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Market Efficiency Impacted by Government Pricing Policy for Gasohol Consumption: A Case of Thailand

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Abstract

The purpose of this study is to investigate market efficiency impacted by the Government pricing policy on gasohol products in Thailand which are taxed and subsidized by the Oil Fund to stabilize domestic fuel prices during the world oil price fluctuation. The period of study is 2004-2013. Deadweight losses are calculated via changes in consumer and producer surplus using Johansen cointegration tests and vector error correction models. The statistical results indicate that prices of gasohol 91, E20 and E85 are significantly elastic to its own consumption in the long run while price of gasohol 95 is significantly elastic to its own consumption in the short run. During 2004-2013 the total deadweight losses for gasohol 91, 95, E20, and E85 are 2937.63, 35611.81, 349.99, and 673.90 MTHB respectively while during 2009-2013 the total deadweight losses for gasohol 91, 95, E20, and E85 are 2348.09, 22861.09, 673.90, and 348.99 MTHB respectively. The highest deadweight loss occurs in the gasohol 95 market. The Government pricing policy is practical to promote using gasohol but it causes market inefficiency. The deadweight losses increase when oil fund tax or subsidy increase. The Government should float the fuel prices by ceasing the Oil Fund or reducing oil fund tax and subsidy as much as possible especially for gasohol 95 to minimize market inefficiency and maximize fairness of using fuels.

Keywords: Market efficiency, Pricing policy, Gasohol consumption, the Oil Fund.

Introduction

Crude oil is the essential resource for economic development in all countries. The crude oil consumption around the world is increasing whereas its supply trend to be reduced. Thailand as a crude oil importer is only a price taker. When the world crude oil price is high and fluctuate, the country will be impacted inevitably. Accordingly, Thai Government establishes the Oil Fund as an instrument to maintain domestic retail fuel price level at a set ceiling in times when the world crude oil price rise. The Oil Fund subsidizes domestic fuel prices when the domestic retail fuel price above the set ceiling prices and levies tax when the domestic retail fuel prices below the set ceiling prices. In addition, the Government launches an Alternative Energy Development Plan (AEDP 2008-2022) that aims to reduce crude oil import, increase domestic alternative energy use, and build energy security; whereas, gasohol is promoted via oil fund tax and subsidy to replace the use of gasoline 91 and 95. Nevertheless, subsidy for some types of fuel products but levying tax on the others will cause market distortion and impact market efficiency. Hence, the study aims to investigate the market efficiency impacted by the Government pricing policy on gasohol products in Thailand taxed and subsidized via the Oil Fund using econometric models to obtain demand and supply elasticities and changes in consumer and producer surplus for deadweight loss (DWL) calculation. The study focuses on the investigation of deadweight losses from gasohol 91, 95, E20, and E85. Johansen cointegration approach is applied to test the long run relationship among the dominant variables of the gasohol consumption and to obtain the long run elasticities. Vector error correction models (VECMs) are employed to examine the short run dynamics between variables to understand how the variables adjust in the long run and to obtain the short run elasticities. The variables are consisted of per capita consumption of gasohol 91, 95, E20, and E85; retail prices of gasohol, gasoline, and high speed diesel based on Bangkok area; and per capita marrow money supply (M1) as a GDP's proxy variable. The period of the study is from 2004-2013 using monthly data.

Methodology

1. Approach to the Study

A dynamic model approach is elegant estimation of the short and long run elasticities within one equation that makes it as the popular technique for separating out the short and long run effects for demand and supply elasticities. The advantages of the model are a simple and flexible use with an intuitively appealing lag shape, obtaining the short and long run estimates immediately and reasonably (Franzen, 1994; Johansson & Schipper, 1994), and easiest interpretation of the dominant elasticity values (Basso & Oum, 2007). Cuddington and Dagher (2011) proposed four popular approaches for dynamic modeling to estimate the short and long run price and income elasticities including (a) the LR demand function with an AR(1) error process, (b) a Partial Adjustment Model (PAM), (c) an Error Correction Model (ECM), and (d) ARDL model. They argued that the ARDL or corresponding ECM should be applied in practice rather than using the AR or PAM specifications.

The study applies a dynamic model approach to analyze the long run relationship between consumption of gasohol products and dominant factors including narrow money supply (M1), their own price, and prices of substitute and complementary fuels. The long run relationship between ethanol supply and a combination of its own prices, gasohol prices, and gasoline prices is examined. Johansen cointegration approach is applied to test the long run relationship. The approach is suitable for a multivariate framework and allowable for the discovery of more than one cointegrating vector. Cointegration analysis can evaluate the co-movement of the long run price and consumption/supply for fuels within an equilibrium model. The cointegration analysis establishes a long run relationship by calculating a long run equilibrium whereas correlation within an error correction model are estimated. Thus, if the cointegration analysis indicates the existence of cointegrating vector, the tested series will not drift apart in the long run and will revert to equilibrium levels following any short run drift that may take place. Cointegration is a modeling process that incorporates non-stationary with both long run relationships and short run dynamics. To examine time series in fuel data using cointegration tests, the time series should be non-stationary at level and integrated of order one or the series becomes stationary after the first different. From the cointegration models, the author normalizes the resulting cointegrating relationship so that the coefficients of dependent variables are equal to one. The coefficients in the error correction terms indicate the long run elasticities and a cointegration equation coefficient in an ECM allows us to understand speed of adjustment or how variables adjust in the long run and the other coefficients indicate the short run elasticities. Thus, the price elasticities of gasohol demand and ethanol supply in the short and long run can be obtained from the models. Subsequently, the supply price elasticity of gasohol is derived from the proportion of the ethanol and gasoline supply elasticities (De Gorter & Just, 2009). The price elasticities of demand and supply for gasohol products are used to determine equilibrium prices. The obtained demand and supply elasticities are applied for a consumer and producer surplus approach to calculate deadweight losses by integrating area under the demand and supply curves moving from the market equilibrium located before taxes and subsidies by the Oil Fund.

