Kasetsart Journal of Social Sciences 44 (2023) 365–376

Kasetsart Journal of Social Sciences

journal homepage: http://kjss.kasetsart.org

Reference-dependent preferences and gasoline consumption in Thailand

Rawadee Jarungrattanapong[a,*], Akarapong Untong[b,†]

[a] *School of Economics, Sukhothai Thammathirat Open University, Nonthaburi 11120, Thailand*
[b] *School of Tourism Development, Maejo University, Chiang Mai 50290, Thailand*

Article Info

Article history:
Received 5 May 2022
Revised 7 July 2022
Accepted 31 July 2022
Available online 21 June 2023

Keywords:
asymmetry,
gasoline consumption,
hysteresis,
loss aversion,
reference dependence

Abstract

Reference-dependent preference is one of the fundamental concepts of the prospect theory that consumers are likely to be more sensitive when prices have increased relative to recent past prices (as a reference point) and less sensitive when prices have reduced. Some evidence over the last few decades suggests that behavior in a variety of settings is partly determined by a reference point. This study investigates this preference empirically by testing the presence of the reference-dependence preference in terms of asymmetry and hysteresis in retail gasoline consumption in Thailand using the price-income-decomposition method. The gasoline 95 data set, as an example, was tested to show evidence of the reference-dependent effect. Asymmetry refers to the differences in the demand responses of an increasing price or income from that of decreasing price or income. Hysteresis refers to the dependence of the impacts of increasing price or income on the previous maximum price or income. The results indicate that the demand responses to gasoline 95 are more elastic when prices rise, especially when prices rise above the historic maximum, than when prices fall. These asymmetric responses can be explained by either vehicle technology fixation or reference-dependent preference. Therefore, if the effects of hysteresis and asymmetry are ignored in gasoline demand forecasts, the demand estimates for gasoline would be overestimated when the price rises and would then be underestimated when income rises above the historic maximum. While our findings are unable to represent the whole gasoline demand, this study serves as an illustration to further develop the demand forecasting model for the future.

* Corresponding author.
E-mail address: rawadee@gmail.com (R. Jarungrattanapong).
† Co-first authors.
E-mail address: akarapong_un@hotmail.com (A. Untong).

https://doi.org/10.34044/j.kjss.2023.44.2.06
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Introduction

The conventional consumer demand theory assumes that demand and its drivers have a perfectly symmetric relationship. Hence, when price or income increases or decreases, demand would change at the same magnitude as the change in price or income, but the change would be in the opposite direction. Understanding this relationship is significantly important when adopting a demand modeling approach since the assumption of how demand would respond to the changes in price or income has a significant effect on the estimates of gasoline demand forecasting. There is a growing interest in recent years in deviations from the conventional model of consumer behavior. Some evidence of this work focuses on reference-dependent preferences where there is a change in the shape of the utility function at some base (reference) level of income or consumption (e.g., Kopalle et al. (1996), Kőszegi and Rabin (2009). These models have strong predictions for how responses to changes in prices are affected by the actual level of consumption or income relative to the reference level (Farber, 2008).

Evidence from the marketing literature also suggested that demand for commodity products depends not only on their current price but also on whether the price is higher than the reference price (a perceived loss) or is lower than it (a perceived gain) (Kopalle et al., 1996). Therefore, the responses to gain (when the price decreases) and loss (when the price increases) are asymmetric. Further, the reference point may change in the sense that the last choice is the new reference point (Apesteguia & Ballester, 2009). Substantial experimental and empirical studies have also suggested that the reference-dependent principle can help to explain how people make decisions on several economic activities that deviate from the standard consumer model (see more reviews of this literature in DellaVigna (2009)). The reference-dependent principle was first proposed under the prospect theory by Kahneman and Tversky (1979) which states that people value losses more than gains depending on their reference point. Kőszegi and Rabin (2009) further developed a model of reference-dependent preferences under the spirit of prospect theory where the gain-loss utility was derived from the consumption utility, and the reference point was determined by an individual's rational expectation rather than the status quo. For example, the windfall money from the lottery may be treated as a gain, however, a profit of $10,000 to a merchant who expected $20,000 would not be assessed as a large gain relative to status quo wealth, but rather as a loss relative to expectations to the wealth.

The transport sector has been the highest energy-consuming sector in Thailand, accounting for 35 percent of total final energy consumption in 2018, and road transport, which plays an important role in economic development, consumed almost 80 percent of energy consumption in the transportation sector (ASEAN Secretariat, 2018). Demand forecasting for transport fuels is one of the most common research areas in energy policy, however, relatively little literature on energy policy has focused on potential asymmetries in the response of consumption to oil and energy prices (Knotek II & Zaman, 2021). There are important reasons to understand how these considerations affect the estimation of gasoline demand elasticities. Evaluation of government policy regarding tax and subsidy programs depends on having reliable estimates of the sensitivity of gasoline demand to price and income levels. Most previous research on energy policy relied on the conventional consumer demand theory assuming that demand and its drivers have a perfectly symmetric relationship, implying that when price or income increases or decreases, consumption would change at the same magnitude as the change in price or income. To the extent that individuals' levels of gasoline demand are the result of optimization with reference-dependent preferences, the usual estimates of price and income elasticities, which assume that demand and its drivers have a perfectly symmetric relationship, are likely to be misleading.

