THE EFFECTS OF GOVERNMENT REGULATED PRICE TRANSPARENCY ON THE RETAIL GASOLINE MARKET IN TAIWAN

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Abstract

This thesis studies possible outcomes of the government's policy (increased price transparency) to the retail gasoline market. Chapter 2 investigates one of possible outcome of the government's price policy on the retail price setting and provides new evidence of 'hot air balloons and bricks' that retail prices respond more quickly to decreases in costs but respond slowly to increases in costs. Chapters 3 and 4 discuss the government's policy served as unilateral disclosure of the leading firm's future price information to the supply and demand sides of the retail gasoline market, respectively. Chapter 3 presents empirical analyses of price leadership and perfect price alignment to explore the effect of an increased price transparency policy on the supply side. We propose evidence that the government's policy is the underlying cause of price leadership and price coordination. Finally, using regional household-level data across 20 Taiwanese regions, Chapter 4 semiparametrically examines the effect of the government's policy on the demand side. We find evidence of intertemporal substitution that the government's policy helps to plan consumers' future purchase.

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Chapter 1

Introduction

Many governments in developed economies have liberalized their energy markets and efficiently regulated their energy prices, but the Taiwan government has re-regulated its energy prices. This thesis is a case study of the Taiwan gasoline market, and it tries to delineate the structure of the Taiwan gasoline market with its price regulation.

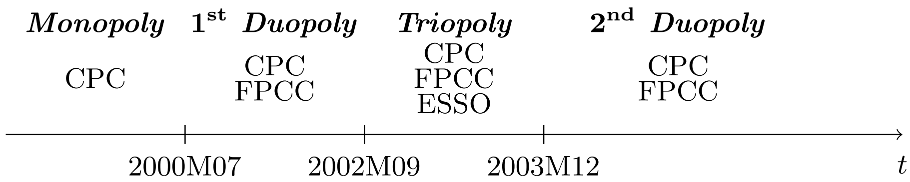
In September 2006, the Taiwanese government introduced a new price regulation policy, the price adjustment formula. Its aims were to stabilize commodity prices and prevent the occurrence of high inflation, when international crude oil prices increased dramatically. However, it seems not to have considered the possible implications for competition in the retail gasoline market.

This thesis consists of three essays, and each one analyzes the competitive impacts of the government's price regulation policy, *the price adjustment formula* (PAF), in: (i) the role of the price adjustment formula on gasoline price setting; (ii) the effect of the price adjustment formula on the future method of information sharing on the supply side; and (iii) the effect of transparent price policy on the demand side. To explore these three main effects, we initially limit our attention to the background of the Taiwan gasoline market.

Due to a lack of natural resources such as energy minerals - crude oil and coal - natural resources of energy minerals have been imported to produce and supply energy utilities (electricity, gasoline and gas) to individuals in Taiwan. Taiwan is heavily dependent on foreign energy minerals to improve economic development. Hence, their economic performance is highly correlated with energy prices, the international prices of minerals and the domestic prices of electricity, gasoline and gas.

The current market structure of the gasoline supply market in Taiwan is a duopolistic industry. Prior to the end of the 1980s, gasoline and diesel in Taiwan had been supplied by the state-owned enterprise, China Petroleum Corporation (CPC), which was effectively a vertically integrated franchised monopoly in the Taiwan petroleum industry. By the end of the 1980s, Taiwan began to deregulate and liberalize its gasoline supply industry. The private sector, Formosa Petrochemical Corporation (FPCC), had been permitted to refine petroleum products in 1992 and supply gasoline and diesel to consumers in Taiwan from mid-2000. In September 2002, the largest refiner, Exxon Mobile, and its subsidiary ESSO, entered the gasoline supply market in Taiwan, and the market structure of the Taiwan gasoline supply market became a triopoly. However, it only operated for a short time, until November 2003. Due to an underlying reason of imbalance of import tariffs between domestic and foreign fuel suppliers, a foreign supplier, Exxon Mobile, withdrew from the Taiwan gasoline market in November 2003. Domestic suppliers (CPC and FPCC) were granted a tax exemption from imposing import tariffs since they imported crude oil to be refined into fuel products. However, a foreign supplier (Exxon Mobile) exported final petroleum products to the Taiwan market and had import tariffs imposed on them - 10% for gasoline products and 5% for diesel. The government's trade policy and the tax imbalance of import tariffs resulted in entry barriers to foreign suppliers and made reductions in the competitive intensity in the Taiwan gasoline market.[1] Since Exxon Mobile withdrew their gasoline and diesel supply from the Taiwan market, the gasoline supply market in Taiwan has become a duopolistic industry again. Figure 1.1 presents a timeline history of the Taiwan gasoline market structure.

[1]Energy tariffs and taxes are listed in Appendix 2.C.



Note: The Taiwan gasoline market structure timeline contains three specific times (2000M07, 2002M09 and 2003M12) and four market structure forms (Monopoly, 1^{st} Duopoly, Triopoly, 2^{nd} Duopoly). A domestic gasoline supplier (FPCC) started to supply gasoline and diesel products to consumers in July 2000, and the gasoline market was restructured as a duopoly. In September 2002, a foreign gasoline supplier (ESSO) entered the Taiwan gasoline market and supplied gasoline products, and the gasoline market was restructured as a triopoly. A foreign gasoline supplier (ESSO) exited the Taiwan market at the end of November 2003. From December 2003, the Taiwan gasoline market was restructured as a duopoly.

Figure 1.1: Taiwan Gasoline Market Structure Timeline

As crude oil prices had a rising tendency in 2006, the government introduced the price adjustment formula to prevent the occurrence of huge fluctuations in retail gasoline prices. The price adjustment formula was introduced to mainly target supplier CPC, the state-owned enterprise, whereas FPCC, as a private supplier, was not subject to the regulation.[2] Hence, FPCC was free to set its own retail prices of gasoline products. In addition, under the price adjustment formula, CPC's future price information was publicly disclosed to consumers as well as to FPCC. The price adjustment formula can be considered as a unilateral dissemination of future price information in the gasoline market.

To conclude in the Taiwan petrol retailing market, the government can intervene in retail gasoline prices in two ways: (i) direct intervention - ownership of the state-owned enterprise; and (ii) indirect intervention use of the price adjustment formula as a framework for retail pricing. In the first pattern, the government might approve an executive order to directly intervene in the retail gasoline prices of the state-owned enterprise. The government would

[2]The price adjustment formula is an executive order made by the Ministry of Economic Affairs, and its effectiveness is only delivered to the state-owned enterprise.

approve an executive order (freezing retail prices) forbidding adjustments of retail prices when rapid increases in international crude oil prices occurred. This direct intervention played an important role in retail gasoline price setting. In the second pattern, the government introduced the price adjustment formula to the state-owned enterprise and established a framework to be an advisory measure of retail prices that can, in principle, be overturned by the first pattern, direct intervention. In this thesis we restrict our attention to the second pattern of indirect government intervention, the price adjustment formula.

In terms of the market structure of the gasoline market and the government's price regulation policy mentioned as above, we can use the Taiwan gasoline market as a case study to provide a different empirical study compared to other developed countries such as European countries, the US and Canada. Furthermore, under the circumstances of the government's transparent price regulation policy, we intend to empirically examine our three main aspects and explore the differences between our main results and the existing literature.

Prior to our empirical studies, we begin by defining the government's transparent price policy, the price adjustment formula. The price adjustment formula is an executive order to the state-owned enterprise (CPC) and is obligatory. However, its effectiveness does not apply to a private supplier (FPCC). A private supplier has no need to enforce compliance with the price adjustment formula. The procedure of the price adjustment formula is publicly disseminated via the website of the state-owned enterprise (CPC) to the public, who include consumers and the competing firm (FPCC). Consumers and the competing firm are able to gather transparent future price information through the procedure of the price adjustment formula. Therefore, this thesis focuses on three aspects to explore the effects of the price adjustment formula. First, we investigate whether the introduction of the price adjustment formula has affected how the retail gasoline price is adjusted in the market. Second, on the supply side we discuss how two existing firms' dynamic price response reacted according to the introduction of the price adjustment formula. Finally, we pay attention to the demand side and explore how consumers' purchase decisions have responded to transparent future price information. These three aspects will be empirically discussed in the following chapters

- 2, 3 and 4.

Returning to our three empirical Chapters 2, 3 and 4, we provide different econometric frameworks to investigate the government-regulated price transparency on competition in the Taiwan gasoline market. The first essay, Chapter 2, addresses a debate about the role of the price adjustment formula in retail gasoline setting. A stylized example of 'rockets and feathers', a phenomenon found in other countries is that the retail price responds rapidly to increases in crude oil prices but responds slowly to decreases in crude oil prices, as has been found in many previous studies. We test whether this phenomenon is observed in the Taiwan gasoline market. In addition, we take into account the effect of the price adjustment formula in our effort to examine the response of retail prices. However, according to the application of the price adjustment formula, the other gasoline suppliers can adopt the same retail prices as the state-owned enterprise sets. Therefore, the effectiveness of the price adjustment formula has become a debate in the Taiwan economy. By analyzing the role of the price adjustment formula and examining retail pricing behavior in Taiwan, this chapter uses standard and quadratic partial adjustment models to provide insights into explanations of the effectiveness of the price adjustment formula and retail gasoline pricing behavior. Our results suggest that the price adjustment formula had significant impacts on retail gasoline price setting, and we provide evidence of the phenomenon of 'hot air balloons and bricks': retail prices respond more quickly to cost decreases than increases under the implementation of the price adjustment formula.

Chapter 3 studies the effect of the government's transparent price regulation policy, the price adjustment formula, in three ways: firms' price setting mechanism, price leadership and anti-competitive outcomes. *A priori*, we characterize the role of the government's transparent price regulation policy in a duopoly. After characterizing the role of pre-announced policy, we focus on examining whether the price adjustment formula has an impact on firms' price setting, and leads to price leadership events and anti-competitive outcomes. We propose empirical analyses on discussing the government's transparent price policy. Our key results present that: (i) the price adjustment formula could soften the impact of positive crude oil shock on the leading firm's retail price setting; (ii) the price adjustment formula resulted in a greater incidence of price leadership; (iii) the government's transparent price policy and consequent price leadership resulted in the competing firm perfectly aligning with the leading firm's retail price. This chapter finds evidence that the government's transparent price policy would lead to a reduction in the degree of competitive intensity in the retail gasoline market.

The effect of the government's transparent price policy on the firms' price response is discussed in Chapter 3. Chapter 4 pays attention to whether the introduction of the government's transparent price policy, the price adjustment formula, affected how consumers made their purchase decisions. In this chapter, we use a variety of semiparametric estimation techniques to model gasoline demand, since semiparametric gasoline demand for households has been applied widely in most relevant literature. The advantages of semiparametric approaches are efficiency improvements to parametric estimates and avoidance of the curse of dimensionality from non-parametric estimates. By combining relevant literature of semiparametric techniques and their advantages, in this study we can have flexible non-parametric estimates and efficient parametric estimates. Our main results show that: (i) price elasticity of gasoline demand for households is relatively inelastic in urban and rich regions but it is relatively elastic in rural and poor regions; and (ii) the introduction of the government's transparent price policy helped consumers to plan future purchase responses, which served as intertemporal substitutions in gasoline consumption decisions for households. This chapter presents evidence that the introduction of the government's transparent price policy offered potential benefits to consumers.

To sum up the overall findings and contributions of this thesis: First, we develop a new pattern of possible retail price response to delineate retail price adjustment in Taiwan, and verify the existence of the new phenomenon of 'hot air balloons and bricks' that is contradictory to the stylized fact of 'rockets and feathers' found by existing literature. Second, we discuss the government's price regulation policy as a unilateral disclosure of future price information. We find that the introduction of the price adjustment formula served as a future method of information sharing, which resulted in price leadership and price coordination in a duopolistic gasoline market. Evidence of price coordination is consistent with existing literature (Albæk et al., 1997). Third, we present disaggregated household gasoline demand using a regional household level dataset, and we give an illustration of a semiparametric approach in a small country. This illustration provides empirical evidence that the government assisted consumers to plan their future purchases as inter-temporal substitutions.

Finally, Chapter 5 summarizes our results and provides considerations for further research.

Chapter 2

Speed of Price Adjustment in Retail Gasoline Prices: 'Rockets and Feathers' or 'Hot Air Balloons and Bricks'?

2.1 Introduction

A stylized fact of 'rockets and feathers' is that retail prices respond rapidly to increases in crude oil prices but respond slowly to decreases in crude oil prices, as has been found in several previous studies (e.g., Bacon, 1991; Borenstein et al., 1997; Balke et al., 1998; Reilly and Witt, 1998; Deltas, 2008; Yang and Ye, 2008; Lewis, 2011; Remer, 2015). In the Taiwan gasoline supply market, many people discuss whether the retail gasoline price adjustment is presented as 'rockets and feathers'. After the market liberalization in 1992, the market structure of the gasoline supply market has been restructured three times to result in four periods with different market structures: (i) a monopoly; (ii) the first duopoly; (iii) a triopoly;

and (iv) the second duopoly. Furthermore, the government has re-regulated retail gasoline prices during the second duopoly period. Hence, the retail gasoline price setting has become a controversial topic in Taiwan society.

In the beginning of the second duopoly period, crude oil prices had dramatic increases, which resulted in increases in retail gasoline prices. In order to stabilize retail gasoline prices after increases in crude oil prices, the government introduced the price adjustment formula (PAF) to regulate retail gasoline prices. However, under the regime of the price adjustment formula, the state-owned enterprise sets petroleum products' retail prices in advance, then the private sector decides to follow the state-owned enterprise's price setting decision. As a result of the same retail price setting by both suppliers, the aim of the price adjustment formula and its contribution have been a subject of debate over the period of implementing the price adjustment formula in the Taiwan gasoline market.

The purpose of this paper is to measure the roles of market structure and the price adjustment formula in a retail price setting and examine whether the phenomenon of 'rockets and feathers' happens in the Taiwan gasoline market. The data of the methodology were collected from the Taiwan gasoline market over a period from August 1999 to December 2012, using monthly data.

This study empirically examines whether asymmetric pricing behavior happened in the Taiwan gasoline market. First we test the speed of price adjustment using the standard partial adjustment model. We next use the quadratic partial adjustment model to precisely evaluate the effect of the price adjustment formula. Given different market structures in Taiwan, we discuss pricing behavior separately in both empirical exercises. In the first empirical exercise, we provide evidence in support of the effects of the government intervention on the retail fuel price setting. For example, we find that under direct intervention, ownership of the state-owned enterprise retail prices responded slowly to changes in crude oil prices, but given indirect intervention, the price adjustment formula retail prices were most likely to respond quickly to changes in crude oil prices. The second exercise provides no support for the presence of 'rockets and feathers' in the current market structure, which is a duopolistic market. The results of the second exercise suggest that retail prices respond slowly to increases in crude oil prices and respond quickly to decreases in crude oil prices. Our results confirm that the retail price response in Taiwan is more a case of 'hot air balloons and bricks' rather than 'rockets and feathers'.

This paper is organized as follows. Section 2.2 summarizes relevant existing studies; Section 2.3 describes econometric methodology in this empirical study; Section 2.4 analyzes econometric results and explains the role of the price adjustment formula; Section 2.5 summarizes the findings of this paper.

2.2 Literature Review

This section briefly summarizes some previous influential studies that are related to this paper, and also shows stylized facts of asymmetry of price setting in a variety of markets. In a broad study, Peltzman (2000) uses large samples of 77 consumer products and 165 producer products to do analysis of asymmetric pricing behavior. His work is different from previous papers which investigated asymmetric pricing behavior in single selected markets, e.g., gasoline, banking, and agricultural products. As Peltzman's finding shows, the tendency of asymmetric pricing behavior is found in more than two of every three markets examined within the abundance of samples. The stylized fact of asymmetric pricing behavior is also found in various markets, such as banking, vegetables and fruit, and pork and beef.[1]

The topic of asymmetric pricing behavior in gasoline market has been increasingly discussed in the most of relevant studies. Bacon (1991) uses the 'rockets and feathers' approach to describe the relationship between gasoline prices and crude oil prices in the UK gasoline market. He finds that this phenomenon involves that the retail prices respond faster to positive oil price shocks than to negative shocks. And in further work, Borenstein, Cameron

[1]See Arbatskaya and Baye (2004) for banking, Ward (1982) for vegetables and fruit, and Goodwin and Harper (2000) for pork and beef.

and Gilbert (1997) examine and confirm the existence of asymmetric price setting in the US gasoline market, and also present that the source of this asymmetric behavior might be from adjustment lags and sellers' market power in the market. Deltas (2008) uses monthly data of the US gasoline market to examine the relationship between retail and wholesale prices, and finds asymmetric behavior in the 48 contiguous states. Remer (2015) uses the US daily station-level gasoline price data to investigate asymmetry in the response of retail prices to cost changes. He provides evidence of asymmetric pricing in the US gasoline market, and particularly finds that the price adjustment of premium gasoline is slower than regular gasoline when costs decrease.

However, However, some of studies present evidence of no emergence of asymmetric pricing behavior in the US and Canadian gasoline markets. Godby et al. (2000) apply the threshold regression model to present no evidence of asymmetric pricing behavior in the Canadian retail gasoline market. Bachmeier and Griffin (2003) use an error correction model with daily price data to test the hypothesis of rockets and feathers in the US gasoline market. They find no evidence of asymmetric pricing behavior in wholesale price, and argue that daily adjustment of gasoline price is instantaneous and symmetrical to changes in crude oil prices.

There is a variety of explanations for asymmetric pricing behavior. First, the oligopolistic coordination theory might be a possible explanation for the asymmetric response of retail prices to changes in cost. Borenstein, Cameron and Gilbert (1997) identify that asymmetric pricing behavior might be explained by the oligopolistic coordination theory. They argue that sellers tend to sustain their coordinated price rather than make a price-cutting decision with a negative cost shock, and for seeking profit maximization, sellers raise retail prices with a positive cost shock. Second, search costs might be another possible explanation for asymmetric pricing. Yang and Ye (2008) exploit a dynamic consumer search model with learning asymmetry. They find that higher consumer search costs may result in asymmetric pricing in the market. Lewis (2011) develops a price search model to provide an alternative explanation for asymmetric price adjustment. He provides theoretical predictions and presents empirical evidence to argue that consumers' search behavior would significantly influence firms' retail price adjustment. Remer (2015) also investigates the relationship between asymmetric pricing and consumer searches, and finds evidence that consumer search costs may be the possible underlying cause of asymmetric pricing.

This paper builds on the previous existing study by Bacon (1991) to examine whether 'rockets and feathers' occurs in the retail gasoline market in Taiwan and identifies the role of the government's policy, the price adjustment formula, on retail price adjustment. Bacon (1991) exploits a quadratic adjustment model to empirically examine the speed of adjustment of the UK retail prices of gasoline to changes in crude oil prices. In contrast to Bacon's paper, we extend a new possible explanation of Bacon's quadratic adjustment model to identify the response of retail gasoline and diesel prices to changes in crude oil prices. This paper uses a standard and quadratic partial adjustment model to evaluate the speed of adjustment of fuel prices to cost shocks and the effect of the government's price regulation policy on price adjustment speed. Given both standard and quadratic partial adjustment models, we re-examine whether the 'rockets and feathers' pattern is observed in the retail gasoline market in Taiwan.

2.3 Methodology

The goal of this study is to examine the presence of asymmetric price response and the importance of the price adjustment formula on the retail price setting. We have set out with four research questions to achieve the objective of this study. These questions are:

(i) How did retail prices respond to changes in crude oil prices and exchange rates?

(ii) Did the response of the retail prices depend on market structure?

(iii) Was there an asymmetry between price rises and falls?

(iv) How did the price adjustment formula affect the response of retail prices?

To answer our research questions and discuss the retail pricing behavior between on-policy and off-policy periods, the econometric model in this study should encompass two concepts from market structure conditions and the links between retail price changes and cost changes. The partial adjustment model was used for the analysis of gasoline price asymmetry in the 1990s. A widely-known study was illustrated by Bacon (1991). The partial adjustment model in the study of British gasoline price asymmetry involves a lagged gasoline price, which would indicate the dynamic nature of gasoline prices. Therefore, the partial adjustment mechanism allows us to examine whether price asymmetry existed in the Taiwan retail gasoline market.

The econometric model of this study is based on the definition of the 'rockets and feathers' hypothesis provided by Bacon (1991), and then we use two approaches to model the links between cost changes and retail gasoline price changes. The first approach, the standard partial adjustment model, simply estimates retail price adjustment speed. Only looking at the estimates of the price adjustment speed is not enough to gather information about the upward and downward retail price adjustment directions if observations of positive and negative price adjustments cannot be split from the retail price data. Even if price data are split into observations of positive and negative price adjustment, the standard partial adjustment model still has difficulties in precisely evaluating the price adjustment directions. The difficulties are that the current price change might be influenced by the current or lagged cost change, and the standard linear partial adjustment model only provides the price adjustment speed evaluation. Therefore, the standard model may neglect to identify the price adjustment directions in response to cost increases and decreases. Although the price adjustment direction cannot be observed by using the standard model, the response of retail prices under the market structure base can be observed.

The second approach, the quadratic partial adjustment model, is the main econometric task in this analysis of price asymmetry. The quadratic model provides possible adjustment directions in response to cost increases and decreases. The difficulty of interpreting the price adjustment directions from the use of the standard model will not be included in the use of the quadratic model. In the quadratic model, there is no need to split price data into observations of positive and negative adjustments in order to infer the price adjustment directions. The use of the quadratic model can make it easier to provide the patterns of the possible adjustment range in response to cost increases and decreases. Then, the discussions of Bacon's quadratic partial adjustment model will be extended as appropriate in relation to deliver contributions in the analysis of price asymmetry. Therefore, the use of the partial adjustment model in this study would provide appropriate results about the retail gasoline price adjustment response over a period of a dozen years.

2.3.1 Standard Partial Adjustment Model

The partial adjustment model has been a popular method of explaining dynamic adjustment activity in the existing literature. The partial adjustment model is assumed to include the lagged actual retail gasoline price and the 'target' level or the 'equilibrium' level retail gasoline price. We suppose that the target-level price is exactly determined by the government's price regulatory policy, the price adjustment formula (PAF), and so the target-level price of this study could be construed as cost changes. This dynamic model would describe the adjustment response of the actual price to cost changes. The first method of this study is the standard partial adjustment model to determine the link between actual retail prices and target-level prices. The standard partial adjustment model is written as

$$p_t = p_{t-1} + \lambda(p_t^T - p_{t-1}), \tag{2.3.1}$$

where p_t is the actual retail price of petroleum product at time t, p_t^T is the target-level retail price of petroleum products at time t, λ is the speed of adjustment for petroleum products, and $\lambda \in [0, 1]$. If $\lambda = 1$, the adjustment of the actual retail gasoline price is instantaneous to the target-level retail gasoline price, while the adjustment of the actual price is infinitesimally slow to the target-level price if $\lambda = 0$. The standard model generally presents the adjustment speed of the actual retail gasoline price, p, to the target-level retail gasoline price, p^T. According to the estimated speed of price adjustment, $\hat{\lambda}$, we could explore whether the actual retail price would be immediately adjusted to the target-level retail price, and find out what constraints cause non-immediate price adjustment response if $\hat{\lambda}$ is a relatively small fraction. Equation (2.3.1) can be re-written as

$$p_t - p_{t-1} = \lambda(p_t^T - p_{t-1}). \tag{2.3.2}$$

2.3.2 Quadratic Partial Adjustment Model

The second approach is the quadratic partial adjustment model, and investigating this quadratic mechanism is the major task in this study. We apply this approach to express possible adjustment directions of the actual retail gasoline price to cost increases and decreases. In addition to existing possible adjustment directions to cost changes proposed by Bacon (1991), we extend the approach to discuss a new pattern of possible adjustment range. The quadratic partial adjustment mechanism is given as

$$p_t = p_{t-1} + \alpha(p_t^T - p_{t-1})^2 + \beta(p_t^T - p_{t-1}). \tag{2.3.3}$$

Re-arranging equation (2.3.3), the new form is written as

$$p_t - p_{t-1} = \alpha(p_t^T - p_{t-1})^2 + \beta(p_t^T - p_{t-1}), \tag{2.3.4}$$

where α and β are the coefficients of the quadratic term and the linear term. If $\alpha = 0$, the quadratic adjustment model would be rearranged as the standard partial adjustment model. Thus, testing the hypothesis, $\alpha = 0$, is the first work in this quadratic mechanism. The null hypothesis is given by

$$H_0 : \alpha = 0,$$

$$H_1 : \alpha \neq 0.$$

If the null hypothesis of the linear adjustment model is not rejected, the quadratic partial adjustment mechanism might be rearranged to the standard partial adjustment mechanism as an equation (2.3.2).

If the null hypothesis of the linear adjustment model is rejected, the possible adjustment range can be interpreted by a variety of values of α and β. Prior to interpreting α and β, equation (2.3.4) can be differentiated with respect to the difference between target price at time t and actual retail price at time $t-1$. Differentiating equation (2.3.4) with respect to $(p_t^T - p_{t-1})$ gives

$$\frac{d(p_t - p_{t-1})}{d(p_t^T - p_{t-1})} = 2\alpha(p_t^T - p_{t-1}) + \beta.$$

Given a variety of values of α and β and a differentiated equation, there are three patterns of possible adjustment range in the retail prices in response to cost shocks. The first and second patterns of possible price adjustment response were discussed by Bacon (1991), but the third pattern was not involved in his study. We begin with the first pattern, where retail price adjustment responds more rapidly to rises in costs than declines in costs if both α and β are positive ($\alpha > 0$ and $\beta > 0$). Then, the second pattern is where price adjustment is faster to react to decreases in costs if α is positive and β is negative ($\alpha > 0$ and $\beta < 0$). In this paper, we exploit the third pattern of possible price adjustment range. The third case is where we suppose that retail price responds slowly to increases in costs and quickly to decreases in costs if α is negative and β is positive ($\alpha < 0$ and $\beta > 0$). These three patterns of possible adjustment in response to changes in costs are depicted in figure 2.1. The solid line interprets the first type of price adjustment with positive values of α and β; the dot line interprets the second type of price adjustment with a positive value of α and a negative value of β; the dash-dot line presents the third type of price adjustment, with a negative value of α and a positive value of β.

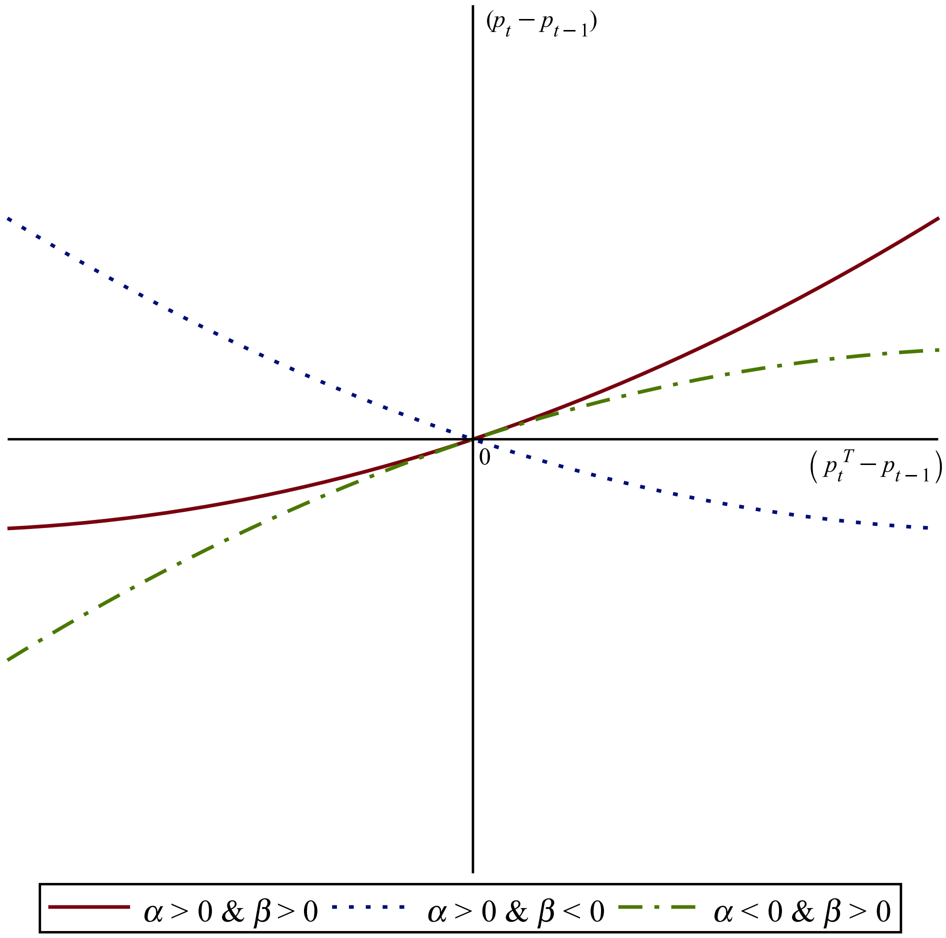


Figure 2.1: Possible Price Adjustment to Changes in Costs

2.3.3 Interpretations of Coefficients in the Linear Term

Testing the hypotheses that the values of λ in the standard linear adjustment form and the values of β in the quadratic adjustment form, if the null hypothesis of the linear adjustment model ($H_0 : \alpha = 0$) holds, is conducted to present the speed of retail price adjustment to changes in costs. The hypotheses are:

(i) testing values of λ:

$$H_0 : \lambda = 0,$$

$$H_0 : \lambda = 1;$$

(ii) testing values of β if $\alpha = 0$:

$$H_0 : \beta = 0,$$

$$H_0 : \beta = 1.$$

These four cases of null hypotheses suggest that: (i) the first and third cases in which the null hypotheses of $\lambda = 0$ and $\beta = 0$ are not rejected give infinitesimally slow adjustments to changes in crude oil prices; (ii) the second and fourth cases of $\lambda = 1$ and $\beta = 1$ show an instantaneous adjustment to changes in crude oil prices.