2. Data

The study utilizes monthly data in the natural log form of per capita consumption of gasohol 91, 95, E20, and E85; per capita supply of ethanol; prices of gasohol 91, 95, E20, and E85; prices of gasoline 91 and 95; high speed diesel prices; ethanol prices, and per capita M1. The period of the study is 2004-2013. The data of gasohol 91, 95, E20, and E85 cover the period 2005-2013, 2004-2013, 2008-2013, and 2009-2013 respectively. The M1 is applied as a possible proxy variable of GDP as Vikitset (2008 & 2010) found strong relationship between M1 and GDP for Thailand. The author obtains the domestic fuel data based on Bangkok area from Ministry of Energy, GDP from Office of The National Economic and Social Development Board, and M1 from Bank of Thailand.

3. Augmented Dickey-Fuller Test

The data series are tested whether they are stationary using Augmented Dickey-Fuller (ADF) test presented as

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

where Δy is the first difference of series *y*, α is a constant term, ε is a residual term, and *k* is the lagged values of Δy_t. In the ADF test, the null hypothesis is that series *y* will be non-stationary if β is equal to zero; otherwise, the series *y* will be stationary if β is significantly negative. Thus, if the absolute value of the t-statistic for β is greater than the absolute critical value, the null hypothesis that *y* is non-stationary must be rejected; otherwise, the null hypothesis could not be rejected and then *y* exists unit root. The optimal lag length (*k*) is obtained from the Akaike Information Criteria (AIC).

4. Johansen and Juselius Cointegration and Vector Error Correction Model

The multivariate approach is developed by Johansen and Juselius. The technique defines a vector of *n* potential variables. The cointegrating vectors can be up to *n*-1 that indicate a long run equilibrium relationship between the variables. Consider its generalization to *n* variables as

$$X_t = A_1 X_{t-1} + \varepsilon_t$$

where X_t and εt are $(n \times 1)$ vectors and A_1 is the $(n \times n)$ matrix of parameters. Rewriting as

$$\Delta X_t = (A_1 - I)X_{t-1} + \varepsilon_t \quad \text{or} \quad \Delta X_t = \pi X_{t-1} + \varepsilon_t$$

where π is defined as $(A_1 - I)$ and its rank equals the number of cointegrating vectors. The equation can be modified for the present of a constant term by letting

$$\Delta X_t = A_0 + \pi X_{t-1} + \varepsilon_t$$

where A_0 is $(n \times 1)$ a constant vector. The equation $X_t = A_1 X_{t-1} + \varepsilon_t$ can be generalized for a higher order autoregressive process as

$$X_t = A_1 X_{t-1} + A_2 X_{t-2} + \ldots + A_k X_{t-k} + \varepsilon_t.$$

This vector autoregression (VAR) can be written as

$$\Delta X_t = \pi X_{t-1} + \sum_{i=1}^{k-1} \pi_i \Delta X_{t-i} + \varepsilon_t$$

where $\pi = -(I - \sum_{i=1}^{k} A_i)$ and $\pi_i = -\sum_{j=i+1}^{k} A_j$. As the rank of π is equal to the number of independent cointegrating vectors, if the rank of π is zero, the variables will not exist of cointegration. Likewise, if the rank of π is *r*, there will be *r* cointegrating vectors. The estimates of π and its characteristic roots can be obtained by applying trace test and maximum eigenvalue test. The test statistics are presented as

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^{n} ln\ (1 - \hat{\lambda}_i)$$

$$\lambda_{max}(r, r+1) = -T \sum ln(1 - \hat{\lambda}_{i+1})$$

where $\hat{\lambda}_i$ is the estimated values of the characteristic roots (eigenvalues) and T is the number of usable observations.

Vector error correction models (VECMs) are employed to examine the short run dynamics and the long run relationship between the variables. The VECM equation is presented as

$$\Delta Y_t = \pi(Y_{t-1} - \beta_1 X_{t-1} - \beta_2) + \sum_{i=1}^{k} \alpha_i \Delta Y_{t-i} + \sum_{i=1}^{k} \lambda_i \Delta X_{t-i}$$

where ΔY_t is the first difference of vector Y_t, π is speed of adjustment, and $Y_{t-1} - \beta_1 X_{t-1} - \beta_2$ is an error correction term while α_i and λ_i are short run coefficients. The equation measures how quickly system adjusts to their long run equilibrium.