In recent years, researchers have become increasingly interested in explanations to understand the asymmetric responses to gasoline consumption. An understanding of how gasoline prices affect consumer behavior would be important for researchers to apply the appropriate model to forecast gasoline demand more accurately. Wadud (2017) cited that the asymmetric response in the transportation sector is mainly due to technology fixation that people invest in fuel-efficient technologies when oil prices increase, yet still use the same technologies when prices fall (Gately, 1992). Further, some studies, including those of Ahrens et al. (2017), Bowman et al. (1999), and Wadud (2017), attempted to provide a behavioral explanation for these responses using the prospect theory that people value losses more than gains depending on their reference point, and this could result in asymmetric responses to price changes. Ahrens et al. (2017) presented a theory of price adjustment based on loss aversion from the prospect theory. Based on the loss aversion phenomenon, the consumer tends to put more weight on the perceived utility losses due to price rises than on the perceived utility gains from price drops, implying that consumption responses are more elastic to price increases than to price decreases. Wadud (2017) also suggested that both technology fixation and behavioral factors (possibly due to loss aversion) are responsible for the asymmetry in the consumption response of gasoline to price and income changes. Heidhues and Kőszegi (2008) explained the behavioral aspect of the asymmetric responses to prices and stated that consumers are averse to paying for goods when the price exceeds their expected price. In other words, consumers are loss-averse relative to a reference point they have attached to the expected price. This behavior is known as loss aversion.

To the best of our knowledge, no energy demand study in Thailand has incorporated the reference-dependence preference into the energy forecasting model and tested the asymmetries in the responses of energy consumption to prices and income. Understanding the relationship between demand and its drivers, especially price, is significantly important when adopting a demand modeling approach since the assumption of how consumers would respond to the changes in price or income has a significant effect on the estimates of energy demand forecasting. The paper was motivated by estimates of the price (or income) elasticity of energy demand for the Thai energy policy that has not incorporated the reference-dependence preference into the energy forecasting model. The conventional demand model assumes that the responses of energy consumption to prices and incomes are symmetry regardless of reference-dependent preferences, however, there is some evidence that suggests that behavior in a variety of settings is in part determined by a reference point.

In view of all these, this study aimed to empirically test the presence of the reference-dependence preference on gasoline consumption using consumption of gasoline 95 in Thailand as a case study. More specifically, this study investigated the asymmetries in the responses of energy consumption to prices and incomes and whether gasoline consumption would show an imperfectly reversible or asymmetric response with respect to price and income changes. If the responses with respect to price or income changes are asymmetry responses, it can be implied that individuals' levels of gasoline demand would be partly the result of optimization with reference-dependent preferences. The gasoline demand offers an appropriate setting to study the reference-dependent effect because gasoline can be considered as a homogenous product due to little brand competition and consumers purchase at transparent prices. By using the gasoline 95 data set, as an example, to show evidence of reference-dependent preference, we applied the price-income-decomposition method to analyze demand for gasoline 95 in Thailand from 2008 to 2019. In particular, we tested whether demand response would be more elastic to a price or an income increase than to a price or an income decrease (so-called asymmetric effect). In addition, we also tested whether the effects of rising prices and incomes and falling prices or incomes would be different depending on the level of the historic maximum price or income (so-called hysteresis effect). The present study contributes to the behavioral science literature by providing evidence of the reference-dependent effect that leads to the asymmetries in the responses of energy consumption to prices and incomes using the demand for gasoline 95 as a case study.

Accordingly, we found statistical evidence of hysteresis for incomes and gasoline prices. This implies that demand responses for gasoline 95 are more elastic to price increases, especially when prices are above the historic maximum, than when prices decrease. Consumers tend to put more weight on utility losses resulting from price increase than on utility gains from price decrease. This behavior bias is known as loss aversion. Further, fuel customers have a stronger response to falling incomes than to rising incomes. Consumers may take a negative income shock as losses in the form of consuming below their reference point.

The rest of the paper is structured as follows. Section 2 reviews the relevant literature. Section 3 describes the data and methods used to analyze the responses of gasoline demand with respect to price and income changes. Section 4 presents the results and discussions. The conclusion is presented in section 5.

Literature Review

In transport economics literature, the assumption of perfect reversibility of consumption has been tested numerous times, specifically, whether gasoline consumption responds equally to an increase and a decrease in the gasoline price. This is known as the asymmetric effect. Gately (1992) argued that consumption response to price increases could be different depending on the price history or on whether the current price is higher or lower than the previous maximum. This kind of effect that depends on past events is known as the hysteresis effect. A hysteretic system is path-dependent; the long-term effects do not depend on the long-term values of the exogenous factors but on the initial condition of each state variable (Wolfgang, 1990). Therefore, future effects would depend on past outcomes. Further, Anderson et al. (2013) also argued that understanding how consumers respond to current gasoline prices requires information about what consumers believe or expect about future gasoline prices.