2.4 Data and Empirical Results

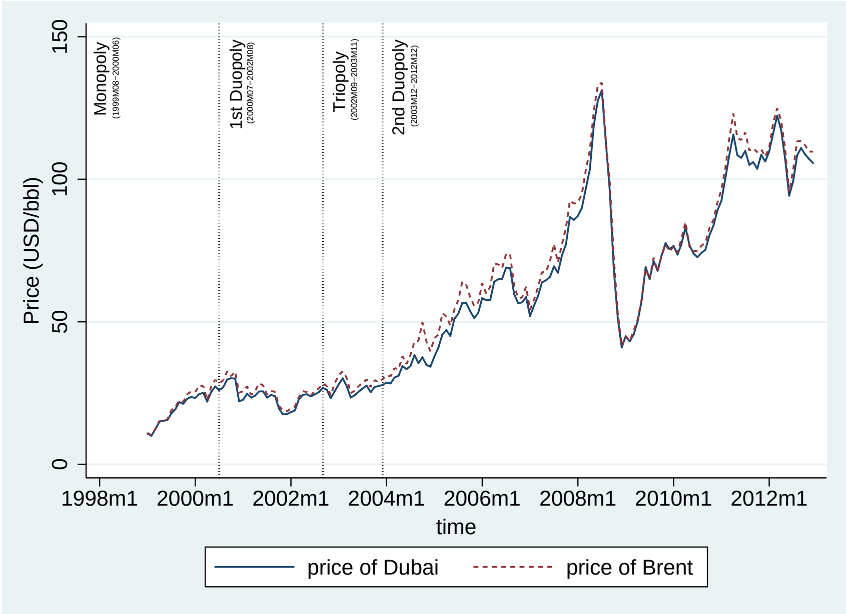
2.4.1 Data Description

This study consists of two different sources of monthly observations from the supply and demand sides from August 1999 to December 2012, for a total of 161 months. The first source from the supply side contains monthly Dubai and Brent crude oil prices and the exchange rate for the US dollar to the Taiwan dollar. Prices of Dubai and Brent crude oil are collected from the Global Economic Monitor (GEM) Commodities and the World Bank. The exchange rate for the US dollar (USD) to the Taiwan dollar (TWD) is gathered from the Central Bank of the Republic of China (Taiwan). The second source, from the demand side, contains the state-owned enterprise's monthly retail price data, which are collected from the Petroleum Price of Information Management and Analysis System, the Bureau of Energy (Taiwan).

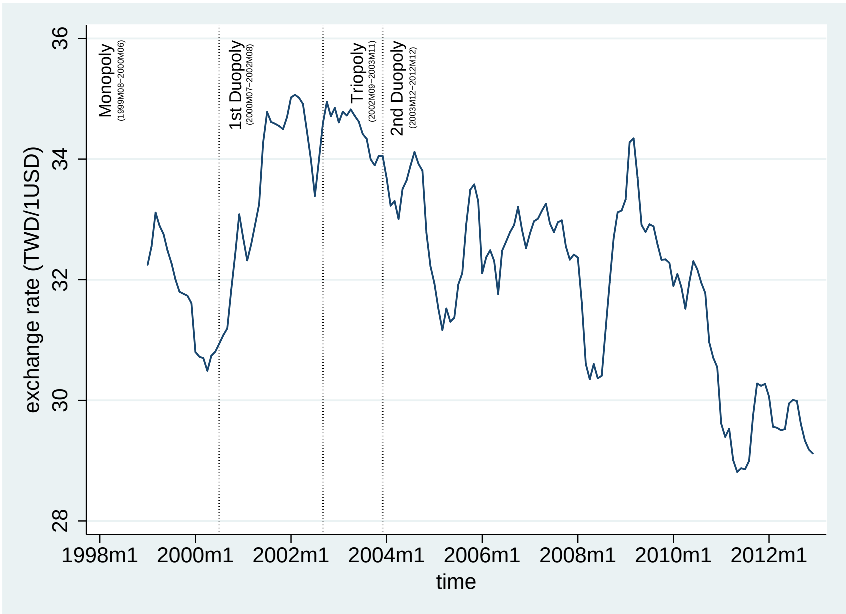
The state-owned enterprise adopted the price adjustment formula to set new gasoline prices on the Sunday of every week from September 2006. During the period of implementing the price adjustment formula, the state-owned enterprise's retail gasoline prices were occasionally frozen by direct government intervention if international crude oil prices increased dramatically. This direct government intervention may influence our outcomes in studying the relationship between the price adjustment formula and the response of retail prices to changes in costs. Therefore, using monthly data is crucial to study a rising concern about the price adjustment formula influencing the retail gasoline price setting, and has advantages to eliminate the possibility of influence of direct government intervention in this study. However, there is a limitation on using monthly data. The state-owned enterprise's new retail gasoline prices were adjusted weekly. We might not provide precise evidence about the effect of the price adjustment formula when we utilize monthly price data. In order to eliminate the government's intervention on retail gasoline price setting (freezing retail prices) this limitation will not be taken into account in this study.

In order to examine the retail price behavior in response to changes in costs, we split the time periods, which are from August 1999 to December 2012, into four time periods that are based on a history of the Taiwan gasoline market structure. A timeline history of the Taiwan gasoline market structure is depicted in figure 1.1 in Chapter 1. The four time periods are: (i) a monopoly (1999M08-2000M06); (ii) the 1^{st} duopoly (2000M07-2002M08); (iii) a triopoly (2002M09-2003M11); and (iv) the 2^{nd} duopoly (2003M12-2012M12). Given different market structures, we individually examine how Taiwan retail gasoline prices respond to changes in costs.

Let us restrict attention to monthly data from the cost side. Historical monthly data of Dubai and Brent crude oil prices and exchange rates are collected from the World Bank and the Central Bank of the Republic of China (Taiwan). Dubai crude oil and Brent crude oil are priced by US dollars per barrel (USD/barrel). Crude oil prices and exchange rate data are graphically presented in figure 2.2. Figure 2.2a interprets that Dubai and Brent crude oil prices had an increasing movement from 2004 to 2007, a quick decline during the second half of 2008, and a positive growth after a dramatic decline in 2008. Figure 2.2b shows the movement of the exchange rate between 1999 and 2012. The exchange rate between Taiwan dollars and US dollars shows a negative tendency over 14 years.



(a) Crude Oil Prices



(b) Exchange Rate

Figure 2.2: Crude Oil Prices and Exchange Rate

Next, we return to focus on monthly observations of the actual retail fuel prices from the leader of the retail gasoline market, CPC. Retail prices of gasoline and diesel are gathered from the Bureau of Energy, Ministry of Economic Affairs (Taiwan), and are presented in figure 2.3. Figure 2.3 lists actual retail prices of four types of fuel products, which are 92 unleaded gasoline, 95 unleaded gasoline, 98 unleaded gasoline and diesel. Three types of gasoline products are categorized into three grades as regular grade (92 unleaded), mid-regular grade (95 unleaded) and premium grade (98 unleaded). This paper pays more attention to mid-regular grade gasoline (95 unleaded) since sales of 95 unleaded gasoline account for the vast majority of the total sales of unleaded gasoline products.[2] Figure 2.3 shows the trend of the actual retail prices of fuel products from August 1999 to December 2012. The actual retail prices of fuel products fluctuated less during the monopoly, first duopoly and triopoly periods. During the second duopoly period, the actual retail prices rose gradually before September 2006; however, the actual prices obviously fluctuated after September 2006. A possible reason to explain these obvious fluctuations of the actual prices is that the retail prices were more tightly linked to the fluctuations of crude oil prices, due to the introduction of the price adjustment formula in September 2006.

Furthermore, to estimate the response of retail prices to changes in costs, we utilize partial adjustment models, which are discussed in Section 2.3. As the purpose of this study aims to present the analysis of retail gasoline price behavior in four types of market structure, we reset the target-level price at the beginning of each market structure in compiling target-level price data. The compilation of the target-level retail prices is exactly determined by following the procedure of the price adjustment formula.[3] Given the procedure of the price adjustment formula, the target-level retail prices are associated with the actual Dubai and Brent crude oil spot prices and the actual spot exchange rate for the US dollar (USD) to the Taiwan dollar (TWD). Thus, variations in the target-level retail prices can be construed as cost variations.

[2]Sales of 95 unleaded gasoline account for around 75% of the state-owned enterprise's total sales of unleaded gasoline products.

[3]The target level retail gasoline price is computed by following the procedure of the price adjustment formula, which is illustrated in Appendix 2.A, where we also reveal a simple illustration to clarify how a new retail gasoline price was set by the procedure of the price adjustment formula.

As market structure setting is considered in this analysis, each market structure period has its own distinct target-level retail gasoline and diesel prices by following the procedure of the price adjustment formula. The target-level price data are diagrammatically presented in Figure 2.4.

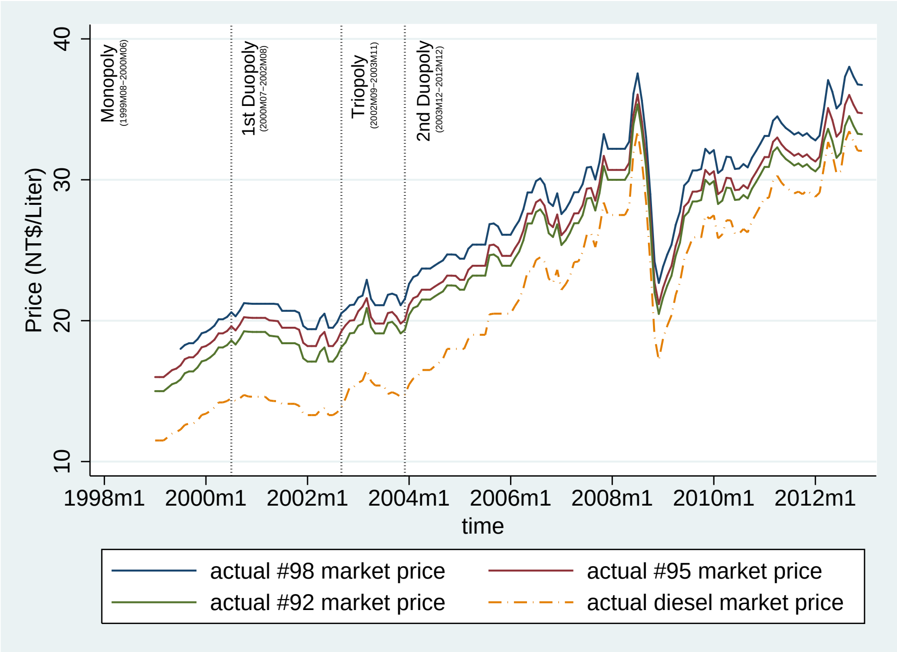


Figure 2.3: Actual Gasoline and Diesel Prices

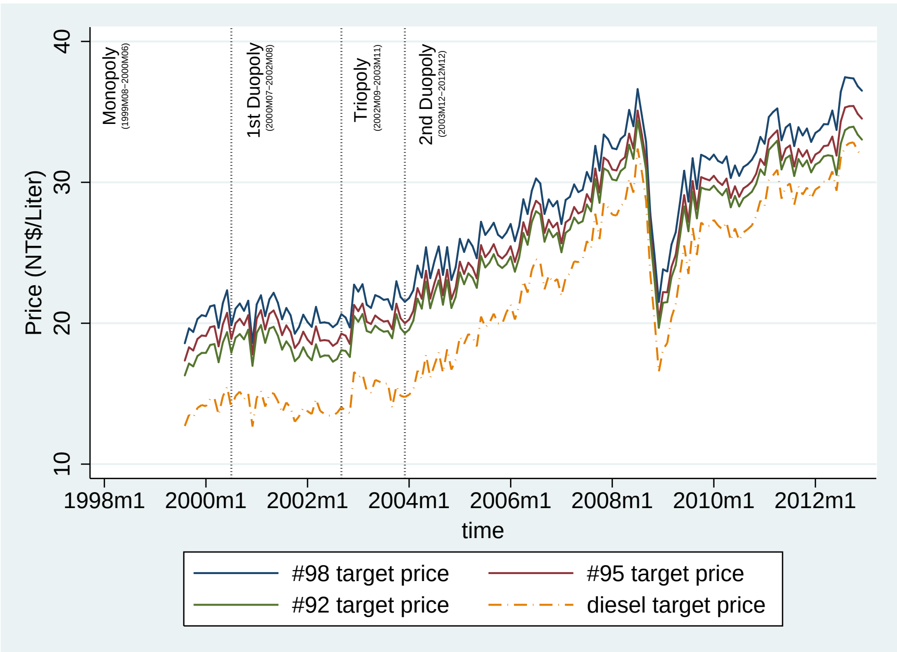


Figure 2.4: Target Prices

2.4.2 Empirical Analysis

This empirical analysis aims to answer the research questions in section 2.3 and provide a precise evidence of retail price adjustment in the Taiwan retail gasoline market. I accomplish this analysis by using the standard and quadratic partial adjustment models. We initially use the standard partial adjustment model in equation (2.3.2) for presenting the simple measure of the speed of retail price adjustment, and then utilize the quadratic partial adjustment model in equation (2.3.4) for testing whether asymmetric pricing behavior existed, and consequently evaluate the effect of the price adjustment formula in the Taiwan retail gasoline market. The estimates of the standard and quadratic partial adjustment models are obtained by using the ordinary least squares. The estimated results of the standard partial adjustment model are reported in tables 2.1 and 2.2 in section 2.4.2.1 and the estimated results of the quadratic partial adjustment model are reported in tables 2.3 and 2.4 in section 2.4.2.2.

2.4.2.1 Estimating Price Response Speed by the Standard Partial Adjustment Mechanism

Given an expression of the speed of price adjustment in equation (2.3.2) and a consideration of the market structure setting in section 2.4.1, table 2.1 presents estimates of adjustment speed parameters over four market structure periods. Moreover, as table 2.1 shows, we split the second duopoly period into two time segments, the pre-PAF (2003M12-2006M08) and the post-PAF (2006M09-2012M12), which are based on the time of implementing the price adjustment formula.

We begin to limit attention to estimated adjustment speed parameters in table 2.1. Estimated adjustment speed parameters of four fuel products, λ, are statistically significant at the monopoly and the second duopoly periods. During the monopoly period and the second duopoly period, there existed retail price regulation on fuel products. First, the gasoline industry and retail prices of fuel products were regulated by the government in the monopoly period. Second, during the second duopoly period the state-owned enterprise's retail prices were regulated by the price adjustment formula from September 2006 and intervened in by the government's executive order - freezing retail gasoline prices from November 2007 to May 2008 when crude oil prices increased. This result suggests that price regulation might explain the significance of the price adjustment speed parameters.

In particular, to compare the price adjustment speed parameters between the monopoly periods and the post-PAF period of the second duopoly period, we find that the speed of retail price adjustment in the post-PAF period was five times greater than in the monopoly period. The retail price adjustment speed parameters of four fuel products in the monopoly period are smaller than 0.2, $\lambda < 0.2$, but in the post-PAF period the parameters are greater than 0.6, $\lambda > 0.6$. Retail prices responded slowly to changes in costs during the monopoly period, when the government directly intervened in retail prices. However, retail prices responded quickly to changes in costs during the post-PAF period when the government indirectly intervened in retail prices through an advisory guide of retail prices by the implementation of the price adjustment formula. This finding reveals that direct government intervention (ownership of the state-owned enterprise) lowered the speed of retail price adjustment, and indirect government intervention (the price adjustment formula) resulted in a close relationship between the response of retail prices and changes in costs.

While finding the significance of the adjustment speed parameters in the monopoly and the second duopoly periods, we find that there is no statistical significance of the adjustment speed parameters of four fuel products in the first duopoly and triopoly periods. Although the adjustment speed parameters of four fuel products in the first duopoly and triopoly periods were not significant, the estimated result presents that there was a slower retail price response to changes in costs. In sum, these results provide evidence about a slow price response to changes in costs existing at the periods of the monopoly, the first duopoly, the triopoly and the pre-PAF, and also confirm that direct intervention would result in a slower price response.

Table 2.1: Estimates of the Standard Partial Adjustment Model

	Period[a]				
	Monopoly	1^{st} Duopoly	Triopoly	2^{nd} Duopoly[b]	
				Pre-PAF	Post-PAF
Obs.	11	26	15	33	76
λ_{92}	0.1840**	0.1000	0.2156	0.2530**	0.7235***
	(0.0697)	(0.1028)	(0.1932)	(0.0992)	(0.0622)
R^2	0.4107	0.0364	0.0817	0.1690	0.6431
Durbin's Alternative	0.8294	0.9052	0.7884	0.3006	0.8482
λ_{95}	0.1545**	0.0946	0.2253	0.2411**	0.6931***
	(0.0560)	(0.0926)	(0.1668)	(0.0947)	(0.0622)
R^2	0.4324	0.0400	0.1151	0.1683	0.6231
Durbin's Alternative	0.7596	0.9226	0.6366	0.2988	0.9191
λ_{98}	0.1148**	0.0950	0.2046	0.2225**	0.6457***
	(0.0360)	(0.0851)	(0.1545)	(0.0867)	(0.0597)
R^2	0.5043	0.0474	0.1113	0.1706	0.6095
Durbin's Alternative	0.6797	0.9545	0.7169	0.2550	0.7988
λ_{diesel}	0.1571**	0.0467	0.0084	0.2815***	0.7374***
	(0.0558)	(0.0620)	(0.1666)	(0.1001)	(0.0693)
R^2	0.4422	0.0222	0.0002	0.1981	0.6010
Durbin's Alternative	0.8999	0.9042	0.5583	0.3366	0.9727

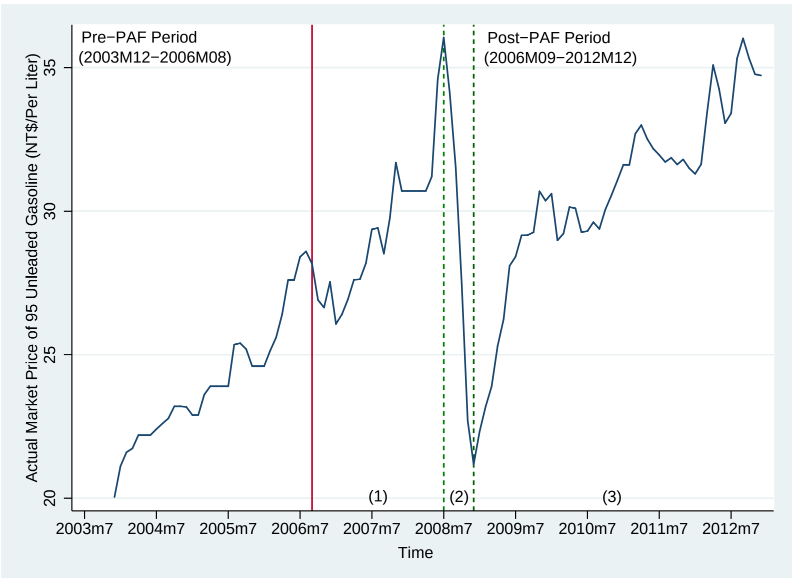
[a] Time periods from 1999 to 2012 include four types of market structure: (i) monopoly (1999M08-2000M06); (ii) 1^{st} duopoly (2000M07-2002M08); (iii) triopoly (2002M09-2003M11); and (iv) 2^{nd} duopoly (2003M12-2012M12).

[b] The time periods during the 2^{nd} duopoly without the application of the price adjustment formula are called the pre-PAF period, and with the application of the price adjustment formula are the post-PAF period.

Standard error in parenthesis. *** Statistically significant at 1 percent level. ** Statistically significant at 5 percent level. * Statistically significant at 10 percent level.

To improve our understanding of the response of retail prices to changes in costs, we test both whether the price adjustment affected the retail price adjustment speed and the response of retail prices to changes in costs. In order to examine the effect of the price adjustment formula we rely on two steps. We first restrict our attention to the second duopoly period. Recalling the market structure setting, the second duopoly period includes the deregulated period (pre-PAF) and the regulated period (post-PAF), which would help us to make a comparison about the effect of the price adjustment formula between deregulated and regulated periods. Second, we split the post-PAF period into three time intervals, as the first price rise time interval (2006M09-2008M07), the price decline time interval (2008M08-2008M12) and the second price rise time interval (2009M01-2012M12). The time interval setting is associated with an upward/downward trend of retail gasoline price, and figure 2.5 clarifies this time interval setting.

Figure 2.5: Time Interval Setting at the Post-PAF Period



Note: A solid vertical reference line at time 2006M09 denotes the time of the implementation of the price adjustment formula. The 2^{nd} duopoly period is split into two time periods as the pre-PAF (2003M12-2006M08) and the post-PAF (2006M09-2012M12) periods. The post-PAF period includes three time intervals: (1) the first price rise time interval (2006M09-2008M07); (2) the price decline time interval (2008M08-2008M12); and (3) the second price rise time interval (2009M01-2012M12).

We estimate the retail price adjustment speed parameters of four fuel products using equation (2.3.2), the standard partial adjustment formula, and the report estimated parameters in table 2.2. The estimated adjustment speed parameters in the deregulated (pre-PAF) period are reported in the first column of table 2.2, and columns 2, 3 and 4 of table 2.2 present estimated adjustment speed parameters in the regulated (post-PAF) period. We focus on a major fuel product, 95 unleaded gasoline. The estimated adjustment speed parameter, λ_{95}, in the deregulated period, is smaller than in the regulated period. This reflects that indirect government intervention, the price adjustment formula (PAF), boosted the retail price adjustment speed. This result is also presented in the studies of three other fuel products.

Next, we compare the retail price adjustment speed parameters on three time intervals over the post-PAF period, and again we focus on 95 unleaded gasoline. The estimated adjustment speed parameters in columns 2, 3 and 4 are statistically significant and present that the retail gasoline prices responded slowly to changes in costs during the price rise time intervals but responded quickly to changes in costs during the price decline time interval. This finding confirms that indirect government intervention (the price adjustment formula) resulted in a slow (quick) adjustment speed in response to increases (decreases) in costs. This result provides a contrast to the existing stylized fact, 'rockets and feathers', and seems instead to be 'hot air balloons and bricks'. Similarly, this finding is presented in connection to three other fuel products. Furthermore, our estimates also present that the premium gasoline (98 unleaded gasoline) price adjustment speed is slower than regular (92 unleaded gasoline) and mid-regular (95 unleaded gasoline) price adjustment speeds. This evidence is consistent with existing evidence by Remer (2015).

To support the finding of 'hot air balloons and bricks', we test hypotheses of the value of the adjustment speed parameter (λ), which is addressed in section 2.3.3. Firstly, both null hypotheses, $H_0 : \lambda = 0$ and $H_0 : \lambda = 1$, are rejected at 1% and 5% significance level at the first and second price rise time intervals. Testing these hypotheses of the values of the adjustment parameters, we can see that over two price rise time intervals, the estimated adjustment speed parameters are different from the exact values, zero and one, and express that the actual retail price had a fractional adjustment in response to cost increases. Secondly, however, we obtain the rejection of the null hypothesis, $H_0 : \lambda = 0$, and fail to reject the null hypothesis, $H_0 : \lambda = 1$ at 1% and 5% significance levels at the price decline time interval. This interprets that there was virtually instantaneous actual retail price adjustment in response to cost decreases.

Given the use of time series data in this study, there is a potential problem about serial correlation. If serial correlation exists in our time series data, our OLS estimators' efficiency will be affected. For example, the presence of serial correlation may cause the underestimated variances of estimators and the rejection of the null hypothesis. Hence, serial correlation may be a concern for the efficiency of our estimates. To deal with this potential problem, we test the null hypothesis of no serial correlation in our model. As equation (2.3.1) expressed, the lagged dependent variable is contained in the partial adjustment model. We therefore use Durbin's alternative test to ensure the efficiency of our least-squares estimates. The p-values of the Durbin's alternative test are reported in tables 2.1 and 2.2. The null hypothesis of no serial correlation failed to reject, so the potential problem of serial correlation would not arise in our estimates.

Although the standard partial adjustment model contributes an essential evidence of 'hot air balloons and bricks' to the analysis of price asymmetry from table 2.2, it still has limitations in supporting this key finding. The main limitation of supporting this finding is estimating the price adjustment parameters with a small number of observations; for example, estimated results of the third column (price decline period) with five observations in table 2.2. An estimation with a small number of observations would potentially result in unreliable results, and any short-lived major shock would be too influential under this condition. Therefore, the standard partial adjustment approach is not effectively appropriate to establish the links between retail price changes and cost changes.

Excluding the limitation of a small number of observations, we can conclude: (i) direct government intervention (ownership of the state-owned enterprise) led to a slower retail price response to changes in costs; (ii) under indirect government intervention (the price adjustment formula) the response of retail prices was closely tied to changes in costs; (iii) given the implementation of the price adjustment formula, there is no evidence of 'rockets and feathers'; (iv) the response of retail prices to cost changes was not affected by market structure, but depended on the government intervention.

Table 2.2: Estimates of Adjustment Speed in the 2^{nd} Duopoly

	Period[a,b]			
	Pre-PAF	1^{st} Price Rise	Price Decline	2^{nd} Price Rise
Observation	33	23	5	48
λ_{92}	0.2530**	0.5637***	0.9441***	0.5762***
	(0.0992)	(0.1649)	(0.1070)	(0.0775)
R^2	0.1690	0.3471	0.9512	0.5405
Durbin's Alternative	0.3006	0.7919	0.2162	0.6005
λ_{95}	0.2411**	0.5466***	0.9128***	0.5421***
	(0.0947)	(0.1598)	(0.1046)	(0.0809)
R^2	0.1683	0.3472	0.9501	0.4888
Durbin's Alternative	0.2988	0.7895	0.1690	0.3233
λ_{98}	0.2225**	0.5134***	0.8541***	0.5002***
	(0.0867)	(0.1500)	(0.0977)	(0.0797)
R^2	0.1706	0.3474	0.9503	0.4557
Durbin's Alternative	0.2550	0.7836	0.1350	0.2376
λ_{diesel}	0.2815***	0.5800***	0.9991***	0.5462***
	(0.1001)	(0.1774)	(0.1134)	(0.0896)
R^2	0.1981	0.3270	0.9510	0.4418
Durbin's Alternative	0.3366	0.8227	0.2024	0.4260

[a] The first period is the pre-PAF period (2003M12-2006M08), and the second, third and fourth periods are the post-PAF period (2006M09-2012M12).