5. Estimation of Deadweight Loss

The deadweight loss from fuel tax or subsidy relies on the amount of the tax or subsidy and the change in consumer and producer surplus caused by the tax or subsidy. Various studies measure the deadweight losses using this approach through the estimated value of demand and supply elasticities, e.g., Vartia (1983); Hausman and Newey (1993); Depro, Jones, Patil, Tom, and Wood (2007); Chenphuengpawn (2011); Vikitset (2014).

The normalized cointegrating coefficient for ethanol supply presented in Table 3 indicates that the ethanol supply is not affected by its own price. Hence, as gasohol is a mixture of ethanol and gasoline, the supply of gasohol is assumed as perfectly elastic relied on the perfectly elastic supply of gasoline because the ex-refinery price of gasoline supply depend on the import parity principle and Singapore is the fuel supplier of Thailand; so, the import prices of gasoline are equal to the Singapore ex-refinery prices plus costs of transportation, insurance, and quality adjustment. Besides, Thailand as a relatively small country can import all of the required fuels at the import prices without effects on the world prices. Moreover, Thai Government determines the local ex-refinery gasoline prices equal to the import prices. Thus, if the refining costs in Thailand are equal to that in Singapore, the local refiners will earn profit on the gap of no costs of transportation, insurance, and quality adjustment. If the local refiners want to sell their products above the import prices, they could not compete with the imported petroleum products (Vikitset, 2008 & 2010).

Accordingly, the monthly deadweight losses from the pricing policy are calculated by integration of the area under the demand curve of gasohol products with respect to the change in prices illustrated as Figure 1. The deadweight loss due to oil fund tax in Figure 1(a) presented as the area *a* can be calculated by

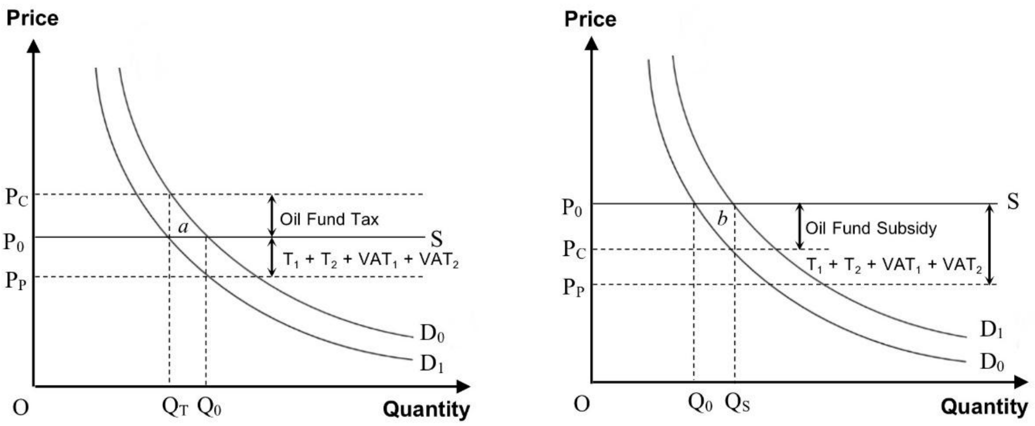
$$DWL_T = \int_{P_0}^{P_C} \left(D(P)_0 - Q_T\right) dP$$

where $D(P)_0$ denotes demand function of gasohol before oil fund tax, Q_T denotes consumption quantity of gasohol after oil fund tax, P_0 denotes gasohol price before oil fund tax, and P_C denotes retail price of gasohol after oil fund tax. Similarly, the deadweight loss due to oil fund subsidy in Figure 1(b) presented as the area *b* can be calculated by

$$DWL_S = \int_{P_C}^{P_0} \left(Q_S - D(P)_0\right) dP$$

where $D(P)_0$ denotes demand function of gasohol before oil fund subsidy, Q_S denotes consumption quantity of gasohol after oil fund subsidy, P_0 denotes gasohol price before oil fund subsidy, P_C denotes retail price of gasohol after oil fund subsidy and P_P denotes producer price.

Figure 1: The deadweight loss from tax (a) and the deadweight loss from subsidy (b)



(a) (b)

Empirical Results

1. Johansen Cointegration Test Results

Table 1 exhibits the results of ADF tests for the data series. Most series fail to reject the null hypothesis at level that indicates unit root of the series at level. After taking the first difference to the series, all series are stationary that indicates the integration of the series at the same order *I*(1).

The cointegration results are presented in Table 2. Trace and Max-Eigen statistics indicate the existence of cointegration between gasohol consumption and its dominant variables for all cases except the existence of cointegration between ethanol supply and its dominant variables which is only verified by Trace statistics. These mean that at least one linear combination exists between the variables which indicates a relationship in the long run despite deviation from equilibrium in the short run.

Table 1: Augmented Dickey-Fuller (ADF) tests

Variables		ADF t-statistic (at level)	ADF t-statistic (at 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 no trend. ** and * denote significant at 1% and 5% level respectively. CV denotes critical value. The numbers in parentheses indicate the optimal lag length obtained from AIC.