Dargay (1992) analyzed the aggregate energy demand in the UK from 1960 to 1990 and tested whether energy demand was perfectly reversible with respect to price changes. The results showed that energy demand was not perfectly reversible to price and income changes, suggesting that the imperfect reversibility of demand assumption could provide better estimates of future energy demand. Furthermore, Gately (1992) investigated the price-reversible response of world oil demand during the 1960–1989 period using the price-decomposition method and found that oil demand was not perfectly price-reversible. The author further argued that if a perfectly price-reversible response is assumed, then the elasticity of demand would be overestimated when the price decreases, which would then underestimate the effect of income growth on future demand. Meanwhile, Adeyemi and Hunt (2007) analyzed the Organisation for Economic Co-operation and Development (OECD) industrial energy demand over the period 1963–2003 using nonlinear least squares. Although the authors found it difficult to conclude precisely, the authors nevertheless summarized that incorporating asymmetric price responses into the specification is preferable for OECD industrial energy demand. Similarly, Bagnai and Ospina (2016) found that price changes have a negative asymmetric effect on oil demand when they examined the asymmetries in the monthly gasoline prices of the 12 Eurozone countries from 1999 to 2015. They also found the negative asymmetric effect of price changes on oil demand, which suggests that reductions in crude oil prices have a greater effect on oil demand than price rises.

Accordingly, Gately (1992) found out that demand is less responsive to price decreases than to price increases above the historic maximum. Meanwhile, Wadud (2014) investigated the effects of asymmetry and hysteresis of income and price changes on air travel demand and found both asymmetric demand responses and a type of hysteresis effect, implying that income and price elasticities are not constant. Gately and Huntington (2002) also found that OECD demand is more responsive to oil price increases than to decreases; likewise, demand adjustment is faster when income changes than when price changes. Meanwhile, Bowman et al. (1999) found an asymmetrical relationship between consumers' responses to positive and negative income shocks, implying that the expected consumption growth is more responsive to decreases in expected income growth than to increases. The authors explained that consumers are likely to reduce their current consumption below their reference level in response to a negative shock to future income. The results from previous studies imply that ignoring the asymmetric responses to and the hysteresis effect of price and income or regardless of reference-dependent preferences may lead to biased demand elasticity estimates, which may then result in misleading demand projections.

Methodology

Data

The variable decomposition method was first proposed by Wolffram in 1971 (Wolfram, 1971). This technique decomposes price series into two components, namely, a monotonically decreasing series of price falls and a monotonically increasing series of price increases. Gately (1992) then improved this decomposition method by incorporating the effect of hysteresis into the estimation. This later became the standard technique used in many transport and energy asymmetry literatures (e.g., Griffin & Schulman, 2005; Wadud, 2014; 2017).

Following the decomposition method, we decompose price and expenditure into three monotonic series: price (or income) increases to previous maximum levels, price cuts, and price recoveries. We express the decomposition of the variable series as follows (Wadud, 2014):

$$V_t^{max} = \max(V_0,...,V_t), \quad (1)$$

$$V_t^{rec} = \Sigma_{i=0}^{t} \max\{0,(V_{i-1}^{max} - V_{i-1}) - (V_i^{max} - V_i)\}, \text{ and} \quad (2)$$

$$V_t^{cut} = \Sigma_{i=0}^{t} \min\{0,(V_{i-1}^{max} - V_{i-1}) - (V_i^{max} - V_i)\}. \quad (3)$$

All these three variable series are monotonical values that are either increasing or decreasing depending on their definitions, such as the gasoline price decomposition in Figure 1. The variable series V_t^{max} refers to the maximum value of the variables (prices and incomes) that exceeds the historic maximum levels at time *t* (Equation (1)). It changes only if the value at time *t* is larger than the maximum value at time $t-1$. The series V_t^{max} is always positive and non-decreasing. On the other hand, the cumulative series of the variable recoveries, V_t^{rec}, represents the sub-maximum increases in the value of the variable; therefore, it is also positive and nondecreasing (Equation (2)). If an increasing value rises to a new maximum value (or exceeds all previous values), then it is treated as a value recovery. The variable series V_t^{cut} indicates the cumulative series of variable cuts (or decreases) and is negative and non-increasing (Equation (3)). When values are increasing, V_t^{cut} is constant; thus, it never increases, and V_t^{max} and V_t^{rec} never decrease (Griffin & Schulman, 2005).