[b] The post-PAF period contains three intervals: (i) the first price rise interval (2006M09-2008M07); (ii) the price decline interval (2008M08-2008M12); and (iii) the second price rise interval (2009M01-2012M12).

Standard error in parenthesis. *** Statistically significant at 1 percent level. ** Statistically significant at 5 percent level. * Statistically significant at 10 percent level.

2.4.2.2 Possible Adjustment Directions by the Quadratic Partial Adjustment Mechanism

This empirical analysis is designed to capture the effect of the price adjustment formula on the retail price setting and the relationship between retail pricing behavior and the price adjustment formula. The analysis of the price adjustment is continued while providing consistent evidence of 'hot air balloons and bricks'. We now return to the main econometric task of this study, the quadratic partial adjustment model. As we addressed in section 2.3.2, the possible price adjustment directions to cost changes can be established by using the quadratic partial adjustment model. The existing two patterns of possible adjustment directions are extended to three patterns, which are also clarified in section 2.3.2. For discussions of the estimated results using the quadratic partial adjustment model, initially we use the quadratic model to separately estimate coefficients at each single market structure period, and then look at coefficient estimates during the second duopoly in exploring the relationship between the price adjustment formula and the retail price response.

The first coefficient estimates over four market structures from the quadratic adjustment model in equation (2.3.4), which are shown in table 2.3. Table 2.3 reports that the estimated price adjustment speed parameters are statistically significant during the post-PAF period. Next, we first test the null hypothesis of the linear adjustment mechanism, as discussed in section 2.3.2. The null hypothesis, $H_o : \alpha = 0$, is rejected at 5% significance level. Because of the rejection of the null hypothesis of linear adjustment ($H_o : \alpha = 0$), there are negative values of α and positive values of β, which provide an opposite finding to evidence found by Bacon (1991). Recalling a discussion in a variety of values of α and β in section 2.3.2, we could use the third pattern of the possible price adjustment range to describe how retail prices responded to changes in costs in the Taiwan gasoline market.

As the new pattern of possible price adjustment direction is defined in section 2.3.2, the estimated results from table 2.3 suggest that when the partial adjustment formula was implemented, the actual retail price had a slow adjustment in response to cost increases and a quick adjustment in response to cost decreases. This finding confirms the previous finding of 'hot air balloons and bricks' by using the standard partial adjustment mechanism in section 2.4.2.1. In particular, the limitation of a small number of observations is removed in this section. Due to the removal of the limitation of a small number of observations, the estimated results from the quadratic partial adjustment mechanism can provide precise and reliable evidence about the retail price adjustment of 'hot air balloons and bricks' in the Taiwan retail gasoline market.

Table 2.4 reports that the estimated coefficients from the quadratic partial adjustment model in equation (2.3.4) and columns 2 and 4 show the significance of the estimated coefficients over the price rise time intervals. Since the significance of the estimated coefficients is found at both price rise time intervals, we test the null hypothesis of linear adjustment mechanism ($H_o : \alpha = 0$) at these two time intervals. We fail to reject the null hypothesis of linear adjustment mechanism, which suggests that the estimated coefficients of quadratic term can be omitted. Given acceptance of the null hypothesis of linear adjustment mechanism and the significance of the estimated coefficients in the linear term, then we test the values of β to explain the retail price adjustment speed in response to changes in costs, which is discussed in section 2.3.3. The null hypotheses of $\beta = 0$ and $\beta = 1$ are rejected at two price rise time intervals. The findings in columns 2 and 4 suggest that retail prices did not respond immediately to increases in costs. Moreover, we turn our attention to a comparison of the price adjustment speed parameters between fuel products. Coefficient estimates confirm that the adjustment speed of premium gasoline price is slower than regular, mid-regular gasoline products and diesel. This finding is consistent with evidence found in section 2.4.2.1.

Again, the quadratic partial adjustment model may cause a potential problem of serial correlation by using time series data. So, we use a test of the null hypothesis of no serial correlation to ensure the efficiency of our estimates. The p-values of the Durbin's alternative test are presented in tables 2.3 and 2.4. These p-values indicate that there is no serial correlation in the model, and the efficiency of our estimates is not affected when the null hypothesis of no serial correlation holds.

Given coefficient estimates in tables 2.3 and 2.4, empirical evidence reveals that the price adjustment formula took an essential role in reducing retail price adjustment speed in response to cost increases, and evidence of 'hot air balloons and bricks' in the response of retail prices in Taiwan retail gasoline market is confirmed by our new pattern of possible adjustment range.

Table 2.3: Estimates of Quadratic Adjustment Model

	Period[a]				
	Monopoly	1^{st} Duopoly	Triopoly	2^{nd} Duopoly[b]	
				Pre-PAF	Post-PAF
Obs.	11	26	15	33	76
α_{92}	0.3547	0.0289	−0.1425	0.0901	−0.0530**
	(0.2107)	(0.0733)	(0.1620)	(0.1079)	(0.0233)
β_{92}	−0.2026	0.1197	0.2211	0.1802	0.6625***
	(0.2385)	(0.1159)	(0.1949)	(0.1325)	(0.0662)
R^2	0.5517	0.0426	0.1333	0.1873	0.6664
Durbin's Alternative	0.8605	0.9392	0.5249	0.3588	0.9145
α_{95}	0.1474	0.0248	−0.0789	0.0813	−0.0491**
	(0.1850)	(0.0604)	(0.1484)	(0.0984)	(0.0227)
β_{95}	−0.0450	0.1123	0.1981	0.1722	0.6355***
	(0.2567)	(0.1036)	(0.1787)	(0.1265)	(0.0664)
R^2	0.4698	0.0467	0.1342	0.1863	0.6456
Durbin's Alternative	0.9764	0.9610	0.3147	0.3560	0.8363
α_{98}	0.0098	0.0236	−0.1114	0.0650	−0.0430**
	(0.1058)	(0.0509)	(0.1145)	(0.0822)	(0.0204)
β_{98}	0.0971	0.1125	0.2187	0.1624	0.5925***
	(0.1955)	(0.0944)	(0.1555)	(0.1158)	(0.0636)
R^2	0.5048	0.0559	0.1713	0.1869	0.6316
Durbin's Alternative	0.6356	0.9893	0.6910	0.3022	0.7084
α_{diesel}	0.2866	0.0081	−0.0448	0.1741	−0.0591**
	(0.1865)	(0.0497)	(0.1619)	(0.1152)	(0.0252)
β_{diesel}	−0.1615	0.0511	0.0048	0.1483	0.6677**
	(0.2138)	(0.0687)	(0.1728)	(0.1319)	(0.0735)
R^2	0.5581	0.0233	0.0060	0.2532	0.6292
Durbin's Alternative	0.8266	0.9011	0.3248	0.6130	0.8467

[a] Time periods from 1999 to 2012 contains four types of market structure: (i) monopoly (1999M08-2000M06); (ii) 1^{st} duopoly (2000M07-2002M08); (iii) triopoly (2002M09-2003M11); and (iv) 2^{nd} duopoly (2003M12-2012M12).

[b] The time periods during the 2^{nd} duopoly without the application of the price adjustment formula are called the pre-PAF period, and without the application of the price adjustment formula are the post-PAF period.

Standard error in parenthesis. *** Statistically significant at 1 percent level. ** Statistically significant at 5 percent level. * Statistically significant at 10 percent level.

Table 2.4: Estimates of Quadratic Adjustment Model in the 2^{nd} Duopoly

	Period[ab]			
	Pre-PAF	1^{st} Price Rise	Price Decline	2^{nd} Price Rise
Observation	33	23	5	48
α_{92}	0.0901	−0.0271	−0.0182	0.0702
	(0.1079)	(0.0964)	(0.1233)	(0.0478)
β_{92}	0.1802	0.5834***	0.8757	0.5336***
	(0.1325)	(0.1824)	(0.4806)	(0.0819)
R^2	0.1873	0.3495	0.9515	0.5610
Durbin's Alternative	0.3588	0.8420	0.2839	0.8425
α_{95}	0.0813	−0.0244	−0.0142	0.0715
	(0.0984)	(0.0904)	(0.1181)	(0.0474)
β_{95}	0.1722	0.5648***	0.8575	0.4980***
	(0.1265)	(0.1767)	(0.4741)	(0.0850)
R^2	0.1863	0.3494	0.9504	0.5130
Durbin's Alternative	0.3560	0.8373	0.2430	0.5573
α_{98}	0.0650	−0.0196	−0.0174	0.0646
	(0.0822)	(0.0794)	(0.1043)	(0.0434)
β_{98}	0.1624	0.5288***	0.7822	0.4566***
	(0.1158)	(0.1556)	(0.4461)	(0.0840)
R^2	0.1869	0.3493	0.9507	0.4807
Durbin's Alternative	0.3022	0.8262	0.1939	0.4456
α_{diesel}	0.1741	−0.0193	−0.0004	0.0650
	(0.1152)	(0.1051)	(0.1272)	(0.0523)
β_{diesel}	0.1483	0.5964***	0.9976	0.5099***
	(0.1319)	(0.2023)	(0.5102)	(0.0937)
R^2	0.2532	0.3280	0.9510	0.4599
Durbin's Alternative	0.6130	0.8631	0.3097	0.6627

[a] The first period is the pre-PAF period (2003M12-2006M08), and the second, third and forth periods are the post-PAF period (2006M09-2012M12).

[b] The post-PAF period contains three intervals: (i) the first price rise interval (2006M09-2008M07); (ii) the price decline interval (2008M08-2008M12); and (iii) the second price rise interval (2009M01-2012M12).

Standard error in parenthesis. *** Statistically significant at 1 percent level. ** Statistically significant at 5 percent level. * Statistically significant at 10 percent level.

2.5 Summary of Chapter 2

In this paper we identify the characteristics of the price adjustment formula in the retail price setting in the Taiwan gasoline market, and study the relationship between the response of retail prices and the price adjustment formula. The empirical exercises, using the standard and the quadratic partial adjustment models, explicitly describe how retail prices responded to changes in costs, and precisely identify the impact of the price adjustment formula in the Taiwan gasoline market.

Following our estimates from the standard and quadratic partial adjustment models, we find that: (i) direct government intervention - ownership of the state-owned enterprise - led to a slower response of retail prices to changes in costs; (ii) retail prices closely followed a trend of changes in crude oil prices; and (iii) under indirect government intervention - the price adjustment formula - we find evidence of 'hot air balloons and bricks': that retail prices responded more quickly to decreases in costs but responded more slowly to increases in costs.

First, under different market structures we individually estimate price adjustment speed parameters. Given the estimated results, we find that direct government intervention - ownership of the state-owned enterprise - resulted in a slower price response to changes in costs. However, under indirect government intervention - price adjustment formula (PAF) it led to a boost of the adjustment speed of retail prices. As the results show, in measuring the effects of both direct and indirect government intervention, direct intervention had a smaller impact on the response of retail prices than indirect intervention.

Second, although our results identify that the price adjustment formula boosted the price adjustment speed, significant estimates also provide evidence in manifesting a slow retail price response to increases in costs and a quick retail price response to decreases in costs during the period of the implementation of the price adjustment formula. This reveals that the price adjustment formula tried to stabilize retail prices of fuel products when costs increased.

Third, coefficient estimates in the second duopoly period, from both the standard and quadratic partial adjustment models, highlight important evidence in the Taiwan gasoline market. We find evidence of 'hot air balloons and bricks' in the Taiwan gasoline market. The results from the standard partial adjustment model present a slower (quicker) retail price adjustment speed than was observed when costs rose (fell). The estimated results from the quadratic partial adjustment model represent a new pattern of possible price adjustment, where retail price responds slowly to increases in costs and quickly to decreases in costs. This evidence suggests that a stylized fact of 'rockets and feathers' is observed in some countries, but a converse fact of 'hot air balloons and bricks' is observed in the Taiwan gasoline market.

Unlike one of the possible explanations for asymmetric retail price adjustment, an oligopoly coordination theory proposed by Borenstein, Cameron and Gilbert (1997), this study finds an alternative possible explanation, consumer search, to the retail price response in the Taiwan gasoline market. Since the price adjustment formula was implemented in September 2006, the retail gasoline price setting became public knowledge to consumers, while consumer search costs reduced. Reduction in search costs might result in faster price response. Our finding is most closely related to Yang and Ye (2008) and Remer (2015).

This paper highlights a significant efficiency of the price adjustment formula on controlling the retail price adjustment speed, and provides evidence of 'hot air balloons and bricks' in the Taiwan gasoline supply market. However, there is at least one potential concern about the price adjustment formula information being shared with competing firm and consumers. The government is taking the part of two characters (a regulator and a leading firm) in the Taiwan gasoline market, which results in a conflict of interests concerning differentiating market efficiency gains and anti-competitive outcomes from the implementation of the price adjustment formula. Therefore, the effect of the price adjustment formula on market efficiency gains and anti-competitive outcomes is worth investigating in a future study.

Negative outcomes may be generated by the government's regulatory policy, the price adjustment formula, but given the evidence of 'hot air balloons and bricks', the government's policy seems to be beneficial to consumers nevertheless. If any potential concerns are not taken into account, the government's regulatory policy obviously restrains the retail price increases in response to cost increases and offers immediate adjustment of the retail price in response to cost decreases.

Appendix

2.A Procedure of the Price Adjustment Formula

Before full liberalization of the gasoline supply market, gasoline market prices were regulated by the domestic gasoline pricing system. Since the gasoline supply market was fully liberalized and formally became a competitive market in the early part of 2000, the domestic gasoline pricing system was abolished and the Petroleum Administration Act was enacted by the Taiwan government.[4] However, in order to reduce the impact of dramatic fluctuations of international crude oil prices in 2005, the Chen administration of the Taiwan government framed the gasoline price adjustment formula in late 2005 and applied it in stabilizing domestic gasoline prices in 2006.[5]

The framework of the price adjustment formula (PAF) contains three steps: (i) adjustment index; (ii) range of adjustment; and (iii) new weekly prices. An illustration is provided at the end of the paper. The contents of each step and an illustration are drawn as follows:

[4]The Domestic Gasoline Pricing System was used to stabilize domestic gasoline prices in the monopolistic and partially liberalized periods. Afterwards, the gasoline pricing policy was re-discussed since, in the early part of 2000, the private enterprise, Formosa Petrochemical Corporation (FPCC), started to provide a domestic gasoline supply. The government of Taiwan deemed that domestic gasoline prices deserved competitive behaviours in the gasoline supply market. Therefore, domestic gasoline prices were deregulated, and meanwhile, the Petroleum Administration Act was also legislated to govern the petroleum industry.

[5]The Price Adjustment Formula (PAF) was introduced in late 2005 and revised and executed in 2006. The main aim of the PAF is to reduce the level of fluctuation of domestic gasoline prices, and the PAF is only used by the state-owned enterprise, China Petroleum Corporation (CPC).

2.A.1 Adjustment Index

The government of Taiwan uses international crude oil prices, Dubai and Brent, to measure the weekly crude oil index. The equation of the adjustment index shows that:

$$AI_t = 70\% \times p_t^{Dubai} + 30\% \times p_t^{Brent} \tag{2.A.1}$$

whereAI_t is the adjustment index at week t, and p_t^{Dubai} and p_t^{Brent} denote the weekly average prices of Dubai and Brent crude oil prices at week t.

According to government publications and the public statement of CPC addressed by the Bureau of Energy and China Petroleum Corporation (2011), the shares of the import expenditure in using Dubai and Brent crude oil prices are 69.27% and 30.73% respectively. Therefore, for approaching the actual proportions of using Dubai and Brent crude oil prices, Dubai crude oil would be weighted at 70% of the adjustment index, and Brent crude oil accounts for the remaining proportion of the adjustment index, 30%.[6]

2.A.2 Range of Adjustment

Before making a decision on domestic gasoline prices, the range of adjusting domestic gasoline prices has to be made. The setting of the range of adjusting domestic gasoline prices is based on fluctuations of international crude oil prices and the exchange rate. The equation of the range of adjustment is written as:

$$AR_t = 80\% \times \left\{ \frac{[(AI_t \times e_t) - (AI_{t-1} \times e_{t-1})]}{(AI_{t-1} \times e_{t-1})} \right\} \tag{2.A.2}$$

[6]According to the public document addressed by CPC and the government publication, Energy Monthly, sources of crude oil and its proportions are listed as Middle-East (67.44%), West Africa (26.6%), Southeast Asia (0.81%), Australia (2.85%), and other areas (2.30%). The whole amount of crude oil from the Middle-East and half the amount of crude oil from Southeast Asia and Australia are valued by the Dubai crude oil price. The Brent crude oil price is used to measure sources from West Africa and other areas, and the remaining amounts of crude oil from Southeast Asia and Australia.

where AR_t is the measure of adjustment for week t, and e_t is the weekly average exchange rate for converting USD (US Dollars) to TWD (New Taiwan Dollars).

As stabilization of domestic gasoline prices is one of the major responsibilities of the state-owned enterprise, CPC absorbs 20% of annual total costs to reduce negative effects, such as increases in international crude oil prices and the exchange rate, on stabilization of domestic gasoline prices. Therefore, the range of adjustment is measured by 80% of the fluctuations of international crude oil prices and the exchange rate.[7]

2.A.3 New Weekly Prices

New weekly domestic gasoline prices are adjusted according to the range of adjustment. Equations are given as:

$$p_{t+1}^{WBT} = p_t^{WBT} \times (1 + AR_t) \tag{2.A.3}$$

and

$$p_{t+1}^{M} = p_{t+1}^{WBT} + T_{t+1} \tag{2.A.4}$$

where p_{t+1}^{WBT} is the new domestic wholesale price of gasoline before taxes at week $t+1$, p_{t+1}^{M} is the new domestic market price of gasoline after taxes at week $t+1$, and T_{t+1} is the taxes of producing gasoline products at week $t+1$.[8]

[7] According to the government publication, Energy Monthly, and the public announcement of CPC, they claim that the imports of crude oil to Taiwan amount to around 80% of the annual total costs of CPC, and the remaining amounts of the annual total costs, which are not affected by fluctuations of international crude oil prices and the exchange rate, are used in administrative, logistic, and productive expenditures, etc. Therefore, in the PAF, the range of adjustment is not fully influenced by fluctuations of international crude oil prices and the exchange rate.

[8] Taxes of producing gasoline products include the import tariff, the trade promotion service fee, excise tax, the soil and groundwater pollution remediation fee, the air pollution control fee, value added tax, and the Petroleum Fund. Energy tariffs and taxes are reported in Appendix 2.C.

2.B Illustration

(1) Adjustment Index:

as the equation (2.A.1) and international crude oil prices of Dubai and Brent at the current week t: $p_t^{Dubai} = 110.46$ and $p_t^{Brent} = 116.80$, given that the current adjustment index can be calculated as:

$AI_t = 70\% \times 110.46 + 30\% \times 116.80 = 112.36.$

(2) Adjustment Range

Since $AI_{t-1} = 109.85$, $e_t = 29.588$, and $e_{t-1} = 29.129$ are known from historical data and the current adjustment index is obtained from the previous step, the range of adjustment is written as:

$AR_t = 80\% \times \left\{ \frac{[(112.36 \times 29.588) - (109.85 \times 29.129)]}{(109.85 \times 29.129)} \right\} = 3.12\%$

(3) New Weekly Price

Given the equations (2.A.3) and (2.A.4), current wholesale price before taxes ($p_t^{BT} = 23.29$) and taxes ($T_{t+1} = 10.708$), the new wholesale price before taxes and the new market price are given as:

$p_{t+1}^{WBT} = 23.29 \times (1 + 3.12\%) = 24.02$

and

$p_{t+1}^{M} = 24.02 + 10.708 = 34.76.$[9]

[9]The amount of taxes is an estimated value, as referred to by the government publication, Energy Monthly.

2.C Table of Energy Tariffs and Taxes

Energy Tariffs and Taxes

Item	Import Tariff*	Promotion Service Fee	Excise Tax	Petroleum Fund**	Soil and Groundwater Pollution Remediation Fee***	Air Pollution Control Fee****	Value Added Tax
Crude Oil	Free/Free	0.04%	Free	109 NT$/KL	-	-	5%
Gasoline	10%/Free	0.04%	6.83 NT$/L	169 NT$/KL	12 NT$/T	0/0.3/0.19 NT$/L	5%
Diesel	5%/Free	0.04%	3.99 NT$/L	144 NT$/KL	12 NT$/T	0.2NT$/L	5%

Note: Source from Energy Statistics Handbook 2011, Bureau of Energy, Republic of China (Taiwan), Environmental Protection Administration, Executive Yuan, Republic of China (Taiwan), Customs Administration, Ministry of Finance, Republic of China (Taiwan) and Laws and Regulations Database of The Republic of China. * The current import tariffs of gasoline and diesel are free, which were amended on 30 December 2008. Before the date of amending import tariffs, gasoline and diesel were imposed import tariffs by 10% and 5%. ** Imposing the Petroleum Fund is based on the Petroleum Administration Act, which was promulgated in October 2001. *** The Ssoil and groundwater pollution remediation fee has been imposed fromNovember2001. **** Prior to 2000, there was an exemption from the air pollution control fees, since the government encouraged individuals to use unleaded gasoline. Between 2000 and 2006, the tariff of the air pollution control fee was set at 0.3 NT$/L. From 2007 the tariff of the air pollution control fee is has been set at 0.19 NT$/L. The tariff of the air pollution control fee on diesel has not been changed, set at 0.2NT$/L.

2.D Data Source of Chapter 2

Table 2.D.1: Data Source

Chapter 2		
Dataset	**Data Type**	**Source**
CPC's Retail Price of 95 Unleaded Gasoline, 1999M01-2012M12	Weekly Data	Bureau of Energy, Ministry of Economic Affairs, Taiwan
CPC's Retail Price of 92 Unleaded Gasoline, 1999M01-2012M12	Weekly Data	Bureau of Energy, Ministry of Economic Affairs, Taiwan
CPC's Retail Price of 98 Unleaded Gasoline, 1999M01-2012M12	Weekly Data	Bureau of Energy, Ministry of Economic Affairs, Taiwan
CPC's Retail Price of Diesel, 1999M01-2012M12	Weekly Data	Bureau of Energy, Ministry of Economic Affairs, Taiwan
Price of Dubai Crude Oil, 1999M01-2012M12	Monthly Data	Global Economic Monitor (GEM) Commodities, World Bank
Price of Brent Crude Oil, 1999M01-2012M12	Monthly Data	Global Economic Monitor (GEM) Commodities, World Bank
Exchange Rate: USD-TWD, 1999M01-2012M12	Monthly Data	Central Bank of the Republic of China (Taiwan)

Chapter 3

Government Regulated Transparency and Price Leadership in Retail Gasoline

3.1 Introduction

In order to deal with a high degree of fluctuations in crude oil prices, in September 2006[1] the Taiwan government introduced and implemented the price adjustment formula (PAF) to regulate the retail gasoline prices charged by the state-owned gasoline supplier, CPC Corporation, As the procedure for determining the price adjustment formula is publicly available on CPC's official website, CPC's future retail price information has become transparent and predictable, both to its competitor, the private gasoline supplier Formosa Petrochemical Corporation (FPCC)[2] as well as to consumers. This type of sharing of price information is deemed to be unilateral disclosure of information by the state-owned enterprise and can

[1]The price adjustment formula is an executive order made by the Ministry of Economic Affairs, and only applies to the state-owned gasoline supplier, CPC Corporation.

[2]For more details about the Taiwan gasoline market, see Chapter 2.

also be characterized as planned future price information exchange. This provision of price information raises concerns about the presence of anti-competitive (collusive) outcomes in this duopolisitic gasoline market. Thus the purpose of this study is to examine the effect of the government's transparent price regulation policy, the price adjustment formula, and the presence in the market of price leadership.

Determining information exchange in competition investigations is a fundamental challenge to competition authorities. Information exchange among firms and consumers could deliver both the benefits and the drawbacks of improving market transparency (Swedish Competition Authority, 2006). These positive and negative effects of increasing market transparency through information sharing have been substantially discussed in recent studies, but the sharing of future information which is unilaterally disclosed by governments is less discussed in the existing literature. It is difficult to give precise evidence of antitrust law violations in relation to unilateral information sharing by governments, but some studies have shown that well-meaning government intervention can result in tacit collusion (e.g. Albæk et al., 1997), and so we consider the case of anti-competitive outcomes resulting from the unilateral sharing of future conduct information. In trying to provide a new insight regarding future conduct information exchange, we present empirical analysis which captures the effect of the information exchange policy implemented by the Taiwan government, in terms of danger to competition and gains in market efficiency. We also consider the case of price leadership behavior. It is important to indicate the effect of information sharing on firms' price-setting strategies, and to examine whether price leadership behavior significantly helps firms to sustain collusive outcomes. Hence, this study's overall approach in which both positives and negatives of the government's unilateral disclosure of future conduct information are detailed.

This study addresses two limitations of the existing literature. The first is the investigation of the case of a duopolistic market (a state-owned enterprise and a private supplier), a situation which rarely exists in the real world and is infrequently discussed in the relevant literature. In the second, the government's transparent price policy, the price adjustment formula, can be seen as serving as an instance of unilateral future price information disclosure to both consumers and to the competing firm. These two aspects allow us to investigate the impact of the government's policy on the degree of competitive intensity in the market.

The empirical analysis in this chapter limits its attention to the supply side of the gasoline retailing market, and studies implications of the introduction of the price adjustment formula for the market, the leading firm and the competing firm. In the first part of the analysis we focus on whether the introduction of the price adjustment formula affects how the leading firm adjusts its retail pricing. This enables us to draw conclusions on the effect of the price adjustment formula on the leading firm's pricing mechanism. In the second part we test the hypothesis of the emergence of price leadership, and use two different econometric methods to demonstrate its emergence. We first use a paired test and the new definition of price leadership proposed by Seaton and Waterson (2013) to quantify leadership pricing events. A paired test allows us to compare the difference between pre- and post-PAF periods in pricing setting. Then we use a logit model to build the link between price leadership and the price adjustment formula. In the final part of the empirical analysis we use two logit models to test the hypotheses of whether the price adjustment formula and price leadership affect how the competing firm makes its dynamic price response. These two econometric models yield some conclusions on the effects of the price adjustment formula and price leadership on the competing firm's pricing. Our empirical results show that the price adjustment formula curbs the leading firm's price increases, but causes the emergence of price leadership. We also find that the competing firm's pricing is based on the leading firm's leadership pricing and on future price information disclosed by the price adjustment formula, rather than on cost-based pricing.

The chapter is organized as follows: section 3.2 give summaries of market transparency, price leadership and future conduct information exchange from the relevant existing literature, section 3.3 describes the observed data, section 3.4 presents our empirical frameworks and discussion of results, and section 3.5 draws a brief conclusion.

3.2 Literature Review

3.2.1 Market Transparency

The issue of transparency in competition policy has been substantially discussed in recent studies in which its effects are reviewed from two dimensions, demand and supply. Firstly, on the demand side, under the conditions of a perfectly competitive market all information is symmetric and the market reaches Pareto efficiency. Stiglitz (1989) demonstrates that if consumers in the market are imperfectly informed and incur higher search costs to maximize their utility, the presence of imperfect information would offer market power to firms. Therefore, if the degree of market transparency can be improved, both consumer search costs and firms' market power would fall, and thus consumers can be benefited by improvements in market transparency. In a Hotelling market, Schultz (2004) studies the transparency effect with horizontal product differentiation on the demand side, and identifies that by means of lower transportation costs, market transparency enhancement creates lower prices, less horizontal differentiation, and greater surplus. Austin and Gravelle (2008) study whether increasing market price transparency leads to market efficiency in the health sector. Their findings suggest that price transparency might bring efficiency to health care markets, enabling patients to obtain better health care services.

The above studies show positive effects of increasing market transparency on the demand side. However, on the supply side the effect of transparency is different. Albæk, Møllgaard, and Overgaard (1997) found that consumers suffered higher prices for ready-mixed concrete with market transparency. The Danish antitrust authority decided to publish a quarterly book of prices of ready-mixed concrete in three regions, with the aim of reducing consumer search costs and suppliers' prices for concrete. The aim of the Danish antitrust authority's intervention was to improve market transparency for the benefit of consumers. The authors' findings suggest that government intervention in the ready-mixed concrete market failed to benefit consumers. Instead, firms could see each other's prices and this led to an increase in the price of concrete and a decrease in the intensity of competition. The Danish ready-mix concrete case indicates that consumers do not receive benefits through market transparency imposed by government intervention. Nilsson (1999) studies a Bertrand duopoly from the aspect of the effects of increased transparency via internet technology. He finds that in a one-stage game a reduction in consumer search costs would lead to a fall in price, but that in a repeated game, firms can easily sustain collusion while consumer search costs decrease. The results in the studies of Albæk, Møllgaard, and Overgaard (1997) and Nilsson (1999) indicate that increasing market transparency may deliver more negative effects to consumers than positive effects, if market information is shared by suppliers.