Table 2: Johansen cointegration test results

Dependent Variable	Independent Variable	Trace	5%CV	Prob.	Rank	Max-Eigen	5%CV	Prob.	Rank
lnC_{G91E10}	lnM1, lnP_{G91E10}, lnP_{UGR91}	43.45	42.92	.04	2	25.51	25.82	.06	2
lnC_{G95E10}	lnM1, lnP_{G91E10}, lnP_{G95E10}	34.60	29.80	.01	2	21.80	21.13	.04	2
lnC_{G95E20}	lnP_{G95E10}, lnP_{G95E20}	32.27	25.87	.01	2	23.47	19.39	.01	2
lnC_{G95E85}	lnP_{G91E10}, lnP_{G95E10}, lnP_{G95E20}	44.02	42.92	.04	3	27.49	25.82	.03	3
lnS_{E}	lnP_{E}, lnP_{G95E10}, lnP_{G95E20} lnP_{ULG95}	74.15	69.82	.02	1	29.38	33.88	.16	0

Note: CV denotes critical value.

Table 3: Normalized Cointegrating Coefficients

Normalized Cointegrating Coefficients					
Gasohol 91 Consumption					
$\ln C_{G91E10}$	$\ln M1$	$\ln P_{G91E10}$	$\ln P_{UGR91}$	Trend	
1.00	12.98	6.46	-12.99	-0.08	
	[4.66]**	[3.20]**	[-5.44]**	[-3.61]**	
Gasohol 95 Consumption					
$\ln C_{G95E10}$	$\ln M1$	$\ln P_{G91E10}$	$\ln P_{G95E10}$		
1.00	-3.56	-2.95	6.06		
	[-2.64]*	[-0.32]	[0.63]		
Gasohol E20 Consumption					
$\ln C_{G95E20}$	$\ln P_{G95E10}$	$\ln P_{G95E20}$	Trend		
1.00	-11.98	12.04	-0.03		
	[-4.32]**	[4.58]**	[-6.67]**		
Gasohol E85 Consumption					
$\ln C_{G95E85}$	$\ln P_{G91E10}$	$\ln P_{G95E10}$	$\ln P_{G95E20}$	$\ln P_{G95E85}$	Trend
1.00	18.37	-11.77	-9.07	4.70	-0.13
	[19.50]**	[-23.58]**	[-14.98]**	[25.77]**	[-80.71]**
Ethanol Supply					
$\ln S_{E}$	$\ln P_{E}$	$\ln P_{G95E10}$	$\ln P_{G95E20}$	$\ln P_{ULG95}$	
1.00	-0.21	-16.77	15.41	2.40	
	[-0.47]	[-6.66]**	[6.75]**	[1.94]	

Note: t-statistics is in [ ]. ** and * denotes 1% and 5% significant level respectively.

Analyzing the normalized cointegrating coefficients allows us to understand how the variables adjust in the long run. The results of the normalized cointegration coefficients are shown in Table 3. In case of gasohol 91 consumption, P_{G91E10} and P_{UGR91} have the expected signs and are statistically significant at 1% level whereas M1 has the unexpected sign. The coefficients indicate that 1% increase in P_{G91E10} leads to 6.46% decrease in C_{G91E10} in the long run and 1% increase in P_{UGR91} leads to 12.99% increase in C_{G91E10} in the long run. For gasohol 95 consumption, M1 has the expected sign and is statistically significant at 5% level, meaning that 1% increase in M1 leads to 3.56% increase in C_{G95E10} in the long run whereas P_{G91E10} and P_{G95E10} have the expected signs but are statistically insignificant; so, we cannot conclude that P_{G91E10} and P_{G95E10} affect C_{G95E10} in the long run. In case of gasohol E20 consumption, P_{G95E10} and P_{G95E20} have the expected signs and are statistically significant at 1% level. The coefficients indicate that 1% increase in P_{G95E10} leads to 11.98% increase in C_{G95E20} in the long run whereas 1% increase in P_{G95E20} leads to 12.04% decrease in C_{G95E20} in the long run. For gasohol E85 consumption, P_{G95E10}, P_{G95E20}, and P_{G95E85} have the expected signs and are statistically significant at 1% level. The coefficients indicate that 1% increase in P_{G95E10} and P_{G95E20} lead to 11.77% and 9.07% increase in C_{G95E85} respectively in the long run whereas 1% increase in P_{G95E85} leads to 4.70% decrease in C_{G95E85} in the long run. In case of ethanol supply, P_E has the expected sign but is statistically insignificant whereas P_{G95E10} have the expected sign and are statistically significant at 1% level. The coefficients indicate that 1% increase in P_{G95E10} leads to 16.77% increase in S_E in the long run.