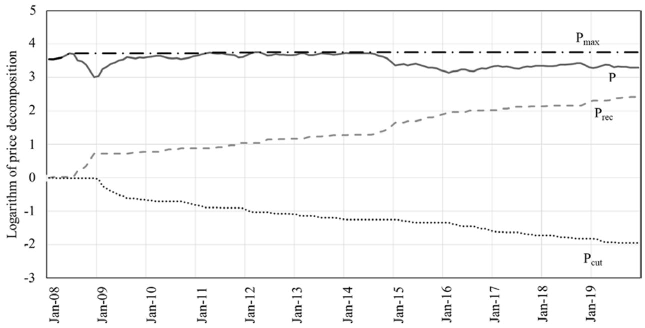

Figure 1 Monthly price decomposition of real gasoline 95 prices in Thailand during 2008–2019
Source: Energy Policy and Planning Office, Ministry of Energy (EPPO-MOE) (2021)

In this study, we investigated evidence of the reference-dependent effects of whether gasoline demand has an asymmetric and hysteresis response to price and income changes. The scope was limited to the gasoline demand over the period 2008–2019 using the data set of the Department of Energy Business, Ministry of Energy, specifically, the monthly data on the demand for gasoline 95 (gasoline with 95 octanes) from January 2008 to December 2019 at 2019 constant price. The demand for gasoline 95 was chosen to represent the gasoline demand because gasoline 95 is the only type of gasoline in Thailand that is not distorted by subsidies; it is thus driven by market forces. Figure 2 represents the monthly demand for gasoline 95 (hereafter referred to as gasoline) from 2008 to 2019. Gasoline demand significantly declined from 2008 to 2012 due to the 2008 energy crisis and the subsequent promotion of biofuel (ethanol-blended gasoline, known as gasohol). In this promotion policy, the Thai government structured gasoline prices in such a way that the retail price of gasohol was lower than that of gasoline. To control for these impacts in our analysis, the dummy variable for the period 2008–2012 (D_P) was added in our regression models. In 2013, gasoline demand increased dramatically due to the government's ban on the sale of gasoline 91, replacing it instead with gasohol 91 (10% ethanol blended with 90% gasoline, i.e., octane 91) (Bloyd, 2017). Consequently, the ban significantly increased the demand for gasoline 95 as a substitute good. Therefore, the dummy variable (D_h) was included to control for cancellation of gasoline 91. Further, the 2010 Thai political demonstrations and the 2011 great flood in Thailand had a profound effect on gasoline consumption. To account for these effects, the models included another dummy variable (D_l) to represent both effects.

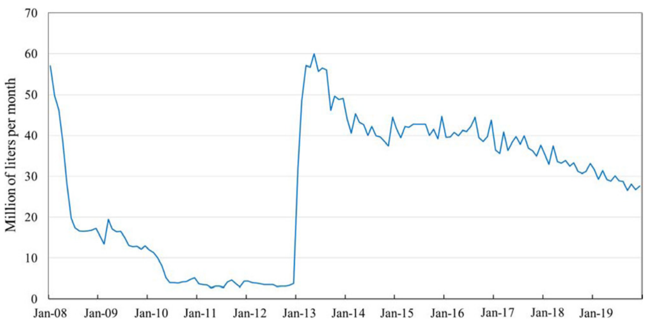

Figure 2 Monthly demand of the gasoline 95 in Thailand during 2008–2019
Source: EPPO-MOE (2021)

The per capita gasoline consumption was modelled as a function of real income per capita, retail price of gasoline, unemployment, effects of energy crisis and biofuel promotion policy, cancellation of gasoline 91, the 2010 Thai political demonstrations, the 2011 great flood and energy-saving technical change. The last variable in the models was added to test whether an asymmetric demand may be associated with technological changes due to consumers' reactions to price increases and decreases (Griffin & Schulman, 2005).

Due to the lack of monthly gross domestic products, we used the data from the Revenue Department on the revenue change of the value-added tax (VAT) to indicate income change. In this sense, we assume that VAT is passed on to the consumers and that the quantity that consumers purchase changes in response to a change in their income thereby becoming a proxy for income. We then followed a dynamic stock adjustment modeling approach, where the lag of the dependent variable is added as an explanatory variable. The following Equation (4) is our specification of gasoline demand, whereas Table 1 enumerates the variable definitions:

$$D_t=\mu+\alpha_{max}Y_t^{max}+\alpha_{rec}Y_t^{rec}+\alpha_{cut}Y_t^{cut}+\beta_{max}P_t^{max}+\beta_{rec}P_t^{rec}+\beta_{cut}P_t^{cut}+\gamma U_t+\delta D_{pt}+\lambda D_{ht}+\theta D_{lt}+\rho D_{et}+\varepsilon_t. \quad (4)$$

The continuous variables (i.e. fuel demand, income, price, unemployment series) are expressed in their natural logarithms; therefore, the parameter estimates, α and β , can be interpreted as the elasticities of gasoline demand with respect to the corresponding variables. We further investigated the perfectly reversible model of Equation (4) by testing for the equality of the parameters. Therefore, the perfectly reversible model response to income is expressed as $\alpha_{max} = \alpha_{rec} = \alpha_{cut}$ and the perfectly reversible model response to price is $\beta_{max} = \beta_{rec} = \beta_{cut}$.