Møllgaard and Overgaard (2006) conclude some general lessons regarding the relationship between competition policy and market transparency. They summarize some theoretical studies which are associated with the effects of transparency on competition and collusion, and detail some existing cases including those of the Danish ready-mixed concrete market, Swedish retail gasoline, liner shipping, the Airline Tariff Publishing Company, the US Ivy League, wood pulp, and UK tractors. Cases involved in the study by Møllgaard and Overgaard (2006) show that it is easier to sustain collusive agreement when market information is shared among firms. Hence, in the case investigated in their study, improving market transparency would harm consumers and negatively affect other outcomes in a well-informed market.

3.2.2 Price Leadership

A consideration of the relationship between leadership pricing and tacit collusion is another topic of this paper.[3] Bain (1962) discussed a specific form of collusive activity, price leadership, and argued that:

[3]Scherer and Ross (1990) have classified three main types of price leadership; the dominant, the collusive, and the barometric. The definition of dominant leadership is that a single firm has at least 40% of the market, and its price-setting mechanism is regularly followed by other smaller firms. Collusive leadership occurs when smaller firms explicitly or tacitly follow a large firm's price initiatives in an oligopolistic industry. Barometric leadership describe situations in which the leader acts as a barometer for the market, and its price nearly approaches competitive price level. These three different types of price leadership enable us to distinguish which type of price leadership is observed in the Taiwan gasoline market. See Scherer and Ross (1990).

> Evidence of such direct consensual action not being found (and it seldom is), it is more usual to recognize price leadership as a form of tacit collusion, resulting from the existence of an "unspoken" agreement (p.277).

As Bain (1962) argued, price leadership can be deemed to be a specific form of collusive behavior in the market. Rotemberg and Saloner (1990) study price leadership with asymmetric information in oligopolistic markets. They demonstrate that the less informed followers could be benefited by the better informed leader's price moves, and so leadership pricing could facilitate collusive pricing with asymmetric information. Mouraviev and Rey (2011) study both Bertrand and Cournot competitions to examine whether the role of price/quantity leadership is associated with collusion, and they find a similar result in which collusion is facilitated by price leadership. Lewis (2012) tests price coordination among stations in the Midwestern US, and find evidence of price coordination. He reveals that the price leader sets a new price level as a signal to competitors, who adjust to the exact same price within 24 hours. These studies suggest that price leadership may be the potential cause of price coordination and anti-competitive outcomes in the market.

The recent literature examines leadership pricing in the British supermarket industry and the Italian petrol market. Seaton and Waterson (2013) propose a new definition of price leadership and use a series of comparisons of two firms' price-change events to quantify leadership pricing, using weekly price data from late 2003 to late 2010. Their new definition of price leadership is as follows:

> Price leadership occurs when one firm makes a change in a price (or set of prices) that is followed within a predetermined short period by the other (more generally, another) firm making a price change of exactly the same monetary amount in the same direction on the same product(s), and doing so significantly more often than would be expected by chance (p.392).

They find evidence of the emergence of price leadership in the British supermarket industry and further indicate that the number of downward price leadership events is greater than upward price leadership events in the supermarket industry.

Furthermore, Andreoli-Versbach and Franck (2015) study the market leader's pre-announced price commitments in the Italian petrol market. The new definition of price leadership proposed by Seaton and Waterson (2013) is adopted in their study, and they find that competitors' pricing behavior significantly follows leadership pricing, resulting in price coordination in the Italian market.

3.2.3 Future Conduct Information Sharing

Some recent studies review the significance of the exchange of planned future conduct information in issues of market efficiency and anti-competitive outcomes.

Kühn (2001) discusses a concern about collusion facilitated by communication between firms. He identifies two types of future conduct information sharing: private communication between firms, and public communication to consumers. It is important to make a distinction when discussing collusion sustained by communication. Kühn argues that private communication about future conduct information eliminates all possibilities of enhancing market efficiency for consumers and leads to coordination among firms, whereas public communication would create significant efficiency effects and is not deemed as breaking antitrust law if the communication is given to consumers. Finally, according to a consideration about communication, he summarizes his suggestion on competition policy as follows: (i) any type of private future information sharing should be prohibited, to prevent potential efficiency losses, and (ii) if communications are clearly stated as public future information sharing relative to consumers, and if potential market efficiency gains are likely to be significant, allowing public future information sharing should be considered. Motta (2004) and Vives (2006) also emphasize that private communication of future conduct information is likely to carry a high potential for collusive, whereas public communication of future conduct information may enhance the degree of transparency in prices for consumers, and should therefore be considered as potential efficiency gains. Discussions of private and public communications about the sharing of future conduct information will enable us to better raise concerns regarding unilateral future price information disclosed by government policy and to confirm its effect on the market.

Furthermore, there are several studies which place restrictions on considerations of unilateral and indirect information sharing (Bennett and Collins, 2010; OECD, 2010, 2012). Bennett and Collins (2010) discuss a conundrum regarding the differentiation between pro-competitive or anti-competitive public dissemination of future pricing intentions. They address two public dissemination scenarios. In the first, it appears that public dissemination of future pricing intentions could help consumers to plan their purchase responses in advance. The second, however, suggests that public dissemination of future intentions seems to be a signal to competitors to achieve fixed price levels, which might significantly harm the degree of competition. The OECD (2010, 2012) also considers unilateral public announcement of future intentions to be anti-competitive behavior. Reports state that unilateral information of future intentions can be deemed as indirect information exchange or as a signal to competitors, if unilateral information of future intentions is disclosed through public announcement (OECD, 2010, 2012). The OECD (2012) delineates that unilateral announcement has anti-competitive effects in concentrated markets with homogeneous products, but on a case-by-case basis competition agencies should carefully review whether the enhancing of efficiencies is greater than any anti-competitive effects.

Faber and Janssen's (2008) study looked at price in the Dutch gasoline market. Since suggested prices were published publicly via websites, retailers' gasoline prices could be easily coordinated,[4] and thus the authors aim to demonstrate the role of suggested prices on retailers' gasoline price setting. To measure the effect of suggested prices on retail gasoline price setting in the Dutch gasoline market a panel data method is applied to a daily dataset

[4]In the Netherlands, suggested prices are put forward by the larger companies, such as BP and Total, and are also published on their websites. For more details about suggested price mechanism, see Faber and Janseen (2008).

of retail gasoline prices and suggested gasoline prices. It is found that suggested price is able to help retail gasoline price coordination.

As indicated by some of the above studies, anti-competitive outcomes may be achieved by future conduct information exchange. Hence, our study casts light on the effect of the unilateral disclosure of future conduct information on price leadership and collusive price coordination in the Taiwan gasoline supply market.

3.3 Data

This chapter adopts two different datasets. The first dataset consists of weekly retail gasoline prices for two existing firms, spot Dubai and Brent crude oil prices and the exchange rate for the US dollar to Taiwan New dollar (USD/TWD). The period of this empirical study spans approximately 14 years (713 weeks) from June 2002 to December 2015. Spot prices of retail gasoline and crude oil are taken from the Petroleum Price Information Management and Analysis System, which records prices of petroleum products on the basis of weekly information. The exchange rate for the US dollar to Taiwan New dollar (USD/TWD) is drawn from the Central Bank of R.O.C. (Taiwan). On the basis of the bulletin of the government's regulatory policy, prices of crude oil and the USD/TWD exchange rate are deemed to be the industry cost of producing retail gasoline product in this study. The first dataset is summarized in table 3.1 and will be used in analyzing the firms' pricing strategies over the empirical study period.

As mentioned above, this chapter analyzes the Taiwan government's regulatory policy. The second dataset consists of a variety of binary variables which will be used in evaluating the effect of the government's intervention. Using a binary dataset can allow us to compare the competitor's reaction between on- and off-policy periods and investigate the emergence of leadership pricing in the retail gasoline market. Therefore, we return to our raw dataset which includes the firms' exact new price-announcement time in hours, $\tau_{i,t} \in \{0, 1, \ldots, 23\}$

and $i \in \{CPC, FPCC\}$. The price-announcement time in hours is recorded by the Bureau of Energy. Using the recorded price-announcement time in hours, we carry out a series of comparisons of firms' exact announcement times in hours during the period in which both firms change their prices, to identify leadership and simultaneous price events, e.g. CPC's leadership price move if $\tau_{CPC,t} < \tau_{FPCC,t}$; firms' simultaneous price move if $\tau_{CPC,t} = \tau_{FPCC,t}$.

On the basis of this empirical analysis, the identification of leadership/simultaneous events enables us to discuss some effects of the price adjustment formula and price leadership. Definitions of key binary variables used in this study are summarized in table 3.2.[5]

Table 3.1: Summary statistics for prices of retail gasoline and crude oil and exchange rate

Variable	Mean	Std. Dev.	Min	Max	Obs.
p^{CPC}	28.026	5.033	18.2	36.4	713
p^{FPCC}	28.064	5.072	18.2	36.4	713
p^{Dubai}	70.357	30.019	22.308	138.092	713
p^{Brent}	73.350	30.38	23.207	142.158	713
p^{crude}	71.255	30.109	22.589	139.312	713
$e^{USD-TWD}$	31.867	1.669	28.696	35.114	713

Note: p^{CPC} and p^{FPCC} are retail gasoline prices of suppliers CPC and FPCC, and are priced in TWD. p^{Dubai} and p^{Brent} are Dubai and Brent crude oil prices, and are priced in the USD. p^{crude} is the weighted crude oil price (Dubai: 70% and Brent: 30%) which is based on the procedure of the price adjustment formula, and is priced in USD.

[5]Details about generating dummy variables are presented in Appendix 3.A.

Table 3.2: Definitions of Binary Variable

Variable	Definition
PAF_t	1 = on-policy period if the government's policy was exactly applied
	0 = otherwise
$PChange_t$	1 = both firms adjusted retail prices in week t
	0 = otherwise
$lead_t^{CPC}$	1 = price leadership made by market leader (CPC) in week t
	0 = otherwise
up_t^{CPC}	1 = market leader (CPC) led positive retail price change in week t
	0 = otherwise
$down_t^{CPC}$	1 = market leader (CPC) led negative retail price change in week t
	0 = otherwise
sp_t^1	1 = Type I perfect price alignment
	0 = otherwise
sp_t^2	1 = Type II perfect price alignment
	0 = otherwise

3.4 Empirical Analysis

The purpose of this study is to explore the impact of the government's regulatory policy from three aspects: (i) how the leading firm behaves in its retail price response after the introduction of the price adjustment formula; (ii) whether the government's unilateral price regulation of the state-owned enterprise results in pricing leadership in the market; and (iii) how the private gasoline supplier reacts after the government's unilateral price regulation of the state-owned gasoline supplier was introduced. In the first part of the empirical analysis we examine whether the leading firm's pricing strategies move closely with cost fluctuations in crude oil prices and the exchange rate. In addition to these pass-through measures in costs we also test whether the leading firm is affected positively or negatively by the government's unilateral regulation policy.

In the second part of the empirical analysis, we turn our focus to the emergence of price leadership, by using two different econometric methods. In the first method we adopt a series of comparisons of exact timings of weekly announcements of retail prices by the leading and competing firms, to provide evidence about the emergence of price leadership. Additionally, we use a logit regression model to confirm that price leadership is related to the implementation of the government's regulatory policy.

In the final part, we focus on the competitor's retail price reaction when the government unilaterally discloses the state-owned enterprise's retail price to the market. In addition to a discussion of the government's policy, we also extensively discuss how the emergence of price leadership is related to the competitor's perfect price alignment decisions. The analysis of government policy and discussion of price leadership will be built on the use of a variety of logit models.

Analysis of the government's policy will surround these three econometric tasks. In the first task we use the firms' retail price data and industry cost data, crude oil prices and exchange rate, to verify the firms' retail price-setting mechanisms and also to extensively consider the impact of the government's policy on the firms' retail price responses. In the second and third tasks we use exact retail price-announcement timing data for the two firms to quantify the emergence of price leadership in the retail gasoline market and to provide evidence about the competitor's perfect price alignment, by using a variety of dummy variable data.

3.4.1 Effect of PAF on the Market Leader's Price Response

A crucial question regarding the government's price regulatory policy relates to what outcomes the policy would offer to the market. In the first part of the analysis we explore how the government's regulatory policy impacts on the leading firm's price-setting mechanism. We use the pass-through model to illustrate the effect of the government's price regulation policy on the retail gasoline price.

As a large share of the retail gasoline market (around 70%) is held by the state-owned enterprise (CPC) it constitutes the leading gasoline supplier in the retail gasoline market in Taiwan.[6] Therefore, we begin by presenting information about how the leading firm's retail price reacts to observed cost shocks, i.e. fluctuations in crude oil prices and the USD/TWD exchange rate, using a pass-through model. The presentation of the firm's retail price response will cover the study period of approximately 14 years.

In addition to pass-through measures, we also have to focus on the fundamental core of this study: the effects of the government's policy. In the case of the Taiwanese retail gasoline market, the government's policy can be discussed from two aspects. The first aspect is that it is a price adjustment constraint applying to the state-owned enterprise, and the second aspect is that the policy is a unilateral disclosure of price adjustment information to the market, both consumers and the competitor. The first aspect allows us to present information which considers how the government's policy restricts the leading firm's further retail price adjustment, and the second aspect permits us to investigate whether the government's policy is beneficial or detrimental to the competing firm and to consumers. This section, section 3.4.1, only focuses on the first aspect, the effect of the policy on the leading firm, and the second aspect, the effect of the introduction of the price adjustment formula serving as unilateral information disclosure of the leading firm's future price to its competitor (and consumers) will be discussed in section 3.4.3 (Chapter 4).

The purpose of this task is to test whether the introduction of the government's price regulation policy, the price adjustment formula, affected how the leading supplier passed on changes in its costs. Thus, we model the leading firm's retail price response to cost fluctuations, and observe the effect of the government's policy on the setting of retail price by the state-owned enterprise. To estimate the leading firm's price response, we use a pass-through model of weekly firm-level retail price data and industry cost data, crude oil prices and exchange rate, over 713 weeks, from June 2002 to December 2015. The leading firm's

[6]According to official reports, CPC held a dominant position and gained above 70% of market share in petroleum products from 2002 to 2015. See CPC Business Operation Review Report (2012) and CPC's Annual Reports.

price response equation is given by

$$\Delta p_t^{CPC} = \beta_0 + \beta_1 \Delta p_{t-1}^{crude} + \beta_2 \Delta e_{t-1}^{USD-TWD} + \beta_3 PAF_t + \beta_4 PAF_t \times \Delta p_{t-1}^{crude} + u_t, \quad (3.4.1)$$

where Δp_t^{CPC} denotes CPC's retail gasoline week-to-week price change in week t, Δ_{t-1}^{crude} denotes crude oil week-to-week price change in week $t-1$, $\Delta e_{t-1}^{USD-TWD}$ denotes the USD to TWD week-to-week exchange rate change in week $t1$, PAF_t is a dummy variable being 1 if the price adjustment formula is implemented in week t, $PAF_t \times \Delta p_{t-1}^{crude}$ is the interaction term of the government's policy and changes in crude oil price in week $t-1$, which captures the leading firm's dynamic retail price response to a change in crude oil price after the implementation of the price adjustment formula, and u_t denotes the error term in week t.

For discussion in this analysis we split equation (3.4.1) into two parts, cost variations and policy analysis. First, in the pass-through of cost variations to the retail price the main coefficients of interest, β_1 and β_2, measure the pass-through rate to the retail gasoline price when crude oil prices and exchange rate change positively or negatively, respectively. Both coefficients enable us to examine whether the retail gasoline price moves in response to cost variations. In general, we may expect that both coefficients are significant and positive for the leading firm's retail price ($\beta_1 > 0$ and $\beta_2 > 0$). Second, in addition to investigation of the relationship between the retail gasoline price and cost variations, we also focus on policy analysis. The price adjustment formula is designed to stem sharp increases in the retail gasoline price in response to a steep climb in crude oil prices. Moreover, based on the procedure of the price adjustment formula, the leading firm's new price should follow the cost fluctuations. Therefore, in equation (3.4.1) we add dummy variable, PAF_t, and interaction term, $PAF_t \times \Delta p_{t-1}^{crude}$, to enable the analysis of the government's policy,[7] and suppose that PAF_t and $PAF_t \times \Delta p_{t-1}^{crude}$ measure the direct and indirect effects of the government's policy, respectively. In the policy analysis, the key coefficients of interest, β_3 and β_4, indicate the

[7]The government's price regulatory policy, the price adjustment formula, aims to reduce an impact of dramatic fluctuations of crude oil prices. Therefore, the leading firm's retail price response, equation (3.4.1), only considers the interaction effect between the policy and crude oil price. The interaction effect between the policy and exchange rate is not encompassed in the price response equation.

pass-through rate to the retail price with respect to the impact of the government's policy, and we may expect that the direct effect of the government's policy is negative for the leading firm's retail price ($\beta_3 < 0$) and the indirect effect is positive for the retail price ($\beta_4 > 0$). This part of the analysis allows us to provide evidence that the government's policy is related to the leading firm's retail price-setting strategy.

To better satisfy the purpose of this task, we consider one potential problem of estimating the model for all the data for the period. In the case of the leading firm's price adjustment strategy in the Taiwanese retail gasoline market, its price was sometimes not adjusted every week, and so may not provide explicit information on the leading firm's price response after the introduction of the government's policy. Hence, to tackle this, we extensively alter the estimation dataset and the model specification. First, for the estimation dataset, we compile price-change-periods data from all such data, and estimate the model for price-changed periods. Second, for model specification, a new model replaces week-to-week cost changes with accumulated cost changes.[8] The standard week-to-week pass-through model may be misspecified when the price-changed-periods data is adopted. Since the price-changed-periods data only covers whole price-changed periods, the standard week-to-week changes in crude oil price and exchange rate, which may involve non-price-changed periods, may be missed. Hence, the accumulated specification enables us to eliminate the potential risk of misspecification by including non-price-changed periods. These two alterations will be applied in estimating the pass-through model, equation (3.4.1).

Table 3.1 reports the coefficient estimates for the leading firm's retail gasoline price response modeled by equation (3.4.1), and the estimates were provided by the ordinary least squares estimation method. We use four different specifications of equation (3.4.1) and estimate the model separately throughout the whole of the 713 periods and during price-changed

[8] Due to no price change decision being made in some periods, the estimation results obtained with the use of the all-periods data may provide under/overestimated coefficients, and cause misleading interpretations of the leading firm's pricing behavior. Therefore, we replace week-to-week changes in crude oil price and exchange rate with accumulated changes. We suppose that week $t-\delta$ is CPC's previous price change period, and $\delta \geq 2$. Then the accumulated crude oil price change is the difference in crude oil prices between week $t-1$ and week $t-\delta$, $(p_{t-1}^{crude} - p_{t-\delta}^{crude})$, and similarly the accumulated change in exchange rate is $(e_{t-1}^{USD-TWD} - e_{t-\delta}^{USD-TWD})$.

periods.[9] Using different specifications of the model allows us to test the following hypotheses: (i) that cost variations serve as a focal point for adjustments to retail price, and (ii) that the introduction of the price adjustment formula to CPC is beneficial. Specification (1) uses cost variations only, over all 713 study periods, to show the pass-through to the retail gasoline price, while we use cost variations and the policy effect in specifications (2) and (3). Specifications (2) and (3) are separately estimated for all periods and for price-changed periods respectively. Finally, specification (4) uses the accumulated changes in crude oil price and exchange rate to indicate how the leading firm reacts to cost variations during on-policy periods and to measure the impact of the government's policy.

First, we focus on the first part of equation (3.4.1): cost variations. The key coefficients of interest are β_1 and β_2, which capture the pass-through rate of cost variations to the retail price. Specifications (1) to (3) use the standard week-to-week crude oil price change, p_{t-1}^{crude}, and, in particular, specification (4) uses the accumulated changes in crude oil price and exchange rate, $(p_{t-1}^{crude} - p_{t-\delta}^{crude})$ and $(e_{t-1}^{USD-TWD} - e_{t-\delta}^{USD-TWD})$. All except specification (2) show that the pass-through rate of crude oil price variation is positively significant for the retail gasoline price ($\beta_1 > 0$). Additionally, we find a positive pass-through rate of exchange rate variations ($\beta_2 > 0$) in specifications (3) and (4). In comparison to the other three specifications, estimated coefficients for specification (4) in table 3.1, for variations in crude oil price and exchange rate, are particularly significant to the retail price, which reflects a positive correlation between the leading firm's pricing and cost fluctuations. Our expectation of positive pass-through rates of crude oil price and exchange rate to the retail price ($\beta_1 > 0$ and $\beta_2 > 0$) is reflected in specification (4), but it is also suggested that fluctuations in crude oil price and exchange rate are not fully passed through to the leading firm's pricing.

We now turn to discussion of the key aspect of this study, policy analysis. To discuss the effect of the price adjustment formula on the leading firm's retail price setting, we focus on key coefficients of interest β_3 and β_4 serving as the direct and indirect effects of the price

[9] We suppose price-changed periods are the time if the leading firm changed its retail gasoline price at any weeks.

adjustment formula, respectively. In table 3.1, specification (4) is the specification of our expectations with respect to direct and indirect effects of the price adjustment formula, i.e. $\beta_3 < 0$ and $\beta_4 > 0$. From specification (4) it can be seen that: (i) the direct effect is negative and significant for the retail price, causing falls in the retail gasoline price with any changes in crude oil price, and (ii) that the indirect effect is positive and significant, which would modestly offset the direct policy effect when crude oil price rises. Finally, when we combine the direct and indirect policy effects as the total effect $(\beta_3 + \beta_4)$, it can be seen that the retail price would rise slightly when crude oil price increases sharply, but the retail price would decrease significantly when crude oil price falls.

Figure 3.1 displays a comparison between actual and model predicted week-to-week retail gasoline price changes (actual blue solid line; model predicted: specification (1) red solid line, specification (2) green solid line, specification (3) yellow solid line, and specification (4) - teal solid line). As the price adjustment formula (PAF) was introduced in September 2006, we consider two time periods, pre-PAF (weeks 1 to 225) and post-PAF (weeks 226 to 713). Figure 3.1 indicates that: (i) during the post-PAF period the predicted price change by specification (4) is more likely to be close to the actual retail price change, and during the pre-PAF period actual price changes did not tend to be based on fluctuations of cost variables, Δp^{crude} and $\Delta e^{USD-TWD}$; (ii) the price adjustment formula imposed reductions in retail price in order to absorb positive cost shocks during crude oil shock periods (2010 and 2011); (iii) actual retail price responded instantaneously to decreases in crude oil prices but lagged in response to increases in crude oil prices.

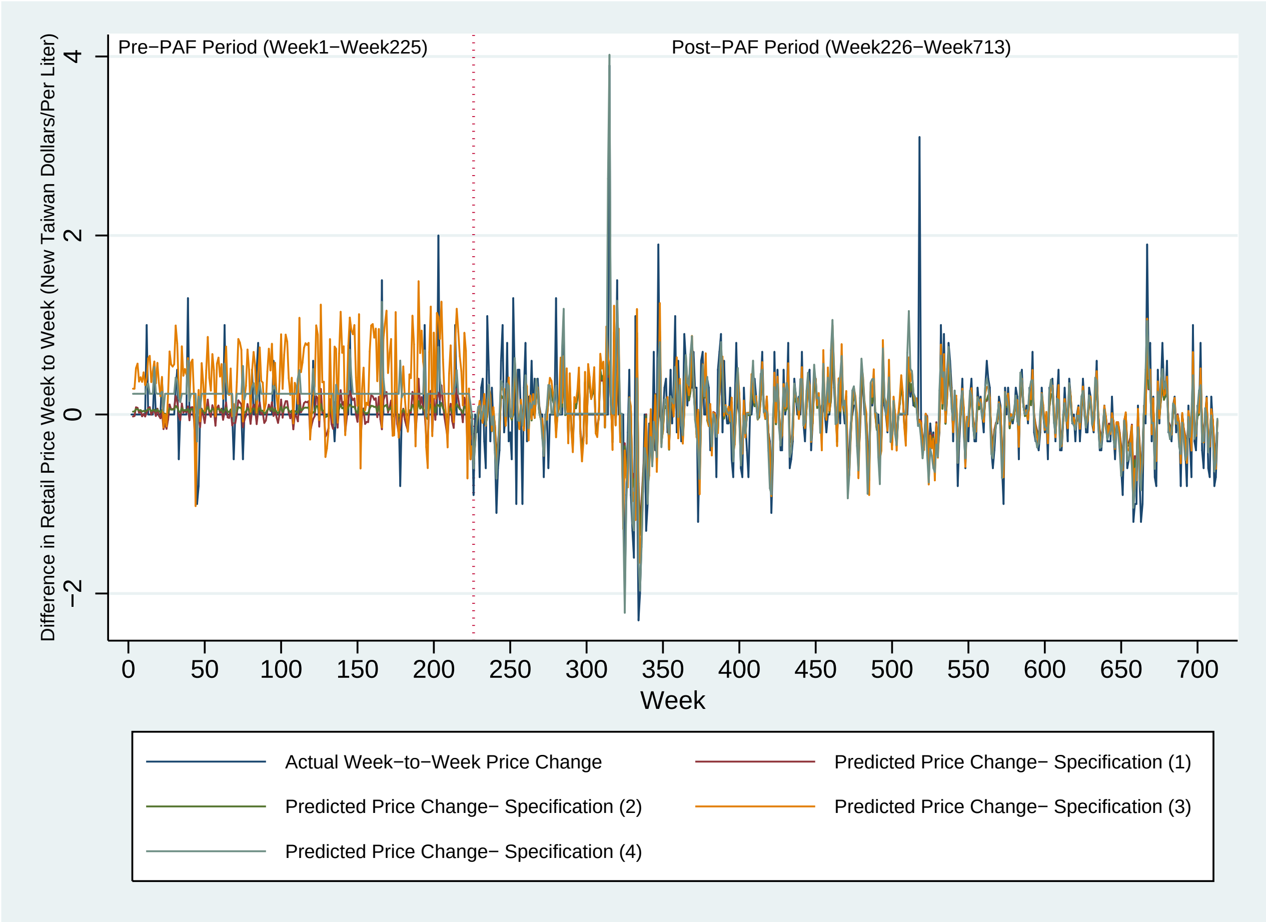
Comparing estimated results of all specifications in table 1 and figure 1, specification (4) is the preferred specification as it better describes the leading firm's pricing behavior after the introduction of the price adjustment formula. Specification (4) significantly expresses that: (i) the leading firm's pricing closely follows fluctuations in costs and (ii) steep rises in the retail price are curbed due to the introduction of the price adjustment formula.

Table 3.1: Leader's Retail Price Response

	(1)	(2)	(3)	(4)
Dependent Variable		Δp_t^{CPC}		
Time Period	All	All	Price change	Price change
Δp_{t-1}^{crude}	0.100***	0.028	0.308***	
	(0.006)	(0.019)	(0.074)	
$(p_{t-1}^{crude} - p_{t-\delta}^{crude})$				0.111***
				(0.006)
$\Delta e_{t-1}^{USD-TWD}$	-0.029	-0.008	0.141	
	(0.100)	(0.099)	(0.173)	
$(ex_{t-1}^{USD-TWD} - ex_{t-\delta}^{USD-TWD})$				0.161*
				(0.085)
PAF_t		-0.046	-0.351***	-0.222***
		(0.032)	(0.097)	(0.079)
$PAF_t \times \Delta p_{t-1}^{crude}$		0.081***	-0.169**	
		(0.020)	(0.074)	
$PAF_t \times (p_{t-1}^{crude} - p_{t-\delta}^{crude})$				0.068***
				(0.007)
Constant	0.003	0.039	0.369***	0.231***
	(0.015)	(0.027)	(0.094)	(0.077)
Observations	711	711	403	403
R^2	0.281	0.298	0.415	0.611

Note: Table 3.1 presents the estimated results of the leading firm's price response function as shown by equation (3.4.1). Given equation (3.4.1), we construct four specifications to separately estimate the leading firm's pricing behavior throughout the whole of the 713 periods and in the midst of price-changed periods. Specification (1) only focuses on cost fluctuations throughout the whole of the 713 periods. Specifications (2) and (3) estimate the leading firm's pricing behavior through the whole of the time and in price-changed periods, respectively. In these two specifications the link between the leading firm's pricing behavior and cost fluctuations, and the effect of government's policy will be discussed. Specifications (1) to (3) are standard specifications of equation (3.4.1). In specification (4) we use accumulated cost changes rather than standard week-to-week cost changes to estimate the leading firm's pricing behavior in price-changed periods. Standard errors are presented in parentheses. *** Statistically significant level at 0.01, ** statistically significant level at 0.05, * statistically significant level at 0.10.