2. Error Correction Model (ECM)

The short run dynamics and the speed of adjustment of cointegrated variables towards their equilibrium values are present in Table 4–8. Table 4 shows an ECM for gasohol 91 consumption. The speed of adjustment has the expected negative sign and is statistically significant at 5% level, meaning that 5% of the disequilibrium is corrected by changes in an error correction term including M1, P_{G91E10}, and P_{UGR91}. However, P_{G91E10} does not cause C_{G91E10} in the short run. Table 5 shows an ECM for gasohol 95 consumption. The speed of adjustment has the expected negative sign and is statistically significant at 1% level, meaning that 9% of the disequilibrium is corrected by changes in an error correction term including M1, P_{G91E10}, and P_{G95E10}. In addition, P_{G95E10} causes C_{G95E10} significantly at 5% level in the short run that the coefficient shows 1% increase in P_{G95E10} leading to 2.58% decrease in C_{G95E10} in the short run. Table 6 shows an ECM for gasohol E20 consumption. The speed of adjustment has the expected negative sign and is statistically significant at 1% level, meaning that 24% of the disequilibrium is corrected by changes in an error correction term including P_{G95E10} and P_{G95E20}. However, P_{G95E20} does not cause C_{G95E20} in the short run. Table 7 shows an ECM for gasohol E85 consumption. The speed of adjustment has the expected negative sign and is statistically significant at 1% level, meaning that 71% of the disequilibrium is corrected by changes in an error correction term including P_{G91E10}, P_{G95E10}, P_{G95E20}, and P_{G95E85}. However, P_{G95E85} does not shown the expected sign in the short run. Table 8 shows an ECM for ethanol supply. The speed of adjustment has the expected negative sign and is statistically significant at 1% level, meaning that 48% of the disequilibrium is corrected by changes in an error correction term including P_E, P_{G95E10}, P_{G95E20}, and P_{ULG95}. However, P_E does not cause S_E in the short run.

Table 4: Error correction model for gasohol 91 consumption

Error Correction:	Coefficient	Std. Error	t-Statistic	Prob.
Cointegrating Equation	-0.05	0.02	-2.28	.03*
$\Delta lnC_{G91E10(-1)}$	0.33	0.09	3.56	.00**
$\Delta lnC_{G91E10(-2)}$	0.10	0.09	1.12	.23
$\Delta lnM1_{(-1)}$	0.67	0.46	1.44	.17
$\Delta lnM1_{(-2)}$	-0.31	0.45	-0.70	.44
$\Delta lnP_{G91E10(-1)}$	0.78	0.65	1.19	.24
$\Delta lnP_{G91E10(-2)}$	-0.11	0.69	-0.16	.82
$\Delta lnP_{UGR91(-1)}$	-0.59	0.73	-0.80	.43
$\Delta lnP_{UGR91(-2)}$	0.14	0.81	0.17	.83
C	0.03	0.01	2.42	.02**
R^2 = .35 *DW* = 1.94 *LM* = .68 *Normality* = .01 *Heteroskedasticity* = .10				

Note: ** and * denotes 1% and 5% significant level respectively.

Table 5: Error correction model for gasohol 95 consumption

Error Correction: ΔlnC_{G95E10}	Coefficient	Std. Error	t-Statistic	Prob.
Cointegrating Equation	-0.09	0.02	-5.09	.00**
$\Delta lnC_{G95E10(-1)}$	0.15	0.09	1.75	.08
$\Delta lnM1_{(-1)}$	0.02	0.33	0.07	.95
$\Delta lnP_{G91E10(-1)}$	2.58	1.06	2.44	.02*
$\Delta lnP_{G95E10(-1)}$	-2.58	1.10	-2.34	.02*
C	0.02	0.01	2.48	.01*
R^2 = .39 *DW* = 1.92 *LM* = .47 *Normality* = .00 *Heteroskedasticity* = .02				

Note: ** and * denotes 1% and 5% significant level respectively.

Table 6: Error correction model for gasohol E20 consumption

Error Correction:	Coefficient	Std. Error	t-Statistic	Prob.
Cointegrating Equation	-0.24	0.05	-4.36	.00**
$\Delta lnC_{G95E20(-1)}$	0.03	0.12	0.24	.81
$\Delta lnC_{G95E20(-2)}$	0.09	0.11	0.84	.40
$\Delta lnP_{G95E10(-1)}$	-2.30	1.19	-1.93	.06
$\Delta lnP_{G95E10(-2)}$	-1.09	1.19	-0.91	.36
$\Delta lnP_{G95E20(-1)}$	2.08	1.11	1.87	.07
$\Delta lnP_{G95E20(-2)}$	1.38	1.11	1.25	.22
C	0.07	1.46	0.05	.00**
R^2 = .41 *DW* = 2.07 *LM* = .06 *Normality* = .00 *Heteroskedasticity* = .01				

Note: ** and * denotes 1% and 5% significant level respectively.