Table 1 Variable description

Variable	Description
D	Log (monthly gasoline demand per capita) (liters per capita)
Y^{max}	Log (monthly revenue of the VAT per capita), maximum series (THB per capita)
Y^{rec}	Log (monthly revenue of the VAT per capita, cumulative recovery series (THB per capita)
Y^{cut}	Log (monthly revenue of the VAT per capita, cumulative fall series (THB per capita)
P^{max}	Log (monthly gasoline price per capita, maximum series) (THB per liter)
P^{rec}	Log (monthly gasoline price per capita, cumulative recovery series) (THB per liter)
P^{cut}	Log (monthly gasoline price per capita, cumulative fall series) (THB per liter)
U	Log (Unemployment rate)
D_p	Dummy for the subsequent effect of energy crisis and the biofuel promotion policy (D_p = 1, 2008–2012)
D_h	Dummy for the gasoline 91 cancellation on 1 January 2013 (D_h = 1, 2013M01-2013M06)
D_l	Dummy for the 2010 Thai political demonstration and the 2011 great flood (D_l = 1, 2010M04-2012M12)
D_e	Time trend variable for the energy-saving technical change (D_e,1 = 2008, …, 12 = 2019)

Note: (1) All monetary values are shown in a 2019 constant price; (2) THB = Thai Baht.

Estimation of Parameters

To estimate the parameters in our time series models, the data need to be stationary. However, the nature of variable decomposition is non-stationary (monotonically increasing or decreasing), and regressions with non-stationary variables are spurious (Granger & Newbold, 1974). Moreover, Engle and Granger (1987) showed that there could be a valid long-term relationship between these non-stationary data if the combination of these data is stationary. In this sense, the variables can be considered cointegrated. Hence, before we can perform the parameter estimation, this cointegration needs to be tested to see whether there is a possible correlation with the time series processes in the long term.

Several parameter estimation methods can be used for single-form equations, such as the fully modified ordinary least squares (FMOLS) method (Phillips & Hansen, 1990), the dynamic ordinary least squares (DOLS) method (Stock & Watson, 1993), the canonical cointegration regression (CCR) method (Park, 1992), and the autoregressive distributed lag (ARDL) method (Pesaran & Shin, 1995). The DOLS and ARDL methods are more widely used than the fully modified ordinary least squares and canonical cointegration regression methods because the former methods are parametric techniques, whereas the latter methods are nonparametric. Further, Panopoulou and Pittis (2004) proved that the ARDL method produces unbiased estimates and provides more valid *t*-statistics than the DOLS method. In addition, the ARDL method is more reliable for small samples (Haug, 2002).

For these reasons, we used the ARDL approach in this study. This method was first developed by Pesaran and Shin (1995) and was further expanded by Pesaran et al. (2001). Accordingly, the ARDL method follows the following steps: stationarity, cointegration, and long-run parameter estimation.

Stationary

The first step in the ARDL analysis is the *unit root analysis*, which is a type of analysis used to test whether the time series of data has significant seasonality. Our data is monthly data, which may display both the trend and seasonality components. Therefore, we applied the Taylor variance ratio test (Taylor-VRT), developed by Taylor (2005), to test for a regular unit root and a seasonal unit root. We also followed Perron's (1997) unit test with structural breaks to test whether a time series abruptly changes at some points in time.

Cointegration

The second step in the ARDL method is the *cointegration test* using the ARDL bound test to test whether the data have a valid long-term relationship within the series (Pesaran et al., 2001). Cointegration testing identifies whether there are scenarios where two or more non-stationary time series are integrated in such a way that they cannot deviate from the equilibrium in the long-term. Cointegration in the ARDL bounds test approach is analyzed under the null hypothesis that no long-term relationship (or no cointegration) exists in the time series. Thus, these non-stationary time series are cointegrated if the null hypothesis is rejected.

Due to our small sample size, we used the critical values developed by Narayan (2004) rather than those by Pesaran et al. (2001). The former values are more appropriate for small samples whereas the latter is used for large samples.

Long-run parameter estimation

After performing the cointegration test and finding no significant seasonality as well as a valid long-term relationship in the series, we then performed the long-run parameter estimation, which is the third step in the ARDL procedure. Accordingly, we estimated the gasoline demand function in Equation 4, and used the following main hypotheses to guide the subsequent tests:

Hypothesis 1: Demand of gasoline 95 is perfectly income-reversible ($\alpha_{rec} = \alpha_{cut}$).

Hypothesis 2: Demand of gasoline 95 is perfectly price-reversible ($\beta_{rec} = \beta_{cut}$).

Hypothesis 3: Demand of gasoline 95 has a perfectly reversible response to historic maximum incomes and sub-maximum income increases ($\alpha_{max} = \alpha_{rec}$).

Hypothesis 4: Demand of gasoline 95 has a perfectly reversible response to historic maximum prices and sub-maximum price increases ($\beta_{max} = \beta_{rec}$).

Thereafter, we performed the equality tests of the parameter estimates of the first two hypotheses using the Wald test to determine the imperfect reversibility of asymmetric effects. The imperfect reversibility or asymmetry with respect to incomes (and to prices) is established if the parameter estimates of $\alpha_{rec} = \alpha_{cut}$ ($\beta_{rec} = \beta_{cut}$) are significantly different (hypotheses 1 and 2). Meanwhile, the hysteresis effect on income (and on prices) is established if the parameter estimates of $\alpha_{max} = \alpha_{rec}$ ($\beta_{max} = \beta_{rec}$) are significantly different (hypotheses 3 and 4).