Figure 3.1: Comparison of between Leading Firm's Actual and Model Predicted Price Changes



Note: The vertical reference line at week 226 indicates the implementation of the price adjustment formula (PAF) at that point (September 2006).

3.4.2 Effect of the Price Adjustment Formula on the Incidence of Price Leadership

As the relevant literature has shown, price leadership has been considered to be one of the institutional patterns resulting from the facilitation of collusive pricing. Therefore, in the second part of this analysis we focus on the link between the leadership pricing behavior seen and the introduction of the price adjustment formula. To determine the link between price leadership and the government's policy, we use two methods, a series comparing the two suppliers' exact new price-announcement timing and a logit model.

In the first, Seaton and Waterson's (2013) method is followed by comparing the two suppliers' exact new price-announcement timings. Given the new definition of leadership proposed by Seaton and Waterson (2013) we first restrict our attention to retail price changes of exactly the same amount, Δp, made by both firms; then we define that $Y_t(\tau_t)$ denotes a price change of Δp observed by supplier Y (i.e. CPC and FPCC) at exact time in hours τ in week t. The paired event between the two suppliers in week t is: $\{CPC_t(\tau_{CPC,t}), FPCC_t(\tau_{FPCC,t})\}$. In respect of this paired event, we compare both firms' exact new price-announcement time at time in hours τ in week t since both firms announced new retail prices in the same week. The relevant events are addressed as follows:

(i) Simultaneous-announcement event:

$$\{CPC_t(\tau_{CPC,t}), FPCC_t(\tau_{FPCC,t})\} = \begin{cases} 1 & \text{if time } \tau_{CPC,t} = \tau_{FPCC,t} \\ 0 & \text{, otherwise,} \end{cases}$$

(ii) Leadership event by CPC:

$$\{CPC_t(\tau_{CPC,t}), FPCC_t(\tau_{FPCC,t})\} = \begin{cases} 1 & \text{if time } \tau_{CPC,t} < \tau_{FPCC,t} \\ 0 & \text{, otherwise,} \end{cases}$$

where $\tau_{CPC,t}$ and $\tau_{FPCC,t}$ are the exact timing in hours of new price announcements by suppliers CPC and FPCC in week t, and $\tau_{CPC,t}, \tau_{FPCC,t} \in \{0, 1, 2, \ldots, 23\}$.

The first paired event, the simultaneous-move event, is defined as the two suppliers announcing retail prices at exactly the same time in hours, τ, in the same week t, $\tau_{CPC,t} = \tau_{FPCC,t}$. The second event, a leadership event by CPC, is defined as CPC's new price-announcement timing being earlier than FPCC's new price-announcement timing in week t, $\tau_{CPC,t} < \tau_{FPCC,t}$. On the basis of a series of comparisons of the two firms' exact new price-announcement timings, we suppose that the paired events are random across all 713 periods and that the simultaneous moves and leadership moves have an equal chance of happening. Therefore, given the above assumptions, we test the following hypotheses: (i) that the chance of outcomes of the leading firm's price leadership compared with simultaneous moves is equal ($probability^{simultaneous} = probability^{leadership} = 0.5$), and (ii) price leadership was unrelated to price movement. Based on substantial and sufficient numbers of observations, the numbers of simultaneous and leadership events follow the Binomial distribution, and the hypotheses are tested by the Normal approximation.

The results of the paired test and significance test are reported in tables 3.2a and 3.2b, respectively. Both tables 3.2a and 3.2b consist of eight time-period segments based on two conditions, the timing of the introduction of the price adjustment formula and transformation of market structure. First, on the basis of the timing of introduction of the government policy we split the whole study period into two sub time periods, pre-PAF and post-PAF, shown in the second and third columns. Second, given the transformation of market structure, the whole period is divided into three sub time periods, 1^{st} duopoly, triopoly and 2^{nd} duopoly in the fourth, fifth and sixth columns, respectively. In addition, in the last two columns we also split the 2^{nd} duopoly period into two sub time periods, pre-PAF and post-PAF. Each segment shows the number of observed periods, the number of leadership events (upward and downward), the number of simultaneous events (upward and downward), the proportion of observed leadership, the proportion of observed simultaneous events, and p-values based on these proportions.

Tables 3.2a and 3.2b report clear results regarding the hypotheses stated above. First, we test the hypothesis of the equal chance of both leadership and simultaneous events. In table 3.2a there is no equal chance of both leadership and simultaneous events in the first, third, fifth, sixth and last columns according to p-values. Whole, post-PAF, 2^{nd} duopoly and post-PAF of 2^{nd} duopoly segments indicate that the leading firm's leadership pricing behavior frequently emerged in the market. In particular, the emergence of price leadership occurs in the post-PAF and post-PAF of 2^{nd} duopoly periods. This finding suggests that price leadership is likely to occur after the introduction of the price adjustment formula. Furthermore, we test the second hypothesis which relates to the link between price leadership and price movement. The significant test result is reported in table 3.2b, and confirms that price leadership is likely to be linked to price movement. With upward and downward price movements, the facts clearly demonstrate that the leading firm's leadership pricing behavior leads to price movement in the whole, post-PAF, 2^{nd} duopoly and post-PAF of 2^{nd} duopoly periods, respectively.

Table 3.2a: Leadership and Simultaneous Moves

	All Periods	All Periods Pre-PAF	All Periods Post-PAF	1^{st} Duopoly	Triopoly	2^{nd} Duopoly	$2nd$ Duopoly Pre-PAF	$2nd$ Duopoly Post-PAF
Periods	1-713	1-225	226-713	1-16	17-75	76-713	76-225	226-713
# of CPC leads up	178	5	173	0	0	178	5	173
# of simultaneous up	17	13	4	1	6	10	6	4
$p(up^{cpc}\|up)$	0.913	0.278	0.977	0	0	0.947	0.455	0.977
$p(up^{simultaneous}\|up)$	0.087	0.722	0.023	1	1	0.053	0.545	0.023
p-value	**0.000**	0.0593	**0.000**	0.317	**0.014**	**0.000**	0.763	**0.000**
# of CPC leads down	177	2	175	0	0	177	2	175
# of simultaneous down	9	5	4	0	5	4	0	4
$p(down^{cpc}\|down)$	0.952	0.286	0.978		0	0.978	1	0.978
$p(down^{simultaneous}\|down)$	0.048	0.714	0.022		1	0.022	0	0.022
p-value	**0.000**	0.257	**0.000**		**0.025**	**0.000**	0.157	**0.000**

Note: $p(up^{cpc}|up)$ and $p(up^{simultaneous}|up)$ are defined as the observed proportions of upward price movements, $p(down^{cpc}|down)$ and $p(down^{simultaneous}|down)$ denotes the observed proportions of downward price movements. Standard errors are presented in parentheses. Statistically significant results of p-value at 5% level are reported in bold.

Table 3.2b: Significant Tests of Leadership Moves

	All Periods	All Periods Pre-PAF	All Periods Post-PAF	1^{st} Duopoly	Triopoly	2^{nd} Duopoly	$2nd$ Duopoly Pre-PAF	$2nd$ Duopoly Post-PAF
# of CPC leads up	178	5	173	0	0	178	5	173
# of simultaneous up	17	13	4	1	6	10	6	4
$p(up^{cpc}\|up)$	**0.913**	0.278	**0.977**	0	0	**0.947**	0.455	**0.977**
# of CPC leads down	177	2	175	0	0	177	2	175
# of simultaneous down	9	5	4	0	5	4	0	4
$p(down^{cpc}\|down)$	**0.952**	0.286	**0.978**		0	**0.978**	1	**0.978**

Note: $p(up^{cpc}|up)$ and $p(up^{simultaneous}|up)$ are defined as the observed proportions of upward price movements, $p(down^{cpc}|down)$ and $p(down^{simultaneous}|down)$ denotes the observed proportions of downward price movements. Standard errors are presented in parentheses. Statistically significant results of p-value at 5% level are reported in bold.

We now turn to the second method to examine the link between price leadership and the introduction of the price adjustment formula. We test the hypothesis that price leadership occurs through the introduction of the price adjustment formula. We use the logit regression model to relate the price leadership by the leading firm to the introduction of the government's policy, using the following regression equation:

$$Pr(lead_t^{CPC} = 1|PAF_t) = \Lambda(\beta_0 + \beta 1 PAF_t), \tag{3.4.2}$$

where $lead_t^{CPC}$ is the leading firm's binary event, being 1 if the leading firm led price change in week t, $\Lambda(\bullet)$ is the logistic transformation, and PAF_t is a dummy, being 1 if the price adjustment formula is implemented in week t.

The key parameter of interest, β_1, captures the linking of the leading firm's leadership pricing behavior to the policy imposed by the government. If the introduction of the price adjustment formula is deemed as facilitating the emergence of price leadership, we would expect that coefficient β_1 to be positive and significant. The estimated coefficient of equation (3.4.2) and its marginal effect are reported in table 3.3a, and the predicted probability of the emergence of price leadership is presented in table 3.3b. When the government's policy was introduced into the market, the probability of the emergence of price leadership increased significantly, by 68.2%. The predicted probability in table 3.3b demonstrates that the probability of the emergence of price leadership is less than 5% before the price adjustment formula is introduced into the market, while the probability is higher than 70% after it is introduced. In comparison to the off-PAF period, the predicted probability of the emergence of price leadership rises dramatically, by approximately 70%, when the policy is introduced. This evidence suggests that the price adjustment formula results in the emergence of price leadership.

The results presented in this section confirm that price leadership was probably linked to the introduction of the price adjustment formula and that the retail gasoline price movements in the market were based on the leading firm's leadership pricing behavior rather than on cost fluctuations. In the case of the Taiwan retail gasoline market, the state-owned enterprise (CPC) has around 70% market share. Additionally, its price initiatives have been explicitly followed by the competing firm (FPCC) in the duopolistic gasoline market as a result of the introduction of the price adjustment formula. Therefore, we may conclude that the classification of price leadership as being a feature of the Taiwan retail gasoline market is a result of a combination of dominant and collusive leadership.

Table 3.3a: Estimation Results of Leadership and Price Adjustment Formula

	Dep. Variable Leadership by CPC $lead_t^{CPC}$	Marginal Effect
Time Period	All Periods	
PAF_t	4.349***	0.682***
	(0.397)	(0.024)
Constant	-3.439***	
	(0.384)	
Observations	713	

Note: Standard errors are presented in parentheses. *** Statistically significant level at 0.01, ** statistically significant level at 0.05, * statistically significant level at 0.10.

Table 3.3b: Predicted Probability of Leadership under the Regime of the Price Adjustment Formula

	$PAF_t = 0$	$PAF_t = 1$
$Pr(lead_t^{CPC} = 1 \mid PAF_t)$	0.031***	0.713***
	(0.012)	(0.020)
$\chi^2(1)$	840.80	
p-value	0.000	

Note: Standard errors are presented in parentheses. *** Statistically significant level at 0.01.

3.4.3 Competitor's Perfect Price Alignment

One of the important questions in this study is whether the introduction of the price adjustment formula as a form of future conduct information sharing can be deemed anti-competitive in the market. In the case of the Taiwanese retail gasoline market, the government introduced the price adjustment formula to the market, allowing consumers and the competing firm (FPCC) to easily obtain future price information for the leading firm (CPC). Therefore, in this section we test the hypothesis that on the basis of unilateral disclosure of the leading firm's future price information provided by the price adjustment formula, the competing firm perfectly matches the leading firm's price. We use the logit model to present the competing firm's binary decision of perfect price match to the introduction of the price adjustment formula. The logit regression equation is:

$$Pr(sp_t^m = 1|PAF_t) = \Lambda(\beta_0 + \beta_1 PAF_t) \quad \text{and} \quad m \in \{1, 2\}, \tag{3.4.3}$$

where sp_t^m is type m competing firm's perfect price alignment decision, $\Lambda(\bullet)$ is the logistic transformation, and PAF_t is a dummy, being 1 if the price adjustment formula is introduced in week t.

In particular, dependent variable,sp_t^m, refers to the competing firm's type m perfect price alignment in week t, $m = \{1, 2\}$. To clearly indicate the competing firm's pricing decision, we first use the two firms' exact price-announcement times in hours and the firms' retail prices to establish two conditions, which are as follows:

(a) The competing firm's retail price is restricted to it being the identical price to the leading firm's retail price, i.e. $p_t^{FPCC} = p_t^{CPC}$, and the competing firm (FPCC) must be a price-follower.

(b) Measure of the competing firm's perfect price match decision is restricted to the price-changed periods. A price-changed period is defined as a period in which both the leading and competing firms had price-changed events, i.e. $p_t^{FPCC} \neq p_{t-1}^{FPCC}$ and $p_t^{CPC} \neq p_{t-1}^{CPC}$.

Then, we widely define that sp_t^1 is a binary competing firm's perfect price match behavior (type I price alignment decision) and as being 1 if condition (a) is satisfied. In addition, for better providing evidence about the competing firm's pricing behavior, we narrowly define that sp_t^2 is a binary competing firm's perfect price match behavior (type II perfect price alignment decision) and being 1 if conditions (a) and (b) are satisfied. The key difference between sp_t^1 and sp_t^2 is that sp_t^2 is restricted to the price-changed periods, while sp_t^1 does not require this restriction.[10]

Table 3.4a reports the estimated parameters and marginal effects of two specifications from equation (3.4.3), and table 3.4b presents the predicted probability of the competing firm's perfect price-match decision. Specification (1) refers to type I competing firm's price-alignment decision, and specification (2) is type II competing firm's price-alignment decision. As sp_t^2, type II perfect price alignment, is narrowly defined to focus on price-changed periods, we can precisely examine whether the competing firm's perfect price match is made after the leading firm's new price is unilateral disclosed by the price adjustment formula. Therefore, we would expect that specification (2) can explicitly indicate the link between the competing firm's pricing behavior and the introduction of the price adjustment formula. The main parameter of interest is β_1 which captures the competing firm's dynamic price response to the introduction of the price adjustment formula. As we suppose that the price adjustment formula is deemed to be future conduct information sharing, the competing firm would perfectly match the leading firm's new price after the introduction of the price adjustment formula. We therefore expect key parameter β_1 to be positive and significant.

The estimated coefficients of two specifications of the logit regression in table 3.4a show that the introduction of the price adjustment formula is significant in raising the probability of perfect price match. In particular, specification (2), type II perfect price match, shows that after the introduction of the price adjustment formula the probability of perfect price match increases by 62%. The predicted probability of perfect price match reported in table 3.4b also reveals the same finding. The probability of perfect price match is greater than 80%

[10]Two types of competing firm's perfect price alignment decision are detailed in Appendix 3.A.

after the introduction of the price adjustment formula according to specification (1), type I price alignment; however, the probability of perfect price match only decreases to 78% before the introduction of the price adjustment formula. On the basis of condition (a) sp_t^1 is widely defined, which may result in a potential issue of overestimation in describing the effect of the price adjustment formula on the competing firm's dynamic price response. For this potential issue, we limit our attention to the probability of specification (2), type II price alignment. The predicted probability after the introduction of the price adjustment formula is 66%, but it falls to 3% when the price adjustment formula was not introduced.

Our analysis confirms the perfect price match hypothesis, where the competing firm is perfectly aligned with the leading firm's new price during the time of the policy. This gives evidence that the competing firm used the price adjustment formula to coordinate its retail price.

Table 3.4a: Estimation Results of Logit Model 1

Model	Logit Model 1			
	Dep. Var. Price Alignment 1 sp_t^1	Marginal Effect	Dep. Var. Price Alignment 2 sp_t^2	Marginal Effect
Time Period	All Periods			
PAF_t	0.559***	0.080**	3.963***	0.624***
	(0.208)	(0.032)	(0.372)	(0.025)
Constant	1.279***		-3.300***	
	(0.162)		(0.360)	
Observations	713	713	713	713

Note: Standard errors are presented in parentheses. *** Statistically significant level at 0.01, ** statistically significant level at 0.05, * statistically significant level at 0.10.

Table 3.4b: Predicted Probability of Competitor's Price Setting

	Logit Model 1	
	$Pr(sp_t^1 = 1 \mid PAF_t)$	$Pr(sp_t^2 = 1 \mid PAF_t)$
$PAF_t = 0$	0.782***	0.036***
	(0.028)	(0.012)
$PAF_t = 1$	0.863***	0.660***
	(0.016)	(0.021)
$\chi^2(1)$	6.48	636.44
p-value	0.011	0.000

Note: Standard errors are presented in parentheses. *** Statistically significant level at 0.01.

An additional concern relating to perfect price match is the emergence of price leadership, and therefore we test the hypothesis that the competing firm's dynamic price response is related to the emergence of price leadership. We use the logit regression to test whether the competing firm's pricing mechanism is based on cost fluctuations or on the emergence of price leadership. The regression model contains two cost variables, crude oil price and exchange rate. These two cost variables are considered as main factors in the procedure of the price adjustment formula. The regression equation is:

$$Pr(sp_t^m = 1|\mathbf{X}) = \Lambda(\beta_0 + \beta_1 up_t^{CPC} + \beta_2 down_t^{CPC} + \beta_3 p_{t-1}^{crude} + \beta_4 e_{t-1}^{USD-TWD}), \qquad (3.4.4)$$

where sp_t^m is the competitor's binary decision with (i) type I price alignment if $m = 1$ and (ii) type II price alignment if $m = 2$, and is interpreted as being 1 if the competitor aligned with the leader's new price setting in week t, $\Lambda(\bullet)$ is the logistic transformation, up_t^{CPC} is a dummy, being 1 if the CPC led an upward price move in week t, $down_t^{CPC}$ is a dummy, being 1 if the CPC led a downward price move in week t,p_{t-1}^{crude} is crude oil price in week $t1$, and $e_{t-1}^{USD-TWD}$ is exchange rate between the USD and the TWD in week $t1$.

Table 3.5a reports the estimated coefficients of the logit regression and its marginal effects. Specifications (1), type I perfect price match and (2), type II perfect price match, show that both cost fluctuations and the emergence of price leadership are significant to the competing firm's perfect price match. In particular, specification (2), type II perfect price match, shows that the emergence of price leadership would increase the chance of the competing firm's perfect price match by at least 75% (upward leadership: 76%; downward leadership: 80%). Comparatively speaking, cost fluctuations (less than 10% in specification (1) and less than 23% in specification (2)) are unlikely to be the main factors in the competing firm's perfect price match decision. This finding suggests that the competing firm's retail gasoline pricing is based on leadership pricing rather than on cost-based pricing, which is consistent with existing literature.[11]

The predicted probability of the competing firm's perfect price match is reported in table 3.5b. The predicted probability indicates that the emergence of price leadership is the key factor in maintaining perfect price match. The predicted probability of specifications (1) and (2) is greater than 90% according to the emergence of price leadership. This shows that the competing firm had an incentive to perfectly match the leading firm's new price given the leading firm's leadership pricing behavior. Similarly, for potential issues of overestimation from type I perfect price match, we pay attention to specification (2), type II perfect price match. Specification (2) further shows that the predicted probability decreases to less than 3% when price leadership does not exist in the market. This means the competing firm has no incentive to perfectly match the leading firm's new price without the presence of price leadership.

Figures 3.2 and 3.3 depict the predicted conditional probability of competitor's price alignment decision given three paired sets of upward and downward leadership events and changes in crude oil price and exchange rate. The upper figure of figure 3.2 presents that given three paired sets of leadership events and changes in crude oil price the predicted conditional probabilities of type I price alignment (sp^1) grows and approaches unity by parallel trends. The lower figure shows that given the emergence of price leadership and changes in crude oil price the predicted conditional probabilities of type II price alignment (sp^2) has a similar growth trend, but without price leadership the probability of type II price alignment rises gradually with changes in crude oil price. The predicted probabilities in figure 3.3 are similar to those in figure 3.2. Figures 3.2 and 3.3 suggest that the emergence of price leadership and increased costs would result in price coordination, and without price leadership price coordination outcomes are difficult to sustain in the case of type II price alignment decision.

This analysis confirms that the emergence of price leadership is the key factor in the competing firm's pricing strategy and identifies that the competing firm's pricing mechanism

[11] See Andreoli-Versback and Franck (2015).

significantly changes from cost-based pricing to leadership-based pricing. The final part of the analysis provides evidence identifying that the competing firm alters its new price through the introduction of the price adjustment formula and price leadership.

Table 3.5a: Estimation Results of Logit Model 2

Model	Logit Model 2			
	Dep. Var. Price Alignment 1 sp_t^1	Marginal Effect	Dep. Var. Price Alignment 2 sp_t^2	Marginal Effect
Time Period	All Periods			
up_t^{CPC}	1.408***	0.080***	6.177***	0.768***
	(0.387)	(0.022)	(0.572)	(0.048)
$down_t^{CPC}$	1.893***	0.106***	6.619***	0.800***
	(0.420)	(0.024)	(0.614)	(0.044)
p_{t-1}^{crude}	0.109***	0.007***	0.091***	0.018***
	(0.013)	(0.001)	(0.014)	(0.003)
$e_{t-1}^{USD-TWD}$	1.149***	0.074***	1.102***	0.221***
	(0.210)	(0.016)	(0.237)	(0.049)
Constant	-43.763***		-45.797***	
	(7.549)		(8.643)	
Observations	488	488	488	488

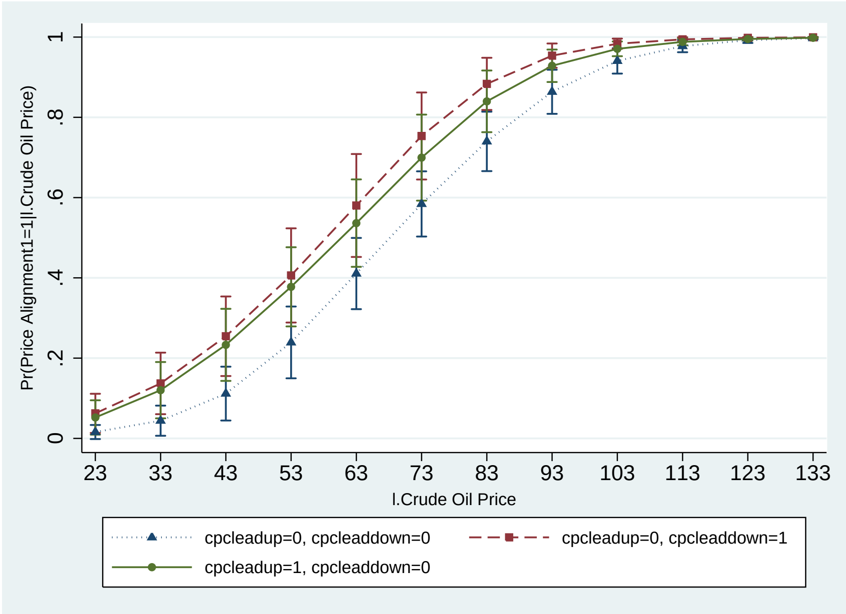
Note: Standard errors are presented in parentheses. *** Statistically significant level at 0.01, ** statistically significant level at 0.05, * statistically significant level at 0.10.

Table 3.5b: Predicted Probability of Competitor's Price Setting

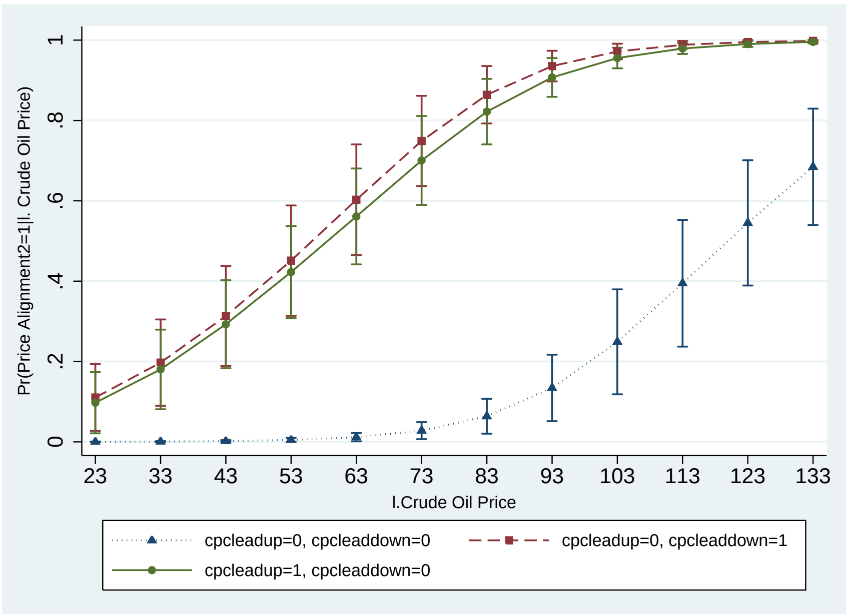
	Logit Model 2	
	$Pr(sp_t^1 = 1 \mid Leadership_t)$	$Pr(sp_t^2 = 1 \mid Leadership_t)$
$\{up_t^{CPC} = 1, down_t^{CPC} = 0\}$	0.944***	0.929***
	(0.017)	(0.019)
$\{up_t^{CPC} = 0, down_t^{CPC} = 1\}$	0.965***	0.953***
	(0.012)	(0.015)
$\{up_t^{CPC} = 0, down_t^{CPC} = 0\}$	0.806***	0.026**
	(0.041)	(0.011)
$\chi^2(1)$	15.28	2200.63
p-value	0.001	0.000

Note: $Leadership_t$ denotes a paired price leadership event as: (i) upward price leadership, $\{up^{CPC} = 1, down^{CPC} = 0\}$, (ii) downward price leadership, $\{up^{CPC} = 0, down^{CPC} = 0\}$, and (iii) no price leadership, $\{up^{CPC} = 0, down^{CPC} = 0\}$. Standard errors are presented in parentheses. *** Statistically significant level at 0.01, ** statistically significant level at 0.05.