Table 7: Error correction model for gasohol E85 consumption

Error Correction: ΔlnC_{G95E85}	Coefficient	Std. Error	t-Statistic	Prob.
Cointegrating Equation	-0.71	0.13	-5.59	.00**
$\Delta lnC_{G95E85(-1)}$	0.19	0.13	1.42	.16
$\Delta lnC_{G95E85(-2)}$	1.02	0.19	5.49	.00**
$\Delta lnC_{G95E85(-3)}$	0.76	0.18	4.22	.00**
$\Delta lnC_{G95E85(-4)}$	0.82	0.18	4.50	.00**
$\Delta lnC_{G95E85(-5)}$	0.53	0.13	4.12	.00**
$\Delta lnP_{G91E10(-1)}$	10.18	2.03	5.01	.00**
$\Delta lnP_{G91E10(-2)}$	16.59	2.87	5.79	.00**
$\Delta lnP_{G91E10(-5)}$	4.27	1.94	2.20	.03*
$\Delta lnP_{G95E10(-1)}$	-10.42	2.17	-4.79	.00**
$\Delta lnP_{G95E10(-2)}$	-12.89	2.11	-6.12	.00**
$\Delta lnP_{G95E10(-3)}$	-2.99	1.67	-1.79	.08
$\Delta lnP_{G95E20(-2)}$	-7.09	2.21	-3.21	.00**
$\Delta lnP_{G95E20(-3)}$	1.61	1.44	1.12	.27
$\Delta lnP_{G95E20(-4)}$	-1.66	0.59	-2.80	.001**
$\Delta lnP_{G95E20(-5)}$	-4.24	1.90	-2.23	.03*
$\Delta lnP_{G95E85(-2)}$	3.32	0.71	4.70	.00**
$\Delta lnP_{G95E85(-3)}$	1.44	0.60	2.40	.022*
$\Delta lnP_{G95E85(-4)}$	2.00	0.65	3.09	.00**
$\Delta lnP_{G95E85(-5)}$	0.97	0.57	1.72	.09
C	-0.29	0.07	-4.08	.00**
R^2 = .81 *DW* = 1.52 *LM* = .09 *Normality* = .00 *Heteroskedasticity* = .37				

Note: ** and * denotes 1% and 5% significant level respectively.

Table 8: Error correction model for ethanol supply

Error Correction: ΔlnS_E	Coefficient	Std. Error	t-Statistic	Prob.
Cointegrating	-0.48	0.11	-4.22	.00**
$\Delta lnS_{E(-1)}$	-0.31	0.13	-2.47	.02*
$\Delta lnS_{E(-2)}$	-0.13	0.14	-0.93	.35
$\Delta lnP_{E(-1)}$	0.33	0.40	0.81	.42
$\Delta lnP_{E(-2)}$	0.22	0.41	0.54	.59
$\Delta lnP_{G95E10(-1)}$	-5.18	3.02	-1.72	.09
$\Delta lnP_{G95E10(-2)}$	-2.10	2.97	-0.71	.48
$\Delta lnP_{G95E20(-1)}$	3.53	2.88	1.23	.23
$\Delta lnP_{G95E20(-2)}$	-0.34	2.84	-0.12	.90
$\Delta lnP_{ULG95(-1)}$	2.75	1.31	2.10	.04
$\Delta lnP_{ULG95(-2)}$	3.71	1.37	2.71	.01*
C	0.00	0.03	0.03	.98
R^2 = .46 *DW* = 2.02 *LM* = .22 *Normality* = .00 *Heteroskedasticity* = .68				

Note: ** and * denotes 1% and 5% significant level respectively.

3. Deadweight Losses

Calculation results of the deadweight losses in the long run due to the Oil Fund pricing policy of gasohol products are presented in Table A1-A4, Appendix A. The long run price elasticities of consumption are used to calculate deadweight losses for all gasohol products through a consumer and producer surplus approach. The deadweight losses impacted by the Government pricing policy in case of gasohol 91 for the period 2005-2013 are presented in Table A1. The deadweight loss peaks at 820.17 MTHB in 2009 and its total deadweight loss is 2937.63 MTHB. Table A2 shows the deadweight losses in case of gasohol 95 for the period 2004-2013. The total deadweight loss is 35611.81 MTHB higher than that of the other gasohol products. It drastically increases during December 2008 up to 11216.31 MTHB because of a huge increase in oil fund tax up to 16.04% of the gasohol 95 price while oil fund tax of the gasohol 95 is 4.90% in average during the period of study. Table A3 shows the deadweight losses in case of gasohol E20 for the period 2008-2013. The deadweight loss increases each year and reaches 160.03 MTHB in 2013, rising almost two times of a previous year and its total deadweight loss is 349.99 MTHB.

Likewise, Table A4 presents the deadweight losses in case of gasohol E85 for the period 2009-2013. The deadweight loss increases enormously each year especially in 2013 at 489.60

MTHB greater than three times of the deadweight loss in 2012 and its total deadweight loss is 673.90 MTHB.

