[-0.96401]	[-0.45898]	[-0.71023]
D(LNPG95E10(-5))	0.155521	0.271093	0.305273	0.630960	0.504212
	(2.56572)	(0.51416)	(0.51402)	(0.63860)	(0.91959)
	[0.06062]	[0.52725]	[0.59389]	[0.98804]	[0.54830]
D(LNPG95E20(-1))	2.499237	-1.205143	-1.003484	-0.428606	-1.633623
	(3.19985)	(0.64124)	(0.64107)	(0.79643)	(1.14687)
	[0.78105]	[-1.87939]	[-1.56533]	[-0.53816]	[-1.42441]
D(LNPG95E20(-2))	-8.755614	-2.064804	-2.458489	-2.425944	-1.514657
	(3.45387)	(0.69215)	(0.69196)	(0.85966)	(1.23792)
	[-2.53501]	[-2.98319]	[-3.55293]	[-2.82199]	[-1.22355]
D(LNPG95E20(-3))	3.691184	-0.754462	-0.103623	-0.135873	-0.928752
	(4.03775)	(0.80915)	(0.80894)	(1.00498)	(1.44719)
	[0.91417]	[-0.93241]	[-0.12810]	[-0.13520]	[-0.64176]
D(LNPG95E20(-4))	-3.385041	-1.394436	-1.792795	-1.559354	-1.628024
	(3.20748)	(0.64277)	(0.64260)	(0.79833)	(1.14961)
	[-1.05536]	[-2.16941]	[-2.78992]	[-1.95327]	[-1.41615]
D(LNPG95E20(-5))	-3.250422	0.421441	0.644662	0.740892	0.289147
	(2.91765)	(0.58469)	(0.58453)	(0.72619)	(1.04573)
	[-1.11406]	[0.72079]	[1.10287]	[1.02024]	[0.27650]

D(LNPG95E85(-1))	-0.474501	1.075117	0.991273	0.878629	1.448012
	(1.63764)	(0.32818)	(0.32809)	(0.40760)	(0.58695)
	[-0.28975]	[3.27601]	[3.02135]	[2.15560]	[2.46699]
D(LNPG95E85(-2))	3.141586	1.158128	1.089632	1.012022	0.651342
	(1.40097)	(0.28075)	(0.28068)	(0.34870)	(0.50213)
	[2.24243]	[4.12511]	[3.88218]	[2.90229]	[1.29716]
D(LNPG95E85(-3))	1.060357	0.662706	0.588946	0.369200	0.863286
	(1.60586)	(0.32181)	(0.32172)	(0.39969)	(0.57557)
	[0.66030]	[2.05930]	[1.83060]	[0.92371]	[1.49989]
D(LNPG95E85(-4))	2.158487	0.780183	0.695234	0.713220	0.577853
	(1.14533)	(0.22952)	(0.22946)	(0.28507)	(0.41050)
	[1.88460]	[3.39918]	[3.02989]	[2.50193]	[1.40767]
D(LNPG95E85(-5))	0.751204	0.136254	0.091279	-0.025195	0.273207
	(1.09735)	(0.21990)	(0.21985)	(0.27313)	(0.39330)
	[0.68457]	[0.61961]	[0.41520]	[-0.09225]	[0.69464]
C	-0.246721	-0.142760	-0.133522	-0.117080	-0.139590
	(0.21077)	(0.04224)	(0.04223)	(0.05246)	(0.07554)
	[-1.17056]	[-3.37987]	[-3.16203]	[-2.23177]	[-1.84780]
R-squared	0.821859	0.796122	0.774570	0.712521	0.693958
Adj. R-squared	0.672451	0.625128	0.585499	0.471410	0.437277
Sum sq. resids	0.371481	0.014918	0.014910	0.023013	0.047721
S.E. equation	0.109468	0.021937	0.021931	0.027246	0.039235
F-statistic	5.500764	4.655838	4.096725	2.955157	2.703586
Log likelihood	64.17192	157.4042	157.4199	144.8335	123.6836
Akaike AIC	-1.281790	-4.496698	-4.497237	-4.063225	-3.333919
Schwarz SC	-0.322618	-3.537526	-3.538065	-3.104054	-2.374747
Mean dependent	0.133641	0.009995	0.010433	0.009208	0.008305
S.D. dependent	0.191271	0.035829	0.034064	0.037475	0.052303

Determinant resid covariance (dof adj.)	2.46E-18
Determinant resid covariance	1.07E-19
Log likelihood	855.1409
Akaike information criterion	-24.62555
Schwarz criterion	-19.61654

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.862457	Prob. F(19,18)	0.624805
Obs*R-squared	27.63941	Prob. Chi-Square(19)	0.090618

White Heteroskedasticity Test:

F-statistic	2.857673	Prob. F(54,3)	0.210667
Obs*R-squared	56.89393	Prob. Chi-Square(54)	0.367844

Table C.5 A Vector Error Correction Model of Ethanol Supply

Vector Error Correction Estimates
Date: 01/01/06 Time: 01:37
Sample (adjusted): 2008M04 2013M12
Included observations: 69 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1
LNSE(-1)	1.000000
LNPE(-1)	-0.212381 (0.45262) [-0.46922]
LNPG95E10(-1)	-16.76800 (2.51957) [-6.65510]
LNPG95E20(-1)	15.41462 (2.28240) [6.75370]
LNPULG95(-1)	2.404742 (1.24041) [1.93867]
C	-1.668673