Figure 3.2: Predicted Probability of Competitor's Price Alignment Given Crude Oil Price



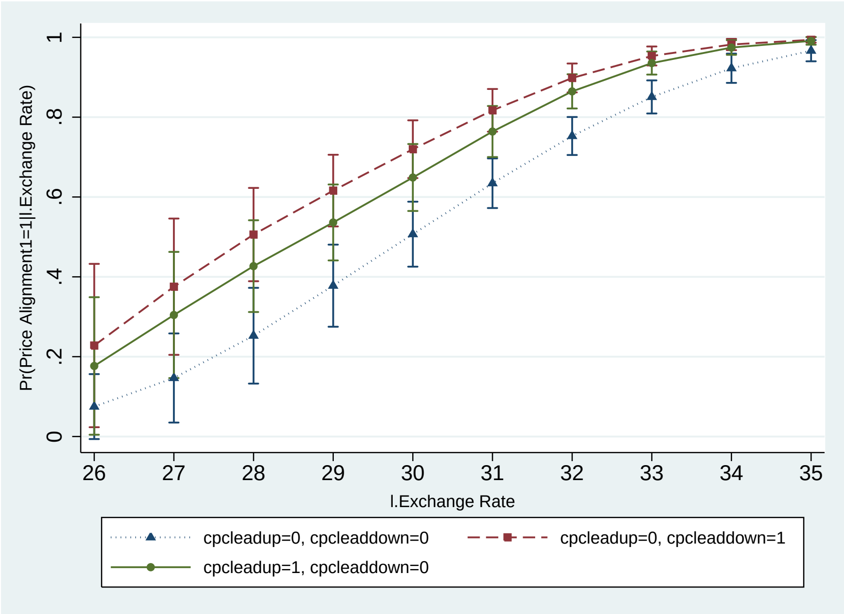
(a) Predicted Probability of Type I Price Alignment



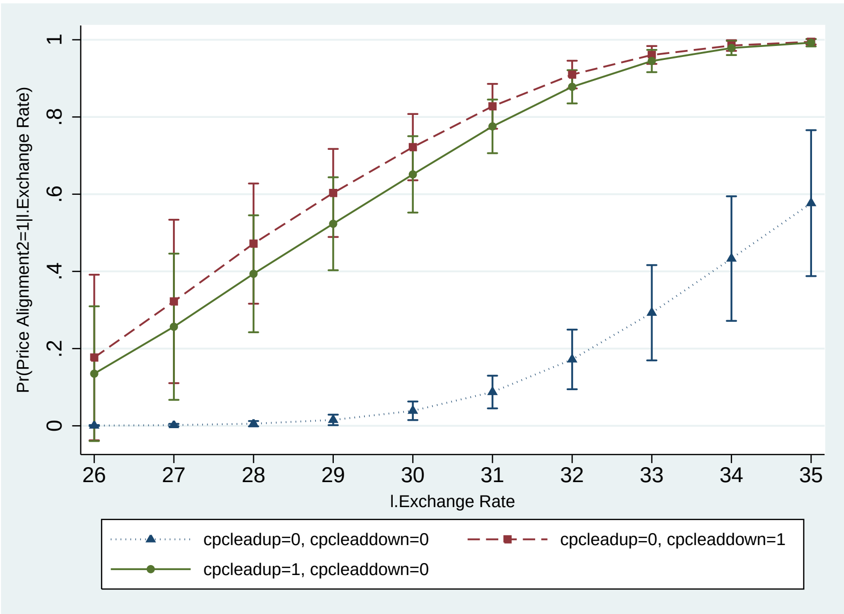
(b) Predicted Probability of Type II Price Alignment

Note: Horizontal line tick values are based on the minimum and maximum values of crude oil price which are presented in table 3.1.

Figure 3.3: Predicted Probability of Competitor's Price Alignment Given Exchange Rate



(c) Predicted Probability of Type I Price Alignment



(d) Predicted Probability of Type II Price Alignment

Note: Horizontal line tick values are based on the minimum and maximum values of exchange rate which are presented in table 3.1.

3.5 Summary of Chapter 3

This paper examines effects of the future information exchange imposed by the government on the following aspects of the gasoline market: the two firms' price-setting mechanisms, price leadership and collusive outcomes. As suggested by our empirical results, we highlight the following insights: (i) there is price match between the leading firm and the competing firm, (ii) price leadership is generated by the government's policy, and (iii) price coordination and collusive outcomes occur as a result of the existence of future conduct information exchange and price leadership via the price adjustment formula via the price adjustment formula.

In the first part of the analysis we use the pass-through model to indicate the link between the leading firm's pricing strategy and the price adjustment formula. We find that during on-policy periods the leading firm's retail gasoline price follows closely with the fluctuations in crude oil price and exchange rate, but that the introduction of the price adjustment formula significantly absorbed part of the impact of steep increases in crude oil price to curb steep increases in retail gasoline price.

In the second part of the analysis we carry out a series of comparisons between both firms' exact price-announcement time in hours, to examine whether price leadership emerges, and use a logit regression model to construct a link between price leadership and the price adjustment formula. A series of comparisons between the two firms' exact price-announcement times provides evidence of the emergence of price leadership during on-policy periods. Additionally, we run the logit regression model to test the link between price leadership and the price adjustment formula, and we find evidence of a significant link between price leadership and the price adjustment formula at the time of the policy.

In the final part of the analysis we run two logit regression models to characterize separately the competing firm's dynamic price response to the introduction of the government's policy and the emergence of price leadership. In the first model, our results show that the competing firm has exhibited perfect price match decisions since the introduction of the price adjustment formula publicly disclosed the leading firm's future price information. In particular, the specification for type II price alignment gives more precise evidence that the introduction of the price adjustment formula served as future conduct information sharing and is the key factor facilitating price coordination and collusive outcomes. In the second model we focus on the competing firm's pricing mechanism, and evaluate whether the competing firm's pricing is based on cost fluctuations or the emergence of price leadership. The results of the two specifications, type I and type II price alignment, show that the competing firm had a significantly higher incentive to make perfect price-match decision due to the emergence of price leadership. Combining findings from the two models, the competing firm's dynamic price response clearly shows that: (i) the effect of the price adjustment formula in serving as future conduct information sharing was to explicitly facilitate price coordination, and that (ii) the competing firm's pricing was leadership-based pricing rather than cost-based pricing. It can therefore be seen that collusive outcomes are unwittingly caused by the government's price regulation policy alongside the main objective of the price adjustment formula. This result is similar to the Danish ready-mix concrete case studied by Albæk, Møllgaard, and Overgaard (1997).

Appendix

3.A Dummy Variable Setting

In order to explore the effect of the price adjustment formula, we first focus our attention on the dummy variable setting of the implementation of the price adjustment formula. The government's transparent price regulation policy was implemented from the end of September 2006 (week 226 in our dataset), and so the period of the price adjustment formula regime is algebraically defined as

$$PAF_t = \begin{cases} 1 & \text{if } t \geq 226 \\ 0 & \text{, otherwise,} \end{cases}$$

where PAF_t is a dummy of 1 after the transparent price regulation policy was implemented by the government in week t.

We consider the effect of the price adjustment formula and the presence of price leadership on the issue of collusive outcomes in the Taiwan gasoline market, and we develop several dummy variables for answering our concerns regarding tacit collusion. These dummy variables are based on our dataset, which is reported in table 3.1 and is categorized into three sets as:

(1) did price change from the previous week?

(2) did CPC lead price changes and FPCC follow?

(3) did CPC and FPCC set identical prices following a price change?

The first set of dummy variables indicates the presence of gasoline suppliers' price-change events and their price-change direction. In the second set of dummy variables, we measure the presence of price leadership events. The third set identifies the presence of identical prices for both suppliers.

Variables in the first set include the presence of the two suppliers' price-change events, and the leading firm's price-change direction. The first three dummy variables characterize the pattern of price change and the fourth category variable identifies the leading firm's price change direction. The forms of price change are

$$PChange_t^{CPC} = \begin{cases} 1 & \text{if } p_t^{CPC} \neq p_{t-1}^{CPC} \\ 0 & \text{, otherwise,} \end{cases}$$

$$PChange_t^{FPCC} = \begin{cases} 1 & \text{if } p_t^{FPCC} \neq p_{t-1}^{FPCC} \\ 0 & \text{, otherwise} \end{cases}$$

and

$$PChange_t = PChange_t^{CPC} \times PChange_t^{FPCC},$$

and firm i's price change direction can be expressed as

$$ChangeDirection_t^{CPC} = \begin{cases} 1 & \text{if } p_t^{CPC} > p_{t-1}^{CPC} \\ 0 & \text{if } p_t^{CPC} = p_{t-1}^{CPC} \\ -1 & \text{if } p_t^{CPC} < p_{t-1}^{CPC}, \end{cases}$$

where $PChange_t^{CPC}$ is a dummy of 1 if CPC adjusted its retail price in week t, $PChange_t^{FPCC}$

is a dummy of 1 if FPCC adjusted its retail price in week t, $PChange_t$ is a dummy of 1 if both suppliers adjusted their prices in week t, and $ChangeDirection_t^{CPC}$ is a category variable of 1 if supplier CPC increased retail price in week t, of 0 if supplier CPC charged previous price level in week t, and of -1 if supplier CPC decreased retail price in week t.

In the second set, we consider leadership events in the Taiwan gasoline market. This set of dummy variables is unique to this empirical study. We have collected data at the exact time of day when price changes were announced. Then, we can define the leadership dummy variable by using the two gasoline suppliers' exact time of announcing new retail price. Thus, the leadership event setting in this study is different from the leadership event setting in Seaton and Waterson (2013).[12] We now turn to our price leadership event setting. We look at the two suppliers' exact timing of price-change announcements, so that leadership and followership events can be distinguished. Given the current duopolistic market structure, we initially define that if supplier i ($i \in \{CPC, FPCC\}$) announces new price strategy at time $\tau_{i,t}$ in week t, a leadership event from supplier i is

$$lead_t^i = \begin{cases} 1 & \text{if } \tau_{j,t} > \tau_{i,t} \text{ and } PChange_t = 1 \\ 0 & \text{, otherwise,} \end{cases}$$

where $\tau_{i,t}$ is firm i's exact timing of new price announcement in week t, and $\tau_{i,t} \in \{0, 1, 2, \ldots, 23\}$.[13] $\tau_{j,t} > \tau_{i,t}$ reflects the extent to which supplier i's exact timing of new price-change announcement in week t is earlier than supplier j's exact timing of new price-change announcement in week t. $lead_t^i$ is a dummy, being 1 when supplier i leads price change in week t. Here we restrict our attention to leadership events from the leading firm, CPC, only.

We will again define that if suppliers CPC and FPCC announce new price strategy si-

[12]To investigate price leadership in the British supermarket industry, Seaton and Waterson (2013) only observe their definition of a price change of exactly the same amount and direction in making a comparison of two supermarket chains price between current and one or two weeks later. They do not take into account the exact time of price change in the price leadership event setting.

[13]Suppliers CPC and FPCC adjusted their prices weekly and adopted new prices on the same day. Therefore, we can make a comparison of the exact timing of new price change announcement between suppliers CPC and FPCC.

multaneously at time τ_t in week t, a simultaneous price change between two suppliers is

$$sm_t = \begin{cases} 1 & \text{if } \tau_{FPCC,t} = \tau_{CPC,t} \text{ and } PChange_t = 1 \\ 0 & \text{, otherwise,} \end{cases}$$

where $\tau_{FPCC,t} = \tau_{CPC,t}$ reflects when suppliers CPC and FPCC announce new price strategy at the same exact timing in week t. sm_t is a dummy, being 1 if suppliers CPC and FPCC announce new prices simultaneously.

Given supplier CPC's leadership event, $lead_t^{CPC}$, simultaneous event, sm_t, and supplier CPC's price-change direction, $ChangeDirection_t^{CPC}$, leadership and simultaneous events can be classified according to price-change directions into upward and downward price changes. First, upward and downward price leadership events of supplier CPC are given as follows:

$$up_t^{CPC} = \begin{cases} 1 & \text{if } lead_t^{CPC} = 1 \text{ and } ChangeDirection_t^{CPC} = 1 \\ 0 & \text{, otherwise,} \end{cases}$$

and

$$down_t^{i} = \begin{cases} 1 & \text{if } lead_t^{CPC} = 1 \text{ and } ChangeDirection_t^{CPC} = -1 \\ 0 & \text{, otherwise,} \end{cases}$$

where up_t^{CPC} is a dummy of 1 if supplier CPC leads positive price change in week t, and $down_t^{CPC}$ is a dummy of 1 if supplier CPC leads negative price change in week t

Second, upward and downward price changes in simultaneous moves between two suppliers can be expressed as

$$up_t^{sm} = \begin{cases} 1 & \text{if } sm_t = 1 \text{ and } ChangeDirection_t = 1 \\ 0 & \text{, otherwise,} \end{cases}$$

and

$$down_t^{sm} = \begin{cases} 1 & \text{if } sm_t = 1 \text{ and } ChangeDirection_t = -1 \\ 0 & \text{, otherwise,} \end{cases}$$

where up_t^{sm} is a dummy of 1 when suppliers CPC and FPCC changed their prices simultaneously and had positive price changes in week t, and $down_t^{sm}$ is a dummy of 1 when suppliers CPC and FPCC changed their prices simultaneously and had negative price changes in week t.

Lastly, we return to consider a case of identical prices set by both suppliers, CPC and FPCC. In an identical price case, we restrict attention to two types of perfect price alignment setting. In the first type of perfect price alignment, we suppose that given the elimination of simultaneous move events between two suppliers, in week t supplier FPCC set exactly the same retail gasoline price as supplier CPC. The first perfect price alignment setting is

$$sp_t^1 = \begin{cases} 1 & \text{if } p_t^{FPCC} = p_t^{CPC} \text{ and } sm_t = 0 \\ 0 & \text{, otherwise,} \end{cases}$$

where sp_t^1 is a dummy of 1 if supplier FPCC charged exactly the same price as that set by supplier CPC in week t and the two suppliers did not adjust their prices simultaneously.

For the second type of perfect price alignment we restrict the first perfect price alignment setting. We suppose that given the elimination of simultaneous move events between the two suppliers, supplier FPCC charged exactly the same price level as supplier CPC when both suppliers made a price change in week t. Thus, the second perfect price alignment setting is expressed as

$$sp_t^2 = \begin{cases} 1 & \text{if } p_t^{FPCC} = p_t^{CPC},\ PChange_t = 1, \text{ and } sm_t = 0 \\ 0 & \text{, otherwise,} \end{cases}$$

where sp_t^2 is a dummy of 1 if supplier FPCC exactly charged the same price as supplier CPC set in week t during price-change period, $PChange_t = 1$, and simultaneous price changes between the two suppliers did not happen.

As relevant data and dummy variables which are used in our econometric analysis of this chapter are introduced and defined in this section, we re-summarize the description of data and dummy variables in table 3.A.1.

Table 3.A.1: Variable Description

Variable	Description
p^{CPC}	CPC's retail gasoline price
p^{FPCC}	FPCC's retail gasoline price
p^{Dubai}	Spot price of Dubai crude oil
p^{Brent}	Spot price of Brent crude oil
p^{crude}	Weighted crude oil price
$ex^{USD-TWD}$	Exchange rate for the US dollar to Taiwan New dollar
PAF	The price adjustment formula
$PChange$	Price-change event
$ChangeDirection$	Price-change direction
$lead$	Leadership move event
sm	Simultaneous move event
up	Upward-price change event
$down$	Downward-price change event
sp^1	Type I perfect price alignment
sp^2	Type II perfect price alignment

3.B Data Source of Chapter 3

Table 3.B.1: Data Source

Chapter 3		
Dataset	**Data Type**	**Source**
CPC's Retail Price of 95 Unleaded Gasoline, 2002M06-2015M12	Weekly Data	Bureau of Energy, Ministry of Economic Affairs, Taiwan
FPCC's Retail Price of 95 Unleaded Gasoline, 2002M06-2015M12	Weekly Data	Bureau of Energy, Ministry of Economic Affairs, Taiwan
Price of Dubai Crude Oil, 2002M06-2015M12	Weekly Data	Bureau of Energy, Ministry of Economic Affairs, Taiwan
Price of Brent Crude Oil, 2002M06-2015M12	Weekly Data	Bureau of Energy, Ministry of Economic Affairs, Taiwan
Exchange Rate: USD-TWD, 2002M06-2015M12	Daily Data	Central Bank of the Republic of China (Taiwan)

Chapter 4

Effect of Transparent Price Policy on Household Gasoline Demand

4.1 Introduction

Since the Taiwanese government implemented its price adjustment formula in September 2006 to regulate the gasoline price of the state-owned enterprise, CPC Corporation, CPC's price information has been publicly disseminated to consumers as well as to its main competitor, Formosa Petrochemical Corporation (FPCC). As a result, improvements in market transparency resulting from the implementation of the price adjustment formula may have arisen. In the previous chapter we investigated the effect of future conduct information sharing on the supply side of the market, and provided evidence about tacit collusive outcomes generated by the government's transparent price regulation policy. In this chapter, we restrict our attention to the effect of information sharing on the demand side. The main objective is to examine whether the sharing of future conduct information carries potential gains for consumers by enabling them to better anticipate price changes.

Gasoline demand has been modeled by parametric techniques in most of the relevant studies, and the relationship between dependent and independent variables has to be appropriately postulated within parametric models. Using a parametric model may be potentially restrictive to the interpretation of the relationship between dependent and independent variables, and involves the risk of misspecification. On the other hand, gasoline demand can become flexible without restrictive assumptions and there is a risk of misspecification if gasoline demand is modeled by pure nonparametric techniques. A pure nonparametric model may suffer the particular issue of 'the curse of dimensionality' and the lack of interpretable parameters. In terms of parametric and nonparametric models, we may face disadvantages from either of the models. Therefore, the motivation for the use of a semiparametric model is that such a model, which consists of parametric and nonparametric components, can combine the advantages of parametric and nonparametric models while reducing the specific limitations arising from each.

This chapter attempts to determine household gasoline demand in response to changes in retail gasoline price and price information sharing, and to model household gasoline demand using semiparametric techniques. The semiparametric specification of household gasoline demand encompasses parametric estimates of explanatory variables and a nonparametric estimate of price elasticity, and this specification can examine whether nonlinear price elasticity of household gasoline demand varies across regions. In the existing literature, regional gasoline demand cannot be explicitly depicted, because of the use of a national household dataset, and we therefore use a regional household dataset to enable exploration of regional household gasoline demand using a semiparametric approach.

This study differs from the existing literature in two aspects. First, in geographically large countries such as the US and Canada, existing studies have modeled gasoline demand semiparametrically, and have obtained similar results from semiparametric estimates. We therefore model household gasoline demand in geographically small country of Taiwan to address the issue of whether differences in gasoline demand exist between geographically large and small countries. Second, in order to assess the impact of future conduct information generated by the government's regulatory policy, the concept of future conduct information sharing is added to the discussion of household gasoline demand. This analysis allows us to examine whether changes in household gasoline demand are impacted by the government's regulatory policy.

The contributions of this study can be outlined as follows: first we model Taiwan household gasoline demand semiparametrically using regional household-level data to disaggregate household demand for gasoline by urban and rural regions. We find that household demand for gasoline is relatively inelastic in urban and rich regions and is relatively elastic in rural and poor regions, with the monthly effects being smaller in an urbanized region. Second, we consider the effect of future conduct information sharing on household demand for gasoline. Our results find that current household gasoline consumption would fall when negative future conduct price-change information is publicly disclosed to consumers. This finding indicates that the implementation of the price adjustment formula helps consumers to plan future purchase responses via intertemporal substitution in household gasoline-consumption decisions. Finally, this study provides an application of a semiparametric approach to gasoline demand outside North America.

The remainder of this study is organized as follows: section 4.2 briefly summarizes relevant existing studies and section 4.3 provides descriptions of our household-level data. Econometric methods and results, which include specification and estimation of semiparametric models, are presented in section 4.4. Finally, section 4.5 provides conclusions for this chapter.

4.2 Literature Review

Stoker (1992) has demonstrated that semiparametric methods can enhance efficiency in comparison with parametric estimates and thus avoid the curse of dimensionality in depicting nonparametric estimates graphically. You et al. (2010) and Wang (2011) have also emphasized similar advantages to using semiparametric techniques. They mention advantages and disadvantages of constructing parametric and nonparametric models, and argue that semiparametric models can deliver advantages and reduce disadvantages of parametric and nonparametric models. Such benefits can be provided by, for example, including the interpretable parameters of parametric models and the flexibility of nonparametric models while reducing the possibility of misspecification of parametric models and the curse of dimensionality of nonparametric models. Semiparametric models encompass advantages of full parametric and pure nonparametric models, and have been considerably used in much of the literature about gasoline demand. In existing studies, semiparametric regression techniques have been applied to estimates of gasoline demand in the US and Canada (Hausman and Newey, 1995; Schmalensee and Stoker, 1999; Yatchew and No, 2001; Manzan and Zerom, 2010; Wadud, Noland and Graham, 2010; Liu, 2014). By the application of flexible semiparametric specification, these studies provide precise parametric estimates using other explanatory variables alongside a graphical interpretation of the relationship between gasoline demand and gasoline price. Therefore, a semiparametric method is appropriate in this study for estimating Taiwanese household gasoline demand.

Hausman and Newey (1995) use household-level data from the Residential Energy Consumption Survey for the years 1979, 1980 and 1981 and from the Residential Transportation Energy Consumption Survey (RTECS) for the years 1983, 1985 and 1988. These surveys were conducted by the US Energy Information Administration (EIA) to estimate gasoline demand semiparametrically. They find that the price elasticity in nonparametric estimation is more complicated than parametric estimation and depends on variety of gasoline price, and they indicate that household income is positively related to gasoline demand. Schmalensee and Stoker (1999) collect RTECS data from the EIA to estimate the household demand for gasoline. They find a positive relationship between household gasoline demand and household income. Moreover, Yatchew and No (2001) use Canadian data from the National Private Vehicle Use Survey which was collected by Statistics Canada between 1994 and 1996 in order to examine Canadian household demand for gasoline. They also confirm positive income elasticity in Canadian household gasoline demand. Similarly, Manzan and Zerom (2010) reexamine RTECS data for the years 1991 and 1994 and show a positive relationship between household consumption and household income in their nonparametric estimate. Liu (2014) gathers a state-level panel dataset to evaluate gasoline demand, and finds income elasticity of between approximately 0.1 and 0.22 across states. These studies indicate that gasoline demand would not be negatively affected by an increase in income.

However, Judson, Schmalensee and Stoker (1999) investigate the relationship between economic development and energy demand by using UN sectoral data covering 123 nations. They point out that energy consumption tends to decline with income in the household sector, particularly in high income groups. Similarly, Wadud, Noland and Graham (2010) study household gasoline demand by using data from 1997 to 2002 from the US Consumer Expenditure Surveys (CEX) conducted by the US Bureau of Labor Statistics. They claim that the income elasticity of gasoline demand becomes negative at high income levels because of substitution from car leisure trips to air-travel leisure trips. As the above literature generally indicates a positive income elasticity of gasoline demand in the US and Canadian markets, we would reconsider the relationship between income effect and household gasoline demand by using a semiparametric method.

Recent studies have paid limited attention to the effects of future conduct information on market efficiency and anti-competitive outcomes. Kühn (2001) has argued that public future conduct information sharing should be considered as a policy option if it is clearly related to consumers and potential efficiency gains, but that private future conduct information sharing should be prohibited for the avoidance of efficiency losses. An OECD analysis report (2010) also demonstrates that increased market transparency would carry benefits for consumers and produce an increase in consumer welfare. Furthermore, Bennett and Collins (2010) discuss the topic of public dissemination of future intentions. They argue that public disclosure of future price would help consumers to plan their future-purchase responses in advance. According to their argument, efficiency gains to consumers can be deemed to reflect intertemporal substitution in household gasoline-consumption decisions. Having discussed the effect of future conduct information sharing to the supply side in Chapter 3, this chapter will consider the effect of future conduct information on the demand side.

4.3 Data Description

In this chapter, we study Taiwan household gasoline demand by using monthly household-level data from the official statistical databases of the ministries of the Interior, Transportation and Communications, and Economic Affairs. The data are presented as a longitudinal dataset which includes 177 periods (January 2001 to September 2015) and 20 regions (20 administrative divisions of Taiwan).[1] As we restrict our attention to household-level data, some variables are compiled as household-level variables. For compiling some of the collected data into household-based format, we collect monthly data for the number of households at regional level. The compiling dataset is comprised of 3540 observations.

Data on gasoline consumption across 20 Taiwan administrative regions and the relevant price of gasoline are directly collected from the Bureau of Energy, Ministry of Economic Affairs. The retail gasoline price is identical across the 20 regions and has been recorded weekly by the Bureau of Energy, and we compile weekly price data for each calendar month. Gasoline-consumption patterns are collected as monthly and regional data, and we also compile consumption data into a household-level dataset.

Data on household income refers to annual household disposable income from 2001 to 2015, and we divide this figure by 12 months to obtain monthly household disposable income. As identical monthly household disposable income data are presented, to accommodate slight variations in household disposable income we observe the monthly consumer price index to generate monthly household real disposable income.

Data on the numbers of registered cars and motorcycles and licensed drivers are gathered from the statistical database of the Ministry of Transportation and Communications. Given our restriction to household-based information, these three variables are reformed as household-level data. However, there are missing values in the data relating to number of licensed drivers. We use the linear interpolation method to fill in missing values in the

[1]The data source and Taiwan administrative map are shown in Appendices 4.G and 4.E.

time-series.

A key objective of this study is to determine whether future conduct information sharing generated by the price adjustment formula delivers an impact on household gasoline demand. Given this objective, some dummy variables need to be constructed and used in our econometric methods. These dummy variables[2] are:

(i) PAF_t is a dummy for the government's regulatory policy, the price adjustment formula ($= 1$ if the price adjustment formula is implemented at time t, and $= 0$ otherwise),

(ii) $PositiveChange_t$ is a dummy for current conduct information sharing of price increase ($= 1$ if retail gasoline price at time t is greater than at time $t-1$, and $= 0$ otherwise) and $NegativeChange_t$ is a dummy for current conduct information sharing of price decrease ($= 1$ if retail gasoline price at time t is less than at time $t-1$, and $= 0$ otherwise),

(iii) $PositiveChange_{t+1}$ is a dummy for expected positive price change ($= 1$ if retail gasoline price at time $t+1$ is greater than at time t, and $= 0$ otherwise) and $NegativeChange_{t+1}$ is a dummy for expected negative price change of price decrease ($= 1$ if retail gasoline price at time $t+1$ is less than at time t, and $= 0$ otherwise).

In particular, to identify the availability of future conduct information sharing to households, we define future conduct information sharing as the interaction term of the price adjustment formula and expected price-change information which is written as

(iv) $PAF_{t+1} \times PositiveChange_{t+1}$ is a dummy ($= 1$ if future positive price change information is available, and $= 0$ otherwise) and $PAF_{t+1} \times NegativeChange_{t+1}$ is a dummy ($= 1$ if future negative price change information is available, and $= 0$ otherwise).

Monthly effects are included in our models. Monthly effects capture whether households display different consumer behavior in each month, thus taking into account holiday periods

[2]Dummy variable setting is detailed in Appendix 4.B.

such as Chinese New Year in February, Dragon Boat Festival in June, Mid-Autumn Festival in September and students' summer vacations during July and August. For testing the possibility of endogeneity, we use cost variables as instrumental variables. The cost variables used are crude oil Dubai and Brent prices, which are valued by the U.S. dollar (USD), and the exchange rate for the US dollar to Taiwan New dollar (TWD).

In using a time-series dataset, trend should be considered. Trend would result in non-stationary data which would produce spurious estimated results. In order to obtain reliable results and meet the assumption of stationarity, we detrend the time-series dataset. Finally, for the data described in this section and used in this empirical study, we summarize the description of data in table 4.1 and report descriptive statistics of the 20 administrative regions in table 4.A.1 in Appendix 4.A.

Table 4.1: Variable Description

Variable	Description
$p^{gasoline}$	Retail gasoline price (TWD/liter)
p^{Dubai}	Spot price of Dubai crude oil (USD/barrel)
p^{Brent}	Spot price of Brent crude oil (USD/barrel)
p^{crude}	Weighted crude oil price (USD/barrel)
$e^{USD-TWD}$	Exchange rate for the US dollar to Taiwan New dollar
$hgas$	Household gasoline consumption (liter)
$hrealhdi$	Real household disposable income (TWD)
$hnrc$	Household the number of registered cars
$hnrm$	Household the number of registered motorcycles
$hnld$	Household the number of licensed drivers
PAF	Government's policy - the price adjustment formula
$PositiveChange$	Positive price change
$NegativeChange$	Negative price change

Note: p^{crude} is the weighted crude oil price (Dubai: 70% and Brent: 30%) and is based on the procedure of the price adjustment formula. USD: US Dollar. TWD: Taiwan New Dollar.

4.4 Econometric Methods and Results

In general, parametric models could provide a constant price elasticity to interpret the relationship between gasoline consumption and gasoline price. However, constant price elasticity cannot reflect a dynamic response of household gasoline consumption across price level. Also, constant price elasticity of gasoline demand is estimated by using a predetermined relationship between gasoline consumption and gasoline price. This predetermined relationship may present with the possibility of misspecification. To reduce the possibility of misspecification and to obtain a dynamic responsiveness of consumption to price, a nonparametric functional form is necessarily involved in the econometric modeling of this study.