Conclusion

The study investigates the market efficiency of gasohol consumption in terms of deadweight losses impacted by the Government pricing policy of the Oil Fund's price stabilization for the period 2004-2013. The time series data are analyzed using ADF tests and the results indicate that the data are non-stationary at level but stationary in the first differences acceptable for cointegration tests. The Johansen cointegration test results indicate that the long run equilibrium relationship exists between consumption and price of gasohol 91 and its normalized cointegrating coefficient indicates the long run price elasticity of consumption equal to -6.46 but the ECM indicates statistically insignificant price elasticity of consumption in the short run. The short run price elasticity of gasohol 95 consumption is equal to -2.58 but its long run price elasticity is insignificant at -6.06 for the period 2004-2013 corresponding to Jirapraprisarn (2007) that current demand for gasohol 95 is elastic to its own price lagged four months at -6.31 for the period 2005-2007. For the period 2008-2013 price elasticity of gasohol E20 consumption is insignificant in the short run but significant elastic at -12.04 in the long run different from Thongchuang and Thungsuwan (2010) showing that gasohol E20 consumption is inelastic to price at -0.23 for the period 2008-2009. It indicates that study in different period bring about the different value of price elasticity of consumption. Gasohol E85 exists the long run equilibrium relationship between consumption and price. Its price elasticity of consumption is equal to -4.70 in the long run but it is insignificant in the short run whereas Anderson (2006) found that consumption of gasohol E85 is elastic to its own price at -13 in Minnesota, U.S. covers the period 1997-2006. Gasohol E85 consumption in Minnesota, U.S is more elastic to its own price than that in Thailand. Besides, the supply of ethanol is statistically insignificant inelastic to its own price both in the short and long run. Consideration of economic growth, M1 exists the long run equilibrium relationships with gasohol 95 consumption. When GDP growth increases 1%, gasohol 95 consumption will increase 3.56%. For substitution effects, gasoline 91 is substitute product of gasohol 91 whereas gasohol 91 is substitute product of gasohol 95. Gasohol 95 is substitute product of gasohol E20 and E85. Likewise, gasohol E20 is substitute product of gasohol E85.

The long run price elasticities of consumption are used to calculate deadweight losses for gasohol products through a consumer and producer surplus approach. The deadweight loss in gasohol 91 market peaks 820.17 MTHB in 2009. Its total deadweight loss is 2937.63 MTHB for the period 2005-2013. The highest deadweight loss occurs in gasohol 95 market. Its deadweight loss is dramatically highest up to 12341.61 in 2008 due to a huge increase in oil fund tax up to 16.04% of the gasohol 95 price during December 2008. Its total deadweight loss is 35611.81 MTHB for the period 2004-2013. Deadweight loss in gasohol E20 market peaks 160.03 MTHB in 2013 and its total deadweight loss is 349.99 MTHB for the period 2008-2013. In 2013 deadweight loss in gasohol E85 market peaks 489.60 MTHB increasing 3.52 times of a previous year and its total deadweight loss is 673.90 MTHB for the period 2009-2013. For the same period 2009-2013, the total deadweight losses for gasohol 91, 95, E20, and E85 are 2348.09, 22861.09, 673.90, and 348.99 MTHB respectively. Comparing to other fuels, Chenphuengpawn (2011) found that deadweight losses of high speed diesel and biodiesel B5 in Thailand are 9208.78 and 2288.01 MTHB respectively for the period 2007-2010.

The study indicates that prices of gasohol are elastic to its own consumption. Thus, the Government pricing policy is practical to promote using gasohol but it causes market inefficiency. The deadweight losses will increase with an increase in tax and subsidy via the Oil Fund. The larger decrease in oil fund tax/subsidy, the lower value of the deadweight losses. The Government should float the fuel prices by ceasing the Oil Fund or reducing it as much as possible. The inequity of fuel consumption will be lower. Ceasing the Oil Fund pricing policy will minimize market inefficiency and maximize fairness of using fuels. Nevertheless, the study does not cover the calculation of deadweight losses derived from gasoline, high speed diesel, and LPG that also generate deadweight losses to the economy. Including these impacts will be beneficial for future study.

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APPENDIX A:

Table A1: Deadweight loss in case of gasohol 91

	Year								
t	2005	2006	2007	2008	2009	2010	2011	2012	2013
Jan	0.001	1.2456	4.9721	0.3813	324.623	55.6521	0.1530	9.9182	6.3001
Feb	0.001	1.2147	5.3142	0.3259	13.9102	39.3753	0.1418	0.0965	16.7333
Mar	0.002	1.2718	3.6501	0.3576	51.5917	36.3685	0.1479	5.8438	117.471
Apr	0.002	0.3059	2.1987	0.3689	95.3214	36.5240	0.1476	5.7912	198.443
May	0.003	0.2859	1.3237	0.3694	12.5306	38.4836	0.1506	6.2125	113.475
Jun	0.003	0.2727	0.9195	0.3752	0.1351	41.5736	0.1549	32.4930	67.6311
Jul	0.004	0.2982	0.1734	0.4204	21.2639	43.4629	0.1557	46.3945	67.1560
Aug	0.009	0.2994	0.2550	0.2720	58.7358	42.3322	0.0413	3.4695	61.5405
Sep	0.014	0.3604	0.5620	2.2519	59.1687	43.7528	22.058	13.5298	13.8725
Oct	0.016	1.8774	0.1519	20.9704	63.4892	42.5415	20.651	4.4502	42.4760
Nov	0.021	5.0804	0.0860	149.542	56.2916	42.0488	19.467	0.0000	48.5107
Dec	0.027	4.8967	0.1875	376.596	63.1041	45.7015	24.757	2.1212	48.1483
Total	0.107	17.409	19.794	552.231	820.166	507.816	88.027	130.320	801.759

Note: Unit, Million Baht. **Source:** By Calculation.