Error Correction:	D(LNSE)	D(LNPE)	D(LNPG95E10)	D(LNPG95E20)	D(LNPULG95)
CointEq1	-0.476926 (0.11313) [-4.21591]	-0.007951 (0.03645) [-0.21814]	-0.074254 (0.02476) [-2.99874]	-0.084611 (0.02610) [-3.24122]	-0.057709 (0.02181) [-2.64579]
D(LNSE(-1))	-0.311889 (0.12637) [-2.46800]	-0.023426 (0.04072) [-0.57530]	0.070878 (0.02766) [2.56232]	0.087735 (0.02916) [3.00855]	0.034028 (0.02437) [1.39653]
D(LNSE(-2))	-0.128810 (0.13805) [-0.93309]	-0.046371 (0.04448) [-1.04251]	0.021857 (0.03022) [0.72333]	0.031453 (0.03186) [0.98735]	0.020287 (0.02662) [0.76218]
D(LNPE(-1))	0.325084 (0.39924) [0.81425]	-0.125683 (0.12864) [-0.97701]	-0.205874 (0.08739) [-2.35583]	-0.209455 (0.09213) [-2.27350]	-0.128924 (0.07698) [-1.67483]
D(LNPE(-2))	0.222202 (0.41430) [0.53633]	-0.057807 (0.13349) [-0.43303]	-0.037297 (0.09069) [-0.41128]	-0.064436 (0.09560) [-0.67398]	-0.014514 (0.07988) [-0.18169]
D(LNPG95E10(-1))	-5.181505 (3.01827) [-1.71672]	-0.231208 (0.97251) [-0.23774]	0.527874 (0.66066) [0.79901]	0.476771 (0.69649) [0.68453]	0.276525 (0.58195) [0.47517]
D(LNPG95E10(-2))	-2.100358 (2.96689)	0.081254 (0.95596)	-0.056484 (0.64942)	-0.171618 (0.68464)	-0.359554 (0.57204)

	[-0.70793]	[0.08500]	[-0.08698]	[-0.25067]	[-0.62855]
D(LNPG95E20(-1))	3.528703	0.977462	-0.455693	-0.429079	-0.579448
	(2.87909)	(0.92767)	(0.63020)	(0.66438)	(0.55511)
	[1.22563]	[1.05367]	[-0.72310]	[-0.64584]	[-1.04384]
D(LNPG95E20(-2))	-0.344891	-0.760310	0.080888	0.302575	0.534094
	(2.83783)	(0.91437)	(0.62116)	(0.65486)	(0.54716)
	[-0.12153]	[-0.83151]	[0.13022]	[0.46205]	[0.97613]
D(LNPULG95(-1))	2.747950	-1.047143	0.639979	0.745641	0.888054
	(1.31153)	(0.42259)	(0.28708)	(0.30265)	(0.25287)
	[2.09523]	[-2.47794]	[2.22930]	[2.46373]	[3.51186]
D(LNPULG95(-2))	3.713200	1.022125	0.035507	-0.173497	-0.247705
	(1.36998)	(0.44142)	(0.29987)	(0.31614)	(0.26414)
	[2.71041]	[2.31554]	[0.11841]	[-0.54880]	[-0.93777]
C	0.000899	0.008483	0.000931	0.000427	0.002761
	(0.02874)	(0.00926)	(0.00629)	(0.00663)	(0.00554)
	[0.03128]	[0.91608]	[0.14800]	[0.06437]	[0.49821]
R-squared	0.455413	0.188061	0.490933	0.513575	0.382485
Adj. R-squared	0.350318	0.031371	0.392692	0.419704	0.263316
Sum sq. resids	2.904360	0.301527	0.139153	0.154657	0.107969
S.E. equation	0.225729	0.072732	0.049409	0.052089	0.043522
F-statistic	4.333322	1.200210	4.997238	5.471048	3.209588
Log likelihood	11.38557	89.53182	116.2102	112.5657	124.9637
Akaike AIC	0.017810	-2.247299	-3.020585	-2.914949	-3.274311
Schwarz SC	0.406350	-1.858759	-2.632044	-2.526408	-2.885770
Mean dependent	0.013256	0.006554	0.004068	0.003146	0.004870
S.D. dependent	0.280051	0.073900	0.063402	0.068379	0.050707

Determinant resid covariance (dof adj.)	3.07E-14
Determinant resid covariance	1.18E-14
Log likelihood	616.8970
Akaike information criterion	-15.99702
Schwarz criterion	-13.89242

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	1.010666	Prob. F(23,34)	0.479170
Obs*R-squared	28.01848	Prob. Chi-Square(23)	0.215083

White Heteroskedasticity Test:

F-statistic	0.762530	Prob. F(30,38)	0.776463
Obs*R-squared	25.92876	Prob. Chi-Square(30)	0.678763

BIOGRAPHY

NAME	Noppadol Sudprasert
ACADEMIC BACKGROUND	Bachelor's Degree in Civil Engineering, Rangsit University, 1994 (Scholarship); Master's Degree in Civil Engineering (Structural), Rangsit University, 1999; Master's Degree in Public and Private Management (International Program), National Institute of Development Administration, 2002; Professional Master's Degree in Offshore Technology and Management, Asian Institute of Technology, 2007 (scholarship).
EXPERIENCES	Planning Engineer in construction, and oil and gas industry, 1994-2004; Structural Engineer in offshore platform construction, CUEL limited, 2005-2011.