Results and Discussion

The results of the Taylor variance ratio test show that our data set on monthly gasoline demand is stationary at I (1, 0) at a 5 percent significance level, implying that our monthly data is stationary with the trend at a first difference but has no seasonal effect. However, the monthly gasoline demand data are non-stationary; hence, we need to test for cointegration. The result of the Perron test also confirms the presence of a structural break in the long-run relationship at a 1 percent significance level. As such, we need to control for the effect of the structural break by using dummy variables in the regressions. Otherwise, the parameter estimation using ordinary least squares regression may generate spurious regressions.

Table 2 presents the four models of the estimated price and income elasticities of gasoline demand. The dependent variable in all models is the per capita gasoline consumption. Model 1 is the reversible model, whereas the other three models are the imperfectly reversible models. The dummy variable for the effects of energy crisis and the biofuel promotion (D_p), and the dummy variables for external events, namely, the benzene 91 cancellation (D_h), and the 2010 Thai political demonstration and the 2011 great flood(D_{lp}), are added in all models to capture the subsequent impacts of these effects. Model 2 is the full imperfectly reversible model, whereas models 3 and 4 were tested to see whether gasoline demand could be determined by unemployment (U) and energy-saving technological changes (D_e), respectively.

Table 2 also shows the results of the hypothesis test, which tests the null hypothesis that no cointegration exists in the series. The results of the bounds test reject the null hypothesis, which implies that gasoline demand has established a long-run equilibrium relationship at a 1 percent significance level for all imperfectly reversible models. Based on both the Akaike information criterion (AIC) and the Bayesian information criterion (BIC), model 4 is the best model among the three imperfectly reversible models. Furthermore, the results show that prices and income are statistically significantly important determinants of gasoline consumption.

Testing for the Perfectly Reversible Model Response to Income When $\alpha_{max} = \alpha_{rec} = \alpha_{cut}$

The long-run income elasticities of Y_{max}, Y_{rec}, and Y_{cut} are statistically significant, where both Y^{max} and Y^{cut} are statistically significant at a 1 percent significant level and Y^{rec} is significant at a 5 percent significant level (Model 4 in Table 2). Meanwhile, the result of the Wald test for the equality of these parameters ($\alpha_{max} = \alpha_{rec} = \alpha_{cut}$) rejected the null hypothesis of the equality restriction ($F = 21.739$, $p < .01$), implying that demand response to income is imperfectly reversible.

When testing the equality of $\alpha_{rec} = \alpha_{cut}$, the result reveals that the sub-maximum income rises and sub-maximum income falls exhibit the asymmetric response at a 10 percent significant level ($F = 3.057$, $p < .10$). The perfectly income-reversible hypothesis is therefore rejected (hypothesis 1), which means that there are asymmetric responses to negative and positive income shocks. This finding further implies that when income falls, people are likely to decrease

Table 2 Estimated long-run elasticities and hypothesis tests of gasoline demand using the ARDL approach

Independent Variables	Parameters			
	Perfectly reversible model	Imperfectly reversible models		
	Model 1	Model 2	Model 3	Model 4
Y	.646***			
Y^{max}		2.190***	2.113***	2.093***
Y^{rec}		.494**	.593***	.552**
Y^{cut}		.661***	.678***	.714***
P	-.773***			
P^{max}		-4.771***	-4.564***	-4.460***
P^{rec}		-.861***	-.750***	-.826***
P^{cut}		-.384**	-.349*	-.306**
U	.114	-.134		
D_p (2008–2012 = 1)	-1.638***	-2.018***	-2.019***	-2.026***
D_h (2013M01-2013M06 = 1)	.625***	.320***	.347***	.336**
D_l (2010M04-2012M12 = 1)	-1.052***	-.745***	-.723***	-.720***
D_e	-.142***	-.001	-.038	
No. of observations	144.000	144.000	144.000	144.000
Bounds test	32.549***	35.633***	38.395***	42.287***
Cointegration eq.	-.466***	-.631***	-.630***	-.632***
Adj-R^2	.642	.746	.744	.745
Akaike information criterion	-1.189	-1.509	-1.507	-1.516
Bayesian information criterion	-1.045	-1.282	-1.301	-1.331
Hypothesis test (Wald test)				
$\alpha_{max} = \alpha_{rec} = \alpha_{cut}$	-	22.102***	21.699***	21.739***
$\alpha_{rec} = \alpha_{cut}$	-	1.328	.401	3.057*
$\alpha_{max} = \alpha_{rec}$	-	40.479***	40.963***	42.975***
$\alpha_{max} = \alpha_{cut}$	-	40.875***	38.578***	39.753***
$\beta_{max} = \beta_{rec} = \beta_{cut}$	-	45.505***	45.763***	48.947***
$\beta_{rec} = \beta_{cut}$	-	3.406*	2.493	6.449**
$\beta_{max} = \beta_{rec}$	-	38.545***	36.725***	38.888***
$\beta_{max} = \beta_{cut}$	-	73.462***	71.078***	71.615***

Note: an asterisk for significant level is reported in the form: * $p < .1$, ** $p < .05$, *** $p < .01$.

their gasoline consumption (α_{cut} = .714) at a faster rate than their increase in gasoline consumption when income rises at the sub-maximum income (α_{rec} = .552). Therefore, fuel consumers respond more strongly to falling incomes than to rising incomes. Consumers' purchasing power due to a higher rise in income may play a role in explaining this behavior. Consumers are likely to take a loss due to this income shock, which manifests through consuming below his/her reference point if we assume that the reference point depends on the consumer's past consumption.