In this chapter, we investigate household demand in two aspects, the panel of 20 regions and an individual region. In accordance with above two aspects, we will apply two different econometric frameworks. In the panel of 20 regions view, we begin by using panel data framework to specify gasoline demand for household. One of advantages of using panel data model is that parameter(s) can be efficiently estimated with the simple computation (Hsiao, 2007). A semiparametric panel data fixed effects model is appropriate to estimate household gasoline demand in the panel of 20 regions. However, the panel data estimation implies the same parameters and nonparametric form for each region, which would not be reasonably accurate to infer the household demand for each independent region. For example, the mix of urban and rural environments is incorporated into the groups, and this mix impacts upon the ability to accurately estimate the level of household demand.

To remove this limitation of a mix of urban and rural environments, we model individual regional household demand. We turn to an individual regional household demand and use semiparametric difference-based model to independently estimate for each individual region. The advantages of using the difference-based model are that: (i) it simplifies computation to obtain parametric and nonparametric estimation; (ii) it can generate efficient estimator in the semiparametric model (Yatchew, 2003). In accordance with above advantages, the difference-based model is more efficient estimation method to infer household gasoline demand for each individual region. Hence, the independent estimation of household demand for each individual region can be appropriate and accurate via using the difference-based model. These two estimation methods will enable us to discuss household demand from two different aspects, the panel of regions and each independent region.

As addressed above, we attempt to model household gasoline demand with Taiwanese data by using semiparametric approaches. We take two semiparametric models as follows: (i) a fixed-effects model with cross-regional data and (ii) the difference-based model with a single regional household data across six specific municipalities in Taiwan.[3] Given these two semiparametric approaches, gasoline price is chosen as the nonparametric variable, and so the dynamic responsiveness of consumption to price can be generated by nonparametric estimate. Parametric factors include household disposable income, the numbers of registered vehicles and licensed drivers, monthly dummies and information sharing of current and future conduct. These factors are simply obtained by parametric estimate, and the relationship between consumption and these factors is easily interpreted. In particular, the inclusion of future conduct information sharing enables examination of how the government's regulatory policy affects gasoline demand for households across regions.

This study also takes into consideration the possibility of endogeneity of gasoline price. It is well known that price and quantity may be related via a supply-side response, so the error term in the demand equation may be correlated with gasoline price. This correlation between error term and gasoline price would result in a biased estimate of price elasticity. If this consideration were not to be involved in our econometric framework, biased and inconsistent results might be estimated in relation to price endogeneity. Hence, the test of endogenous gasoline price is necessary, and is introduced in the following section.

Prior to carrying out the semiparametric estimation, we provide basic econometric modeling ideas regarding the fixed-effects model, the difference-based model and the test of endogeneity. These econometric modeling ideas allow us to understand how the econometric models, introduced in sections 4.4.1.1, 4.4.2.1 and 4.4.4 respectively, work in this study.

In sections 4.4.1 and 4.4.2 the specification and estimation of the semiparametric fixed-effects model and Yatchew's difference-based semiparametric model are presented; the monthly effects on gasoline demand for households are discussed and depicted in section 4.4.3; and finally the test of gasoline price endogeneity is discussed in section 4.4.4.

[3]The six specific municipalities are Taipei City, New Taipei City, Taichung City, Tainan City, Kaohsiung City and Taoyuan City, in each of which population is above 1.5 million.

4.4.1 Specification and Estimation of the Semiparametric Fixed-effects Model

4.4.1.1 Specification of the Fixed-effects Model

In this chapter, we consider the semiparametric fixed-effects model, and its functional form is defined as

$$y_{i,t} = x_{i,t}\beta + f(z_{i,t}) + \alpha_i + u_{i,t}, \quad i = 1, \ldots, N; \quad t = 1, \ldots, T, \tag{4.4.1}$$

where $y_{i,t}$ is a dependent variable, $x_{i,t}$ is a vector of explanatory variables and $z_{i,t}$is a non-parametric variable, α_i represents fixed effects, and $u_{i,t}$is an error term which also assumes $E[u|x, z] = 0$.

We follow the series estimation method of Balgati and Li (2002) to estimate our panel data model with fixed effects. We start to eliminate the fixed effects by using first differencing, and equation (4.4.1) is rewritten as

$$y_{i,t} - y_{i,t-1} = (x_{i,t} - x_{i,t-1})\beta + [f(z_{i,t}) - f(z_{i,t-1})] + \varepsilon_{i,t} - u_{i,t-1}, \tag{4.4.2}$$

or is as follows

$$Y_{i,t} = X_{i,t}\beta + F(z_{i,t}, z_{i,t-1}) + U_{i,t}, \tag{4.4.3}$$

where $Y_{it} = y_{i,t} - y_{i,t-1}$, $X_{it} = x_{i,t} - x_{i,t-1}$, $F(x_{i,t}, x_{i,t-1}) = f(z_{i,t}) - f(z_{i,t-1})$, and $U_{i,t} = u_{i,t} - u_{i,t-1}$.

Since an additive nonparametric function, $F(z_{i,t}, z_{i,t-1}))$, is generated in equation (4.4.3), we can meet difficulties in estimating the unknown additive nonparametric function. As in the series estimation method proposed by Balgati and Li (2002), we use series $p^K(z)$ to approximate unknown nonparametric function, $f(z)$ and an additive nonparametric function, $F(z_{i,t}, z_{i,t-1})$, is approximated as $p^K(z_{i,t}, z_{i,t-1}) = p^K(z_{i,t}) - p^K(z_{i,t-1})$. Therefore, equation (4.4.3) is rewritten as

$$Y_{i,t} = X_{i,t}\beta + [p^K(z_{i,t}) - p^K(z_{i,t-1})]\theta + U_{i,t} \tag{4.4.4}$$

and parameters, $\hat{\beta}$ and $\hat{\theta}$, can be estimated by using ordinary least squares. The fixed effects, $\hat{\alpha_i}$, can be obtained by using estimated parameters, $\hat{\beta}$ and $\hat{\theta}$, and we could estimate the error term as

$$u_{i,t} = y_{i,t} - x_{i,t}\hat{\beta} - \hat{\alpha_i} = f(z_{i,t}) + \varepsilon_{i,t}. \tag{4.4.5}$$

Equation (4.4.5) can be estimated by using a standard nonparametric regression estimator, such as the B-spline method (Libois and Verardi, 2013).

4.4.1.2 Estimation of the Fixed-effects Model

Having presented a description of a semiparametric fixed-effects model in section 4.4.1.1, we recall equation (4.4.1) and summarize our household gasoline demand in a semiparametric regression equation which is as follows:

$$\begin{aligned}\ln hgas_{i,t} = f(\ln p_t^{gasoline}) &+ \beta_1 \ln hrealhdi_{i,t} + \beta_2 \ln hnrc_{i,t} + \beta_3 \ln hnrm_{i,t} \\ &+ \beta_4 \ln hnld_{i,t} + \beta_5 PositiveChange_t + \beta_6 NegativeChange_t \\ &+ \beta_7 PAF_{t+1} \times PositiveChange_{t+1} + \beta_8 PAF_{t+1} \times NegativeChange_{t+1} \\ &+ \theta MonthDummies + \varepsilon_{i,t}, \end{aligned} \tag{4.4.6}$$

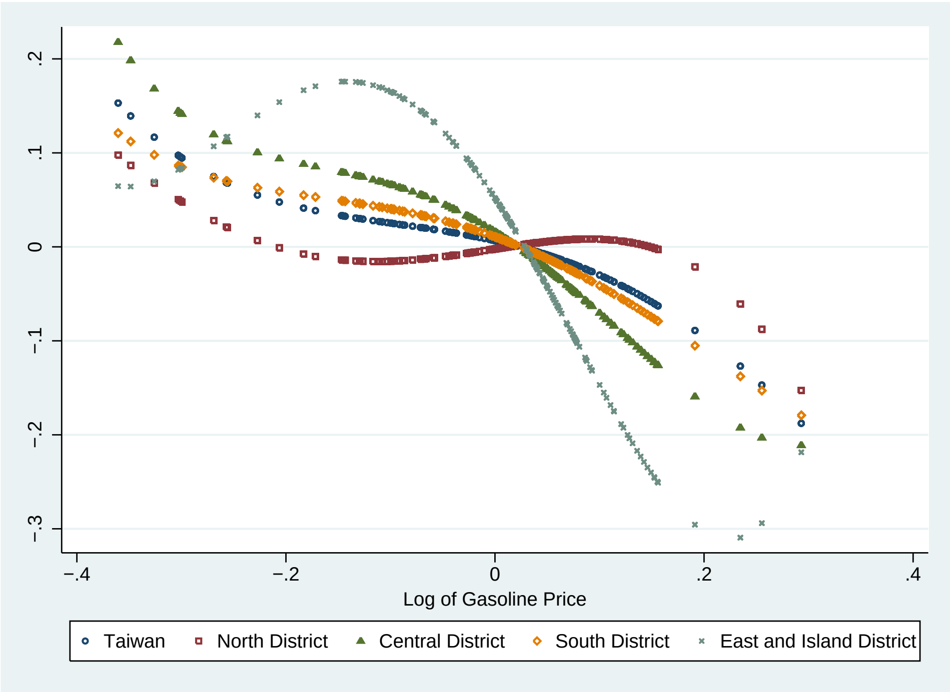
where $\ln hgas_{i,t}$ is the log of household gasoline consumption in region i at period t, $\ln p_t^{gasoline}$ is the log of an identical gasoline price at period t, $\ln hrealhdi_{i,t}$ is the log of real household disposable income in region i at period t, $\ln hnrc_{i,t}$ and $\ln hnrm_{i,t}$ are logs of the numbers of registered cars and motorcycles in region i at period t, $\ln hnld_{i,t}$ is the log of the number of licensed drivers in region i at period t, $PositiveChange_t$ and $NegativeChange_t$ denote current conduct price information sharing to households, $PAF_{t+1} \times PositiveChange_{t+1}$ and

$PAF_{t+1} \times NegativeChange_{t+1}$ are the interaction terms between PAF and future price-change information and are defined as future conduct information sharing to households, $MonthDummies$ are monthly effects, and $\varepsilon_{i,t}$ is an error term.

Equation 4.4.6 is the semiparametric specification of gasoline demand for households. We assume that household gasoline demand is a function of gasoline price, household income, the numbers of registered vehicles and licensed drivers, information sharing components, and monthly effects. In particular, we accommodate gasoline price as a nonparametric variable. Nonparametric gasoline price can deliver dynamic rather than constant price elasticity, which allows us to explore how the price elasticity varies with gasoline price. Moreover, as the price adjustment formula constitutes unilateral information sharing to the public, we assume the price adjustment formula is the information-sharing component in gasoline demand. We suppose that an interaction term between the introduction of the price adjustment formula and future price-change information serves as future conduct information sharing. Because consumers are able to fully anticipate the new retail price via the introduction of the price adjustment formula, they will decide to consume more or less gasoline in the current period. Also, current conduct information sharing is taken into account as a simple comparison between current and previous prices. We suppose that variation in household income will affect household gasoline demand. Additionally, some demographic effects, such as the numbers of registered vehicles and licensed drivers per household, are included in household gasoline demand. Finally, due to the inclusion of seasonality in household gasoline demand, monthly effects are included in our model and discussed.

In our semiparametric panel data fixed-effects model, described in equation (4.4.6), we follow the approach of Balgati and Li (2002) in estimating household demand for gasoline. We begin to categorize 20 Taiwan administrative regions into four districts, North, Central, South, and East and Island, and define characteristics of these four districts. First, the North district contains the Greater Taipei metropolitan area and Hsinchu Science Park, and we therefore characterize it as urban and the richest district. Second, as the South district contains two of the high-population specific municipalities and four suburban counties, we defined it as the second-richest district. Third, the Central district contains one of the specific municipalities and three suburban counties, and is therefore characterized as the third-richest district. Finally, due to a lack of public infrastructure and low population density, the East and Island district is characterized as a poor and rural area.

We now turn to semiparametric estimation. The semiparametric estimates of equation (4.4.6) are presented in figure 4.1 for nonparametric variables and in table 4.1 for parametric variables. Given equation (4.4.5) and the B-spline method, nonparametric estimates of price effect are depicted in figure 4.1. Figure 4.1 displays nonparametric price effects in four regions (North: red; Central: green; South: yellow; East and Island: teal) and Taiwan across all 20 regions (Taiwan: blue). The horizontal axis represents the log of gasoline price and the vertical axis represents the residual, which corresponds to household gasoline consumption. Figure 4.1 represents the sensitivity of price effect for households. As price effect is depicted in figure 4.1, we find: (i) less sensitivity of price effect in the North district; (ii) more sensitivity of price effect in the East and Island district and (iii) medium level of sensitivity of price effect in the Central and South districts and Taiwan. In accordance with these findings, we conclude that there seems to be inelastic household gasoline demand in the urban North, South and Central districts, but elastic demand in the rural area East and Island district.



Note: Nonparametric price effect is estimated using equation (4.4.5). The horizontal axis represents log of gasoline price and the vertical axis represents the residual which corresponds to household gasoline consumption.

Figure 4.1: Nonparametric Price Effect in Fixed Effects Model

In returning to the estimated results of parametric variables in table 4.1, where the estimated monthly effects are plotted in figure 4.3 in section 4.4.3, we find that income elasticities are negative in the household demand of Taiwan and four districts. This result is consistent with similar findings in the existing literature (see Judson, Schmalensee and Stoker, 1990; Wadud, Noland and Graham, 2010), and it also suggests that in the case of the Taiwan gasoline market, households display a reduction in gasoline consumption when their incomes increase. Households may be willing to change to more luxurious or public substitutes (for example, from car travel to air travel or from private transport to public transport). Second, the number of registered motorcycles is strongly significant in the Central and South districts. That indicates that household gasoline demand would rise by approximately 1.85% in the Central district and 1.1% in the South district if the number of registered motorcycles increases by 1%.

In the final part of this analysis, we restrict our attention to consumer price expectation through the effects of the sharing of current and future conduct price information. First, table 4.1 reports the effect of current conduct positive price-change information sharing for households in each district and in Taiwan as a whole, where generally household gasoline consumption falls by around 1% if households receive current positive change information. In particular, the East and Island district displays a significantly greater effect from such information than the other three districts. The coefficients of current conduct negative price-change information in table 4.1 indicate that household gasoline consumption would gradually rise if current conduct negative price-change information is received. The analysis of current conduct information sharing confirms that in general all households increase (decrease) household gasoline consumption if current conduct negative (positive) information is available.

Second, the coefficients for the sharing of future conduct information show that future conduct negative price information is significant in decreasing current household gasoline consumption. Current household gasoline consumption would fall by approximately 5% if future conduct negative price-change information is transparent to consumers. This finding indicates that consumers would become more patient in their gasoline-consumption behavior if future conduct information is disclosed publicly to consumers.

The results reported in this empirical exercise suggest that current conduct positive price-change information, obtained from a price comparison between current and previous periods, and future conduct negative price-change information, as publicly disseminated through the government's transparent price policy, would result in significant decreases in current household gasoline consumption. In particular, future conduct information sharing offers intertemporal substitution opportunities to households planning their future purchases.

Table 4.1: Semiparametric Estimates of Fixed Effects Model

District	Taiwan	North	Central	South	East and Island
Dependent Variable	Log of Household Gasoline Consumption				
Period	All Periods				
Log of Real Household Disposable Income	-0.172**	-0.170*	-0.161	-0.301**	-0.096
	(0.072)	(0.092)	(0.196)	(0.125)	(0.206)
Log of # of Registered Cars/Per Household	1.359**	0.884	2.390	1.849	2.509
	(0.660)	(0.760)	(1.928)	(1.231)	(2.014)
Log of # of Registered Motorcycles/Per Household	1.039***	0.311	1.845**	1.104**	0.654
	(0.321)	(0.443)	(0.754)	(0.493)	(1.092)
Log of # of Licensed Drivers/Per Household	0.188*	0.069	0.200	0.594	-2.804
	(0.113)	(0.237)	(0.133)	(0.412)	(1.915)
Current Conduct Information Sharing					
Positive Change	-0.016***	-0.013**	-0.007	-0.016**	-0.036**
	(0.005)	(0.005)	(0.011)	(0.007)	(0.018)
Negative Change	0.009*	0.005	0.025**	0.010	-0.007
	(0.005)	(0.006)	(0.011)	(0.008)	(0.019)
Future Conduct Information Sharing					
PAF×Positive Change	-0.013	-0.016	-0.027	-0.017	0.015
	(0.012)	(0.015)	(0.029)	(0.020)	(0.047)
PAF×Negative Change	-0.059***	-0.048***	-0.080***	-0.064***	-0.052
	(0.012)	(0.015)	(0.029)	(0.020)	(0.047)
Monthly Effects	-	-	-	-	-
Observations	3462	1218	696	1044	504
R^2	0.268	0.427	0.285	0.302	0.283

Note: All 20 administrative regions are grouped for this study into four districts, North, South, Central, and East and Island. North district includes Taipei City, New Taipei City, Taoyuan City, Yilan County, Hsinchu County, Hsinchu City and Keelung City. Central district includes Taichung City, Miaoli County, Changhua County, and Nantou County. South district includes Tainan City, Kaohsiung City, Yulin County, Chiayi County, Chiayi City, and Pingtung County. East and Island district includes Taitung County, Hualien County and Penghu County. For monthly effects, see figure 4.3 in section 4.4.3. Standard errors are presented in parentheses. *** Statistically significant level at 0.01, ** statistically significant level at 0.05 and * statistically significant level at 0.1.

4.4.2 Specification and Estimation of the Semiparametric Difference-Based Model

4.4.2.1 Specification of the Difference-Based Model

We now turn to individual regional analysis. For estimating individual regional household gasoline demand, we use Yatchew's difference-based estimation technique (Yatchew and No, 2001; Yatchew, 2003). To begin this section, the standard specification of semiparametric model is written as

$$y = f(z) + x\beta + \varepsilon \text{ with } E[\varepsilon|x, z] = 0, \tag{4.4.7}$$

where y denotes a dependent variable, x denotes a vector of explanatory variables, z denotes an explanatory variable, $f(\bullet)$ denotes an unknown smoothed function, ε denotes an error term with $E[\varepsilon|x, z = 0]$ and $Var[\varepsilon|x, z] = \sigma_\varepsilon$.

In following Yatchew's semiparametric differencing technique (2003), we apply a differencing matrix, D, into the above semiparametric regression function, equation (4.4.7), to remove nonparametric smoothed function.[4] Then, we have

$$Dy = Dx\beta + Df(z) + D\varepsilon \cong Dx\beta + D\varepsilon. \tag{4.4.8}$$

As a basic semiparametric regression function has been reformed as equation (4.4.8), we could use ordinary least squares to estimate parameter, $\hat{\beta}_{diff}$. As $\hat{\beta}_{diff}$ is estimated, we use $\hat{\beta}_{diff}$ to subtract parametric variables in equation (4.4.7). Then, we obtain

$$y - x\hat{\beta}_{diff} = x(\beta - \hat{\beta}_{diff}) + f(z) + \varepsilon \cong f(z) + \varepsilon. \tag{4.4.9}$$

[4] Yatchew (2003) proposes the higher order of differencing procedures to estimate the partial linear model. He supposes that m is the order of differencing and $d_0, d_1, \ldots, d_m$ are differencing weights which satisfy conditions as $\sum_{i=0}^{m} d_i = 0$ and $\sum_{i=0}^{m} d_i^2 = 1$. As these conditions are restricted, the differencing matrix can be defined. Yatchew's optimal differencing weights are shown in Appendix 4.F.

Given equation (4.4.9), we could estimate an unknown smoothed function by using the standard nonparametric method.

4.4.2.2 Estimation of the Difference-Based Model

We compare findings of the fixed-effects model with the difference-based model described in section 4.4.2.1. Compared with the fixed-effects model, the difference-based model is able to provide consistent evidence that gasoline demand for households at individual region level varies with the availability of future conduct information sharing. For a comparison between fixed-effects estimates and individual regional estimates, we apply Yatchew's higher order differencing technique (Yatchew and No, 2001; Yatchew 2003) to estimate individual regional household gasoline demand and use the same variable setting as in the fixed-effects model for exploring consistent evidence. Given equation (4.4.7) in section 4.4.2.1, an individual regional semiparametric specification of household gasoline demand is as follows

$$\begin{aligned} \ln hgas_t = f(\ln p_t^{gasoline}) &+ \phi_1 \ln hrealhdi_t + \phi_2 \ln hnrc_t + \phi_3 \ln hnrm_t \\ &+ \phi_4 \ln hnld_t + \phi_5 PositiveChange_t + \phi_6 NegativeChange_t \\ &+ \phi_7 PAF_{t+1} \times PositiveChange_{t+1} + \phi_8 PAF_{t+1} \times NegativeChange_{t+1} \\ &+ \gamma MonthDummies + \varepsilon_t, \end{aligned} \tag{4.4.10}$$

where $\ln hgas_t$ is the log of household gasoline consumption at period t, $\ln p_t^{gasoline}$ is the log of an identical gasoline price at period t, $\ln hrealhdi_t$ is the log of real household disposable income at period t, $\ln hnrc_t$ and $\ln hnrm_t$ are logs of the numbers of registered cars and motorcycles at period t, $\ln hnld_t$ is the log of the number of licensed drivers at period t, $PositiveChange_t$ and $NegativeChange_t$ denote current conduct price information sharing to households, $PAF_{t+1} \times PositiveChange_{t+1}$ and $PAF_{t+1} \times NegativeChange_{t+1})$ are the interaction terms between PAF and future price-change information and is defined as future conduct information sharing to households, $MonthDummies$ are monthly effects, and ε_t is the error term.

We follow Yatchew's difference-based estimation method procedure of difference-based estimation, as described in section 4.4.2.1 (Yatchew and No, 2001; Yatchew, 2003). Yatchew (2003) emphasizes that the estimator would be asymptotically efficient if the order of differencing (m) and sample size increase, and states that the estimator has a relative efficiency of 95 percent if the order of differencing is at 10, $m = 10$. However, Lokshin (2006) demonstrates that Yatchew's difference-based estimation in the Monte Carlo simulations with large sample size (30,000 observations or more) would obtain efficient estimation if using a higher order of differencing ($m = 10$), but with a small sample size (between 1000 and 3000 observations) would lead to biased estimates. Since our sample size is 177 observations in each individual region, we use the first order differencing throughout this section to avoid the occurrence of biased estimates.

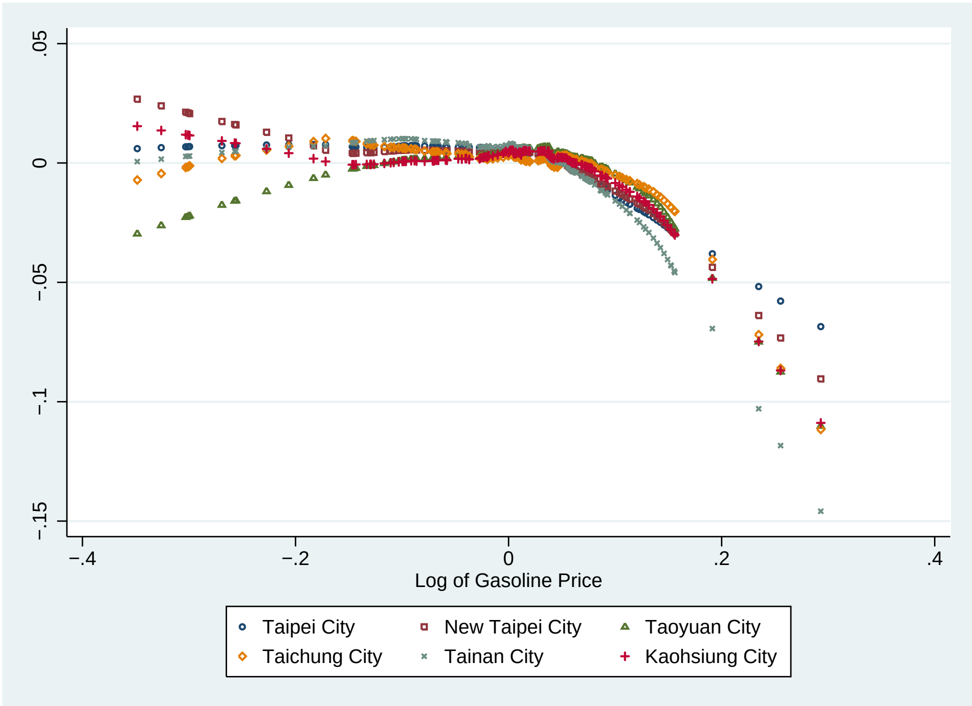
This empirical exercise uses a difference-based model to estimate household gasoline demand in six specific municipalities: Taipei City, New Taipei City, Taoyuan City, Taichung City, Tainan City and Kaohsiung City. Since these six municipalities contain two thirds of the total population of Taiwan, they are deemed to be representative selections for this exercise.[5] According to the general grant from the central government, these six municipalities are classified into six grades of economic prosperity: 1^{st} richest Taipei City, 2^{nd} richest New Taipei, 3^{rd} richest Kaohsiung City, 4^{th} richest Taichung City, 5^{th} richest Tainan City and 6^{th} richest Taoyuan City.[6] Semiparametric estimates of equation (4.4.10) are shown in figure 4.2 and reported in table 4.2.

Given equation (4.4.9), nonparametric price effects are depicted in figure 4.2. The horizontal axis represents the log of gasoline price and the vertical axis represents the residual which corresponds to household gasoline consumption. Figure 4.2 shows nonparametric price effects for the six municipalities and indicates that household demand for gasoline is inelastic

[5]Total population of the six municipalities is approximately 15.8 million (Taipei City: 2.7 million, New Taipei City: 3.9 million, Taichung City: 2.7 million, Tainan City: 1.8 million, Kaohsiung City: 2.7 million and Taoyuan City: 2 million). The total population of Taiwan is approximately 23.3 million.

[6]According to a report of the general grant to local government, amounts of general grant from the central government are reported as: Taipei City NT$39.648 billion, New Taipei City NT$29.071 billion, Kaohsiung City NT$27.962 billion, Taichung City NT$24.205 billion, Tainan City NT$18.757 billion, Taoyuan City NT$18.664 billion.

if a lower retail gasoline price is charged; in contrast, household demand for gasoline is elastic if households face a higher retail gasoline price. Furthermore, figure 4.2 also shows that the richest city has the most inelastic household demand for gasoline. We proceed to test the significance of the nonparametric gasoline price effect. The significance test presented at the foot of table 4.2 suggests that nonparametric estimates in price effect are appropriate to describe the relationship between gasoline consumption and gasoline price in five municipalities: Taipei, New Taipei, Taoyuan, Tainan and Kaohsiung.



Note: Nonparametric price effects are estimated using equation (4.4.9). The horizontal axis represents the log of gasoline price and the vertical axis represents the residual which corresponds to household gasoline consumption. The significance test of nonparametric price effect is reported in table 4.2.

Figure 4.2: Nonparametric Price Effect in the Six Specified Municipalities

We return to parametric estimates of equation (4.4.10) in table 4.2 in which the estimated monthly effects are depicted in figure 4.4 in section 4.4. Negative income elasticity in the six municipalities is consistent with our previous finding in the semiparametric fixed-effects model. In the richest regions, households seem to consume less gasoline, possibly because of substitution from using private vehicles to using public transportation. The number of registered cars is strongly significant except for Taipei City. In the other five cities, an increase in the number of registered cars delivers a growth in household gasoline consumption. A growth in the number of registered motorcycles results in a reduction in household consumption of gasoline in Taipei City. Our estimates of the number of licensed drivers suggest that an increase in the number of licensed drivers causes a decrease in household gasoline consumption in the Greater Taipei metropolitan area (Taipei City, New Taipei City and Taoyuan City) and a growth in household gasoline consumption in the other three cities (Taichung City, Tainan City and Kaohsiung City). Because of the efficient public transportation infrastructure and lack of parking spaces in the Greater Taipei metropolitan area, increases in numbers of licensed drivers would not boost household gasoline consumption.

Again, we limit our attention to the effects of information sharing for current and future conduct. Current conduct positive (negative) price-change information sharing is not significant in affecting household demand for gasoline; in contrast, future conduct negative price-change information is significant in resulting in decreases in current household consumption for gasoline, except in Taichung City. Our estimates provide evidence of a negative effect of future conduct negative price-change information sharing on current household consumption of gasoline, and this evidence is consistent with previous evidence of intertemporal substitution found in section 4.4.1.2.