Table A2: Deadweight loss in case of gasohol 95

	Year									
t	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Jan	0.041	0.0382	13.8842	48.4542	0.9278	4766.23	225.152	211.915	8.9772	318.023
Feb	0.049	0.0032	13.2654	47.8209	1.2157	6.7871	330.933	186.047	47.4961	412.840
Mar	0.054	0.0060	14.3331	30.6896	1.2243	295.110	386.162	175.685	92.4021	1108.39
Apr	0.051	0.0069	3.9146	17.0633	1.2083	470.336	372.222	166.054	90.3588	1709.42
May	0.073	0.0079	3.6767	9.0559	1.0873	92.5128	403.197	164.219	100.336	1060.16
Jun	0.090	0.0100	3.5057	5.9642	0.9843	23.6764	452.007	169.953	232.769	676.754
Jul	0.090	0.0105	3.5490	6.2312	1.0262	117.868	468.558	163.533	285.012	617.588
Aug	0.057	0.0147	3.5849	12.7004	2.7746	240.224	449.207	156.500	41.1805	596.856
Sep	0.054	0.0161	3.8513	17.1226	25.7540	241.543	476.510	28.9151	27.7734	281.066
Oct	0.051	0.0171	19.2701	10.2280	121.8820	263.456	442.864	25.6116	61.2541	486.249
Nov	0.001	0.0580	50.2754	2.2407	967.2168	225.815	421.756	1.0876	129.891	511.922
Dec	0.037	14.894	50.8847	1.8102	11216.30	259.370	393.962	0.5690	205.721	483.068
Total	0.653	15.082	183.995	209.381	12341.60	7002.93	4822.53	1450.09	1323.17	8262.35

Note: Unit, Million Baht. **Source:** By Calculation.

Table A3: Deadweight loss in case of gasohol E20

	Year					
	2008	2009	2010	2011	2012	2013
Jan	0.0056	0.1288	0.3264	3.2861	10.7827	20.7164
Feb	0.0084	3.1518	0.2754	3.2854	4.1620	14.4347
Mar	0.0154	0.2862	0.2620	3.5182	1.8544	1.2903
Apr	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
Jun	0.0371	2.1094	0.3147	3.8646	0.8045	8.2028
Jul	0.0398	1.0029	0.3295	4.0753	0.1779	8.7799
Aug	0.0288	0.2822	0.3305	4.5065	7.7692	17.9258
Sep	0.0556	0.2928	0.3337	13.2879	6.6229	29.4463
Oct	0.0705	0.3208	0.3559	11.8645	13.7105	19.3457
Nov	0.0290	0.3079	0.3583	10.3549	22.7270	18.1953
Dec	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

Note: Unit, Million Baht. **Source:** By Calculation.

Table A4: Deadweight loss in case of gasohol E85

	Year				
	2009	2010	2011	2012	2013
Jan	-	0.2448	1.7095	6.1640	22.3723
Feb	0.0146	0.3245	1.7389	6.4942	20.4491
Mar	0.0200	0.4488	2.3376	7.4346	24.8252
Apr	0.0090	0.4158	2.2534	7.7732	28.4531
May	0.0238	0.4331	3.1890	8.6598	33.4333
Jun	0.0314	0.5161	3.3698	9.0731	38.5669
Jul	0.0279	0.5946	3.8334	10.9771	42.5596
Aug	0.0368	0.6649	4.0461	13.9256	49.6137
Sep	0.0372	0.7153	3.9955	13.5933	51.7105
Oct	0.1056	0.8683	3.9873	15.0358	55.4566
Nov	0.1604	0.9270	3.5103	16.5331	58.5354
Dec	0.1983	1.1444	5.5105	21.1955	63.6196
Total	0.6649	7.2976	39.4813	136.8591	489.5953

Note: Unit, Million Baht. **Source:** By Calculation.

APPENDIX B

Table B: Retail price structure of gasoline and gasohol in Bangkok at 1 October 2012

	Gasoline		Gasohol			
	91	95	91	95	E20	E85
(1) Ex-refinery Gate Price	25.29	25.72	25.11	25.32	24.84	20.83
(2) Excise Tax (T1)	7.00	7.00	6.30	6.30	5.60	1.05
(3) Municipal Tax (T2)	0.70	0.70	0.63	0.63	0.56	0.10
(4) Oil Fund	6.10	7.40	-0.60	1.70	-0.90	-11.80
(5) Energy Conservation	0.25	0.25	0.25	0.25	0.25	0.25
(6) Wholesale Price	39.34	41.07	31.69	34.20	30.35	10.44
(7) VAT1	2.75	2.88	2.22	2.39	2.12	0.73
(8) Wholesale Price + VAT1	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) VAT2	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

Note: The retail price structure of gasoline and gasohol are demonstrated by ex-refinery gate price that derives from crude oil price plus cross refining margin whereas marketing margin is storage costs plus transportation costs, marketing costs, and retail margin. Unit: Baht/Liter.

Source: Energy Policy and Planning Office: Ministry of Energy.