To determine the presence of hysteresis, we tested the equality of $\alpha_{max} = \alpha_{rec}$ and found that demand responds differently to a rise in income depending on the level of the previous maximum income (F = 42.975, $p < .01$). Accordingly, we rejected the hypothesis of no hysteresis effect (hypothesis 3). The estimated parameters of the long-run elasticities reveal that when income rises above its previous maximum, people tend to increase their gasoline consumption (α_{max} = 2.093) at a faster rate than their increase in consumption when the rising income is lower than the previous maximum (α_{rec} = .552).

Another test performed in this study to check for the hysteresis effect is the equality test for $\alpha_{max} = \alpha_{cut}$. The result also shows that demand responses to sub-maximum income decreases and increases (F = 39.753, $p < .01$) are significantly different at a 1 percent significance level. This implies that the rate of decrease in gasoline consumption when income falls (α_{cut} = .714) is lower than the rate of increase in consumption when income rises above the historical maximum (α_{max} = 2.093).

Testing for the Perfectly Reversible Model Response to Prices When $\beta_{max} = \beta_{rec} = \beta_{cut}$

The long-run price elasticities of P^{max}, P^{rec}, and P^{cut} are all significant, where both P^{max} and P^{rec} are statistically significant at a 1 percent significant level and P^{cut} is significant at a 5 percent significant level (Model 4 in Table 2). Moreover, the results of the Wald test for the equality of $\beta_{max} = \beta_{rec} = \beta_{cut}$ show that demand response to prices is imperfectly reversible ($F = 48.947$, $p < .01$). To determine the presence of the asymmetric response to prices, we tested the equality of $\beta_{rec} = \beta_{cut}$ and found that the sub-maximum price rises and falls exhibit the asymmetric response ($F = 6.449$, $p < .05$). This implies that there are asymmetric responses to negative and positive price shocks. Hence, the perfectly price-reversible hypothesis is rejected (hypothesis 2). This finding further implies that when prices rise, people are likely to decrease their gasoline consumption ($\beta_{rec} = -.826$) at a faster rate than their decreasing gasoline consumption when prices fall ($\beta_{cut} = -.306$). This evidence shows the loss aversion phenomenon that people are likely to put more weight on the perceived utility losses due to price rises than on the perceived utility gains from price falls, implying that demand responses are more elastic for price increases than for price decreases.

Further, the differences in the estimates of elasticities with respect to the historic maximum price, β_{max}, and price recovery, β_{rec}, are statistically significant at a 1 percent level ($F = 38.888$, $p < .01$); therefore, the hypothesis that there is no hysteresis effect on prices (hypothesis 4) is rejected. This evidence then establishes the presence of a hysteresis effect, implying that when prices increase above the previous maximum, people are likely to reduce their gasoline consumption ($\beta_{max} = -4.460$) at a faster rate than they would decrease their consumption when the sub-maximum price ($\beta_{rec} = -.826$) increases. This result can be explained by both vehicle technology fixation and consumers' loss aversion. Even though the value of β_{max} is quite elastic for gasoline, it should be noted that this is the case of the previous maximum (or a new high record). Consumers might be loss-averse when the present price increase exceeds their reference point (or the previous maximum), which is given by their expectations to pay a certain price for a commodity (Heidhues & Kőszegi, 2008). Further, our result is also in accordance with Wadud (2014) that a demand response when the prices rise above the previous maximum is about five times larger than the estimated price elasticity of the reversible model.

Another evidence of the hysteresis effect is shown in the results of the equality test for $\beta_{max} = \beta_{cut}$. Our result shows that demand response to the decrease of the sub-maximum price and the increase of the historic maximum price is also significantly asymmetric ($F = 71.615$, $p < .01$). Hence, a fall in sub-maximum prices increases gasoline consumption ($\beta_{cut} = -.306$) at a slower rate compared to the rate of a decrease in consumption when prices rise above the historical maximum ($\beta_{max} = -4.460$). This evidence shows that consumers put more weight on utility losses due to the historic maximum price increases than on utility gains from the sub-maximum price falls.

In summary, our results confirm the presence of asymmetries and hysteresis when prices of gasoline 95 and income changes, especially when prices and incomes rise above the historic maximum. Our findings are in line with those found in previous studies on air transport demand in the US (Wadud, 2014); world oil demand (Gately, 1992); oil demand in 96 of the world's largest countries (Gately & Huntington, 2002); gasoline demand in 12 Eurozone countries (Bagnai & Ospina, 2016); and gasoline demand in the US (Wadud, 2017). Therefore, ignoring the presence of these effects may lead to a highly biased analysis of gasoline demand.

Comparison between the Imperfectly and Perfectly Reversible Models

We then compared the imperfectly reversible model with the perfectly reversible model by analyzing the parameter estimation results of Models 1 and 4 (Table 2). The estimated price elasticity (P) of the perfectly reversible model (Model 1) is -.773, while the elasticity with respect to the price above the historic maximum (P^{max}) of Model 4 is -4.460. This result is in accordance with Wadud (2014) of a demand response when the price above the previous maximum is about five times larger than the estimated price elasticity of the reversible model. While the estimated elasticity (-.826) of the sub-maximum price recovery (P^{rec}) from the imperfectly reversible model (Model 4) and the price elasticity of the perfectly reversible model (-.773) is not highly significantly different, the price elasticity of the perfectly reversible model is about two times larger than the estimated price elasticity (-.336) of the sub-maximum falls (P^{cut}) from the imperfectly reversible model. These results raise the concern that the estimated gasoline demand of the perfectly reversible model would be overestimated when the price rises, especially when prices rise above the previous maximum.

Our findings also complement those of earlier studies (Gately & Huntington, 2002; Wadud, 2014, 2017), which found that the price elasticity of the imperfectly reversible model is more elastic than that of the perfectly reversible model. In our case, fuel consumers may take the past price as a reference point, which serves as their anchor; consequently, purchasing at a higher price than that reference point would be treated as a loss. In line with the prospect theory suggested by Ahrens et al. (2017), consumers put more weight on the perceived utility losses from price increases than on the perceived utility gains from price decreases.

Furthermore, vehicles are durable goods. People invest in fuel-efficient vehicles when fuel prices increase, yet they do not dispose of these vehicles when fuel prices fall. The sunk cost nature of these investments and longevity of capital can explain why those past investments are still in place (Dargay, 1992). Technology fixation can also be another reason for the asymmetry in gasoline demand as suggested by previous studies (e.g., Dargay, 1992; Gately, 1992; Wadud, 2017). This finding provides a significant policy implication. It reveals that the effect of the tax policy that increases gasoline prices, especially when prices exceed the historic maximum, is likely to be underestimated (as the case of gasoline 95) if the price elasticity of the perfectly reversible model is applied.

The same concept applies to the estimated income elasticities of the imperfectly and perfectly reversible models. The estimated income elasticities in this study are .646 in the perfectly reversible model (Model 1) and 2.093 in the imperfectly reversible model when incomes rise above the historic maximum income (Model 4). This indicates that the income elasticity of the perfectly reversible model is three times lower than that of the imperfectly reversible model. Therefore, the effect of income growth on future demand of gasoline 95 would be underestimated if the perfectly reversible model is used in predicting gasoline demand. Accordingly, Dargay (1992) explained that when income increases, people consider energy use for residential purposes as the superior good, which leads the composition of demand to shift toward higher-quality products. In our case, gasoline 95 would be defined as a normal good ($0 < \varepsilon_Y < 1$) if the perfectly reversible model is applied, whereas it would be treated as a luxury good ($\varepsilon_Y > 1$) when income rises above the previous maximum in the imperfectly reversible model. These findings could then serve as a guide for policymakers when formulating and imposing taxes and subsidies on prices for gasoline 95 consumption.

Conclusion

This study finds evidence of the reference-dependent effects in terms of hysteresis for incomes and gasoline prices in the case of gasoline 95 consumption. This research argues that the hysteresis in gasoline is not only due to technology fixation, as suggested by earlier studies such as Wadud (2017), but also due to the reference-dependent effect that gasoline demand is more responsive to price increases when the price rises above the historic maximum than when the price recovers (sub-maximum price). This is implied that demand for gasoline 95 is likely to be more price-sensitive when gasoline prices have increased above the maximum past price (the reference point). This finding is remarkably important, especially when policymakers formulate and impose taxes or subsidies on gasoline prices and in forecasting gasoline demand.

The same logic applies to income changes. Demand for gasoline 95 is more responsive to income increases when income rises above the maximum than when income recovers (sub-maximum income). The consumer's purchasing power due to a higher rise in income could explain this behavior. Further, consumers have a stronger response to decreasing income than to increasing income. People may take an income shock as a loss in the sense that they could choose to consume below their past consumption (their reference point). Consequently, consumers may choose to commute through public transportation rather than commute by private vehicles when their income falls.

The difference in the price and income elasticities of demand for gasoline 95 between the reversible and irreversible models has important policy implications. The demand estimates of gasoline 95 would be overestimated when the price rises and would then be underestimated when income rises above the historic maximum. In sum, ignoring the reference-dependent effects of asymmetries and hysteresis on demand for gasoline 95 when gasoline price and income changes may lead to biased estimates in demand forecasting. While our findings are unable to represent the whole gasoline demand, we present new evidence of the reference-dependent effects in the demand forecasting model and this study will serve as an illustration to further developing the research for the demand forecasting model in the future.

Conflict of Interest

The authors declare that there is no conflict of interest.

Acknowledgments

A special thanks go to Jack Knetsch for inspiring the research idea. Comments from Suparee Boonmanunt are gratefully acknowledged. We also wish to thank Panthita Kumman for her assistance.

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