Table 4.2: Household Gasoline Demand in Six Special Municipalities

Region	Taipei City	New Taipei City	Taoyuan City	Taichung City	Tainan City	Kaohsiung City
Dependent Variable	Household Gasoline Consumption					
Period	All Periods					
Log of Real Household Disposable Income	-0.207	-0.364	-0.114	-0.232	-0.041	-0.467**
	(0.174)	(0.224)	(0.166)	(0.221)	(0.151)	(0.220)
Log of # of Registered Cars/Per Household	0.209**	0.884***	0.829***	1.533***	1.330***	0.990***
	(0.095)	(0.318)	(0.204)	(0.430)	(0.227)	(0.238)
Log of # of Registered Motorcycles/Per Household	-0.170**	0.070	-0.505*	0.094	0.103	-0.116
	(0.074)	(0.295)	(0.280)	(0.368)	(0.152)	(0.148)
Log of # of Licensed Drivers/Per Household	-0.416***	-0.322	-0.108	0.434	0.562**	0.106
	(0.140)	(0.397)	(0.143)	(0.294)	(0.217)	(0.145)
Current Conduct Information Sharing						
Positive Change	-0.008	-0.011	-0.015	0.017	-0.012	-0.010
	(0.009)	(0.013)	(0.016)	(0.026)	(0.017)	(0.015)
Negative Change	-0.000	-0.009	-0.007	0.030	-0.002	-0.004
	(0.009)	(0.013)	(0.016)	(0.027)	(0.017)	(0.015)
Future Conduct Information Sharing						
PAF×Positive Change	-0.032***	-0.014	-0.029	-0.011	-0.025	-0.006
	(0.010)	(0.013)	(0.018)	(0.027)	(0.017)	(0.021)
PAF×Negative Change	-0.040***	-0.029**	-0.062***	-0.041	-0.059***	-0.042*
	(0.011)	(0.015)	(0.018)	(0.028)	(0.018)	(0.022)
Monthly Effects	-	-	-	-	-	-
Observations	174	174	174	174	174	174
R^2	0.852	0.784	0.701	0.314	0.535	0.626
Significance Test for Price Effect						
V_{stat}	5.059	3.231	2.218	0.632	2.968	2.695
$p-value$	0.000	0.001	0.013	0.264	0.001	0.004

Note: Significant test of nonparametric price effect is based on Yatchew's significance test procedure (2003). Significance Test statistic as follows $V_{stat} = (m \times n)^{1/2}\frac{(s^2_{nopeffect} - s^2_{diff})}{s^2_{diff}} \xrightarrow{D} N(0,1)$, where m denotes the order of differencing, n denotes sample size, $s^2_{nopeffect}$ denotes the estimator of the residual variance without price effect, s^2_{diff} denotes the m-th order differencing estimator of the residual variance. For more details, see Proposition 4.3.1, Yatchew (2003). For monthly effects, see figure 4.4 in section 4.4.3. Standard errors are presented in parentheses. *** Statistically significant level at 0.01, ** statistically significant level at 0.05 and * statistically significant level at 0.1.

4.4.3 Monthly Effects

Since gasoline consumption for households typically shows seasonal variation, studying seasonality allows us to investigate whether household gasoline consumption varies with seasonal patterns. These seasonal patterns include national holidays and students' summer vacations, i.e. Chinese New Year (February), Boat Festival (June), Mid-Autumn Festival (September) and students' longest break, which occurs in the summer (July and August). Therefore, we add monthly dummies in both the fixed-effects model and the difference-based model, and estimated monthly effects are plotted in figures 4.3 and 4.4.[7]

Figure 4.3 depicts the estimated monthly effects in the semiparametric fixed-effects model and shows that the North, Central, and South districts have similar monthly effects on household demand for gasoline, while the East and Island district has obvious monthly variations in gasoline consumption. Peak gasoline consumption occurs during July and August due to the summer holiday period. The estimated February effect shows that households in the North district reduce their gasoline consumption by roughly 10%. Short-term reduction in gasoline consumption in the North district happens during the Chinese New Year celebration in February since households celebrate Chinese New Year with family in the Central, South and East and Island districts. In consequence, the Chinese New Year celebration in February results in short-term increases in gasoline consumption in the Central, South and East and Island district. Although both Dragon Boat and Mid-Autumn festivals are celebrated in June and September, there are no obvious increases in gasoline consumption in these months during these two festivals. Comparatively speaking, the monthly effect in rural and poor districts is greater, and differs from the other three richer districts.

Returning to the semiparametric difference-based model, Figure 4.4 displays that the six specified municipalities have similar estimated monthly effects. However, households who live in the Greater Taipei metropolitan area (Taipei City, New Taipei City and Taoyuan City)

[7]The monthly dummies of semiparametric difference-based model of remaining 14 regions are plotted in figures 4.D.2 in Appendix 4.D.

consume 10% less gasoline in February because many of these households celebrate Chinese New Year in their parents' native homes located in central or southern Taiwan.[8]

The estimates of the monthly effects from equations (4.4.6) and (4.4.10) present a consistent finding about obvious reduction in gasoline consumption in February in the northern parts of Taiwan, and also identify that the monthly effects on gasoline consumption would lessen if a region becomes more urbanized.[9]

[8]The estimated monthly effects of the remaining 14 regions are graphically shown in figure 4.D.2, and we find that Hsinchu County, Hsinchu City and Keelung City also have similar estimated February effects.

[9]The estimated monthly effects of the remaining 14 regions in figure 4.D.2 also show that Taitung County, Hualien County and Penghu County have dramatic monthly variations in household gasoline consumption.

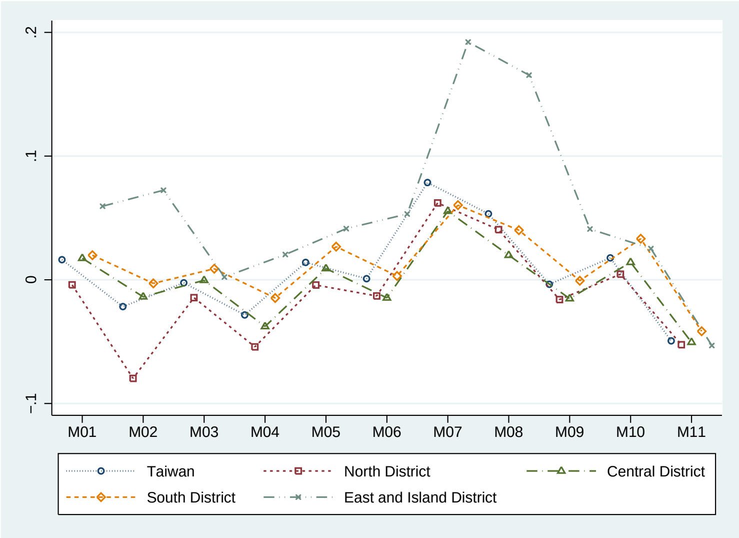


Figure 4.3: Monthly Effects in Fixed Effects Model

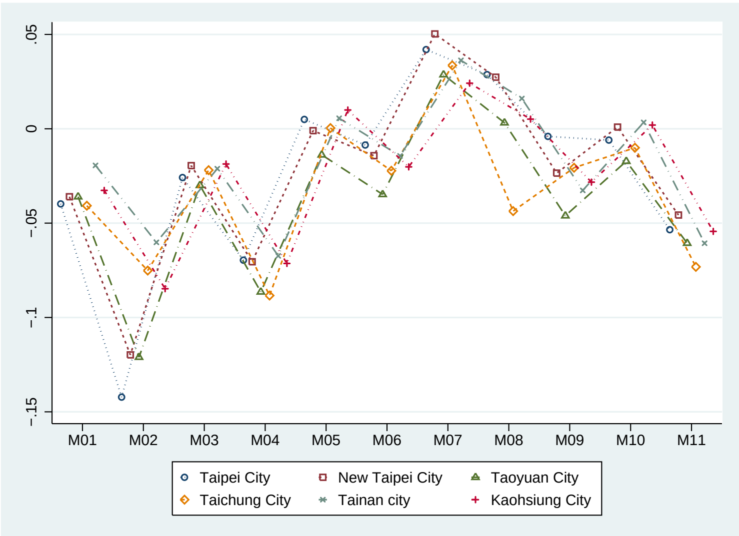


Figure 4.4: Monthly Effects in Six Special Municipalities

4.4.4 Endogeneity

As a concern about the possibility of endogeneity of nonparametric variable is discussed by existing studies in adopting semiparametric and nonparametric regression methods, we begin to introduce a standard semiparametric specification, and then assume that a nonparametric variable, z, is endogenous. The functional form is written as

$$y = f(z) + x\beta + \varepsilon \text{ with } E[\varepsilon|z] \neq 0. \tag{4.4.11}$$

Therefore, we follow the approach of correcting endogeneity in estimating the semiparametric regression model which has been described in several studies by Blundell and Duncan (1998), Blundell et al. (1998), Yatchew and No (2001) and Yatchew (2003). In the case of the endogeneity of z, there exists an instrumental variable, w, which is uncorrelated with the residual such that

$$z = w\gamma + \nu \text{ with } E[\nu|w] = 0. \tag{4.4.12}$$

Then, we add the residual of equation (4.4.12), ν, into equation (4.4.11), and a new semiparametric model is as follows

$$y = f(z) + x\beta + \rho\nu + \varepsilon \text{ with } E[\varepsilon|z, x, \nu] = 0, \tag{4.4.13}$$

where x is a vector of explanatory variables, z is a nonparametric variable, ν is the residual in the instrumental variable function from equation (4.4.12), and ε is an error term.

In the new semiparametric regression model shown in equation (4.4.13), we could estimate ρ to construct a test of exogeneity as null hypothesis $H_0 : \rho = 0$. If the estimated coefficient of the residual, $\hat{\rho}$, is significantly different from zero, then we could argue that endogeneity exists in our model.

4.4.4.1 Testing Endogeneity

Recalling equation (4.4.11) in section 4.4.4, we can test the null hypothesis that gasoline price is endogenous in our semiparametric model, equation (4.4.11). We follow the approach of correcting endogeneity to take the possibility of endogeneity into account. Yatchew and No (2001) and Manzan and Zerom (2010) use regional dummies as instrumental variables and Liu (2014) use three state-level instrumental variables, gasoline tax, the domestic oil first purchasing price and average gasoline price of nonadjacent states, to test possible price endogeneity. However, since gasoline price in Taiwan is identical, with identical petroleum product taxes across all 20 regions, we are be unable to use either regional dummies or regional-level variables such as gasoline tax as our instrumental variables. Hence, according to the procedure of the price adjustment formula, we use cost variables, crude oil price and exchange rate, as instrumental variables to examine whether retail gasoline price is endogenous.

We suppose retail gasoline price is endogenous and that there exist instrumental variables, crude oil price (p^{crude}) and exchange rate ($e^{USD-TWD}$), which are uncorrelated with the residual such that

$$\ln p_t^{gasoline} = \gamma_1 p_{t-1}^{crude} + \gamma_2 e_{t-1}^{USD-TWD} + \nu_t \text{ with } E[\nu | p^{crude}, e^{USD-TWD}] = 0, \tag{4.4.14}$$

where $p_t^{gasoline}$ is retail gasoline price at period t, p_{t-1}^{crude} is crude oil price at period $t-1$, $e_{t-1}^{USD-TWD}$ is the exchange rate for USD to TWD at period $t-1$, and ν denotes the residual.

Then, we rewrite our semiparametric models to include the residuals in equation (4.4.14), and new semiparametric models are given by

- Semiparametric fixed-effects model

$$\ln hgas_{i,t} = f(\ln p_t^{gasoline}) + x\beta + \rho\nu_{i,t} + \varepsilon_{i,t}, \tag{4.4.15}$$

and

- Semiparametric difference-based model

$$\ln hgas_t = f(\ln p_t^{gasoline}) + x\phi + \rho\nu_t + \varepsilon_t, \quad (4.4.16)$$

where $\ln hgas$ is the log of household gasoline consumption , $\ln p^{gasoline}$ is the log of an identical gasoline price, x is a vector of explanatory variables: the log of real household disposable income ($\ln hrealhdi$), the log of the number of registered cars and motorcycles ($\ln hnrc, \ln hnrm$), the log of the number of licensed drivers ($\ln hnld$), and dummy variables (*Current conduct information sharing, Future conduct information sharing, MonthDummies*). ν is the residuals in equation (4.4.14) and $E[\varepsilon | \ln p^{gasoline}, \nu, x] = 0$.

We estimate equations (4.4.15) and (4.4.16) by using Balgati and Li's approach (2002) for fixed-effects models and Yathchew's differencing technique (2003) for differenced-based models, and report parametric estimates in tables 4.3 and 4.4.[10] Recalling equation (4.4.13), we would fail to reject the null hypothesis as exogenous gasoline price if our estimated coefficient of residual, $\hat{\rho}$, is insignificantly different from zero. As the estimated parameter, $\hat{\rho}$, reports in tables 4.3 and 4.4, we are unable to reject the null hypothesis of exogenous gasoline price. This result is consistent with existing literature.[11] Since exogenous gasoline price is unable to be rejected, our estimates of other explanatory variables are similar to semiparametric estimates in previous sections 4.4.1.2 and 4.4.2.2.[12] The results of the price exogeneity test suggest that gasoline price can be treated as an exogenous variable when we follow the price adjustment formula and use crude oil price and exchange rate as instrument variables. Finally, it is worthwhile to emphasize that the test of price endogeneity enables us to examine

[10]The estimated monthly effects of equation (4.4.15) and (4.4.16) are graphically shown in figures 4.C.

[11]In testing the possibility of price endogeneity, Yatchew and No (2001) and Manzan and Zerom (2010) fail to reject the null hypothesis as price exogeneity by using regional dummies as instrumental variables, and Liu (2014) also obtains price exogeneity by using gasoline tax, the domestic oil first-purchasing price and the average gasoline price of nonadjacent states.

[12]We also test the possibility of endogeneity in the remaining 14 regions by using equation (4.4.16), and report the estimated results in table 4.D.2 and plot the monthly effects in figure 4.D.4 in Appendix 4.D. The estimated results suggest that we are unable to reject the null hypothesis, exogenous gasoline price.

whether measurement errors emerge in the estimation of household gasoline demand. The rejection of the hypothesis of price endogeneity demonstrates that the nonparametric estimate of price elasticity achieved by using semiparametric approaches is reasonably accurate and without measurement errors.

Table 4.3: Semiparametric Fixed-effects Model with Possible Endogeneity

District	Taiwan	North	Central	South	East and Island
Dependent Variable	Log of Household Gasoline Consumption				
Period	All Periods				
Log of Real Household Disposable Income	-0.173**	-0.180*	-0.162	-0.301**	-0.084
	(0.072)	(0.092)	(0.196)	(0.125)	(0.206)
Log of # of Registered Cars/Per Household	1.359**	0.875	2.382	1.849	2.496
	(0.660)	(0.760)	(1.929)	(1.231)	(2.013)
Log of # of Registered Motorcycles/Per Household	1.036***	0.292	1.825**	1.104**	0.729
	(0.321)	(0.443)	(0.756)	(0.494)	(1.094)
Log of # of Licensed Drivers/Per Household	0.188*	0.064	0.199	0.594	-2.779
	(0.113)	(0.237)	(0.134)	(0.413)	(1.915)
Current Conduct Information Sharing					
Positive Change	-0.016***	-0.011*	-0.006	-0.016**	-0.041**
	(0.005)	(0.006)	(0.011)	(0.008)	(0.018)
Negative Change	0.009*	0.004	0.025**	0.010	-0.006
	(0.005)	(0.006)	(0.011)	(0.008)	(0.019)
Future Conduct Information Sharing					
PAF×Positive Change	-0.013	-0.016	-0.026	-0.017	0.014
	(0.012)	(0.015)	(0.029)	(0.020)	(0.047)
PAF×Negative Change	-0.059***	-0.047***	-0.080***	-0.064***	-0.054
	(0.012)	(0.015)	(0.029)	(0.020)	(0.047)
ν	-0.010	-0.119	-0.066	-0.002	0.293
	(0.064)	(0.077)	(0.151)	(0.105)	(0.245)
Monthly Effects	-	-	-	-	-
Observations	3462	1218	696	1044	504
R^2	0.268	0.429	0.286	0.302	0.285

Note: All 20 administrative regions are regrouped into four districts, North, South, Central, and East and Island. North district includes Taipei City, New Taipei City, Taoyuan City, Yilan County, Hsinchu County, Hsinchu City and Keelung City. Central district includes Taichung City, Miaoli County, Changhua County, and Nantou County. South district includes Tainan City, Kaohsiung City, Yulin County, Chiayi County, Chiayi City, and Pingtung County. East and Island district includes Taitung County, Hualien County and Penghu County. For monthly effects, see figure 4.C.1 in Appendix 4.C. Standard errors are presented in parentheses. *** Statistically significant level at 0.01, ** statistically significant level at 0.05 and * statistically significant level at 0.1.

Table 4.4: Household Gasoline Demand in Six Special Municipalities with Possible Endogeneity

Region	Taipei City	New Taipei City	Taoyuan City	Taichung City	Tainan City	Kaohsiung City
Dependent Variable	Household Gasoline Consumption					
Period	All Periods					
Log of Real Household Disposable Income	-0.204	-0.406*	-0.134	-0.208	-0.030	-0.473**
	(0.175)	(0.240)	(0.167)	(0.231)	(0.153)	(0.220)
Log of # of Registered Cars/Per Household	0.211**	0.889***	0.775***	1.549***	1.336***	0.999***
	(0.095)	(0.317)	(0.210)	(0.432)	(0.227)	(0.239)
Log of # of Registered Motorcycles/Per Household	-0.177**	0.022	-0.650**	0.175	0.143	-0.093
	(0.080)	(0.313)	(0.315)	(0.432)	(0.173)	(0.161)
Log of # of Licensed Drivers/Per Household	-0.414***	-0.339	-0.120	0.415	0.561**	0.107
	(0.140)	(0.399)	(0.143)	(0.298)	(0.217)	(0.144)
Current Conduct Information Sharing						
Positive Change	-0.008	-0.011	-0.015	0.016	-0.012	-0.010
	(0.009)	(0.013)	(0.016)	(0.026)	(0.017)	(0.015)
Negative Change	-0.001	-0.010	-0.010	0.031	-0.000	-0.002
	(0.009)	(0.013)	(0.016)	(0.027)	(0.017)	(0.016)
Future Conduct Information Sharing						
PAF×Positive Change	-0.032***	-0.013	-0.026	-0.015	-0.028	-0.007
	(0.011)	(0.014)	(0.018)	(0.029)	(0.018)	(0.021)
PAF×Negative Change	-0.040***	-0.029*	-0.061***	-0.043	-0.061***	-0.043*
	(0.011)	(0.015)	(0.018)	(0.029)	(0.018)	(0.022)
ν	-0.015	-0.054	-0.130	0.084	0.070	0.047
	(0.072)	(0.114)	(0.131)	(0.235)	(0.145)	(0.131)
Observations	174	174	174	174	174	174
R^2	0.852	0.784	0.704	0.315	0.536	0.627
Significance Test for Price Effect						
V_{stat}	4.264	2.406	2.137	0.552	2.830	2.513
$p-value$	0.000	0.008	0.016	0.290	0.002	0.006

Note: Significant test of nonparametric price effect is based on Yatchew's significance test procedure (2003). Significance Test statistic as follows $V_{stat} = (m \times n)^{1/2}\frac{(s^2_{nopeffect} - s^2_{diff})}{s^2_{diff}} \xrightarrow{D} N(0,1)$, where m denotes the order of differencing, n denotes sample size, $s^2_{nopeffect}$ denotes the estimator of the residual variance without price effect, s^2_{diff} denotes the m-th order differencing estimator of the residual variance. For more details, see Proposition 4.3.1, Yatchew (2003). For monthly effects, see figure 4.C.2 in Appendix 4.C. Standard errors are presented in parentheses. *** Statistically significant level at 0.01, ** statistically significant level at 0.05 and * statistically significant level at 0.1.

4.5 Summary of Chapter 4

Using household structure in modeling Taiwanese gasoline demand provides precise findings which simply describe household gasoline consumption in different regions. In this study we use regional household-level data to determine Taiwan's household gasoline demand in areas of different levels of economic development. Our results highlight the following insights: (i) the household demand for gasoline seems to be inelastic in urban regions, but elastic in rural regions; (ii) negative income elasticities are estimated in urban and rich regions; (iii) there are potential benefits for consumers under the sharing of future conduct price-change information.

First, we use a semiparametric fixed-effects model and a difference-based model to nonparametrically estimate price effect on the household demand for gasoline, and explore inelastic household gasoline demand in rich urban regions and elastic household gasoline demand in poor rural regions. The nonparametric price effect varies according to each district at semiparametric fixed-effects estimates. Moreover, our nonparametric estimates of price effect across six municipalities find little evidence of inelastic gasoline demand in the richest and most urban region, which is consistent with nonparametric estimates of price effect from the fixed-effects model.

Second, both semiparametric estimates reveal negative income elasticities. Following our empirical semiparametric specifications, we discover that in rich urban regions, households would reduce gasoline consumption as income rises. This finding may reflect substitution from privately owned vehicles to public transportation.

Third, we turn to the main discussion on the effect of information sharing. We consider future conduct information sharing in relation to our empirical specifications. Our estimates suggest that future conduct negative price-change information sharing has a larger effect for decreases in current gasoline consumption. This finding evidently shows that potential efficiency gains to consumers come from future conduct information sharing because it enables intertemporal substitution. Nevertheless, the effect of future conduct information sharing to consumers does not seem likely to outweigh the costs of tacit collusion found in the earlier chapter.

It is interesting to reflect on the difference between our finding from Taiwan and the previous semiparametric literature based on the US and Canadian data. For example, our results demonstrate that gasoline consumption would not increase as household income rises in a geographically small country such as Taiwan, in contrast to larger countries such as the US and Canada. We also graphically present differences in price effect across an individual region, an effect not discussed in existing literature in which most of them study price effect at the national level. In general, in both large or small countries, the semiparametric approach is reasonably accurate to model gasoline demand.

Moreover, we identify the potential market efficiency gains generated by the sharing of future conduct information. On the other hand, in comparing our discussion of collusive outcomes from future conduct information sharing in Chapter 3 with the study in this chapter, future conduct information sharing seems to maximize its effect on the supply side rather than the demand side.

Appendix

4.A Descriptive Statistics

Table 4.A.1: Descriptive Statistics

Region	Variable	Mean	Std. Dev.	Min.	Max.
Taipei City	$p^{gasoline}$	27.275	5.466	18.2	36.052
	hgas	76.94	7.87	58.537	93.552
	hrealhdi	104997.73	2421.166	99953.102	110845.461
	hnrc	0.649	0.034	0.605	0.708
	hnrm	1.082	0.051	0.935	1.129
	hnld	1.391	0.045	1.338	1.541
New Taipei City	$p^{gasoline}$	27.275	5.466	18.2	36.052
	hgas	91.347	10.751	68.693	113.761
	hrealhdi	76911.505	1874.385	73548.156	82498.219
	hnrc	0.629	0.019	0.603	0.664
	hnrm	1.588	0.06	1.449	1.653
	hnld	1.196	0.034	1.145	1.279
Taichung City	$p^{gasoline}$	27.275	5.466	18.2	36.052
	hgas	133.561	12.671	70.807	163.859
	hrealhdi	73456.066	3970.287	66981.906	81837.883
	hnrc	1.028	0.028	0.966	1.069

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Region	Variable	Mean	Std. Dev.	Min.	Max.
	hnrm	1.893	0.079	1.771	2.013
	hnld	1.59	0.041	1.525	1.664
Tainan City	$p^{gasoline}$	27.275	5.466	18.2	36.052
	hgas	120.704	10.218	98.409	145.725
	hrealhdi	65757.187	2905.579	59526.813	70650.102
	hnrc	0.872	0.032	0.8	0.92
	hnrm	2.085	0.11	1.913	2.238
	hnld	1.423	0.031	1.377	1.485
Kaohsiung City	$p^{gasoline}$	27.275	5.466	18.2	36.052
	hgas	94.81	10.241	75.276	117.934
	hrealhdi	71469.911	3830.518	64735.902	79877.555
	hnrc	0.747	0.02	0.708	0.786
	hnrm	2.108	0.108	1.867	2.23
	hnld	1.398	0.15	1.267	1.731
Taoyuan City	$p^{gasoline}$	27.275	5.466	18.2	36.052
	hgas	143.871	17.702	109.403	178.967
	hrealhdi	82087.394	3893.021	75649.625	91560.945
	hnrc	0.922	0.021	0.886	0.968
	hnrm	1.587	0.056	1.478	1.669
	hnld	1.426	0.064	1.34	1.665
Yilan County	$p^{gasoline}$	27.275	5.466	18.2	36.052
	hgas	104.778	9.247	86.476	133.737
	hrealhdi	66184.888	5979.009	57263.563	81073.414
	hnrc	0.845	0.027	0.783	0.89
	hnrm	1.867	0.071	1.647	1.928
	hnld	1.355	0.064	1.264	1.479
Hsinchu County	$p^{gasoline}$	27.275	5.466	18.2	36.052
	hgas	167.715	16.283	137.895	211.455

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Region	Variable	Mean	Std. Dev.	Min.	Max.
	hrealhdi	84553.425	5607.987	74236.547	93248.938
	hnrc	1.1	0.021	1.068	1.144
	hnrm	1.686	0.051	1.525	1.738
	hnld	1.528	0.17	1.381	1.971
Miaoli County	$p^{gasoline}$	27.275	5.466	18.2	36.052
	hgas	137.607	10.847	112.049	163.355
	hrealhdi	66788.242	3916.041	60331.746	76812.211
	hnrc	1.085	0.031	1.019	1.131
	hnrm	1.984	0.081	1.746	2.077
	hnld	1.517	0.081	0.988	1.713
Changhua County	$p^{gasoline}$	27.275	5.466	18.2	36.052
	hgas	123.089	12.291	94.604	152.16
	hrealhdi	64688.93	2374.824	57996.938	68954.945
	hnrc	1.142	0.046	1.028	1.209
	hnrm	2.41	0.107	2.146	2.539
	hnld	1.688	0.049	1.631	1.872
Nantou County	$p^{gasoline}$	27.275	5.466	18.2	36.052
	hgas	131.453	12.932	104.356	173.483
	hrealhdi	62290.701	3900.647	56174.328	70232.938
	hnrc	1.06	0.041	0.962	1.133
	hnrm	1.971	0.091	1.768	2.103
	hnld	1.481	0.077	1.404	1.742
Yunlin County	$p^{gasoline}$	27.275	5.466	18.2	36.052
	hgas	116.412	8.809	96.799	138.87
	hrealhdi	56949.579	3559.862	50325.188	64304.844
	hnrc	0.971	0.047	0.863	1.052
	hnrm	2.059	0.096	1.803	2.161
	hnld	1.418	0.054	1.36	1.54

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Region	Variable	Mean	Std. Dev.	Min.	Max.
Chiayi County	$p^{gasoline}$	27.275	5.466	18.2	36.052
	hgas	116.994	12.219	93.036	151.949
	hrealhdi	55901.963	3452.781	50303.672	63355.688
	hnrc	0.959	0.045	0.85	1.029
	hnrm	2.016	0.086	1.803	2.121
	hnld	1.409	0.12	1.314	1.681
Pingtung County	$p^{gasoline}$	27.275	5.466	18.2	36.052
	hgas	116.847	11.603	91.614	146.813
	hrealhdi	60768.37	2610.543	55783.258	67135.398
	hnrc	0.877	0.045	0.771	0.950
	hnrm	2.399	0.145	2.151	2.605
	hnld	1.383	0.037	1.332	1.462
Taitung County	$p^{gasoline}$	27.275	5.466	18.2	36.052
	hgas	97.754	11.991	77.163	132.913
	hrealhdi	53202.678	3434.831	46968.84	60755.496
	hnrc	0.786	0.05	0.681	0.887
	hnrm	2.1	0.121	1.867	2.278
	hnld	1.225	0.086	1.133	1.421
Hualien County	$p^{gasoline}$	27.275	5.466	18.2	36.052
	hgas	101.56	11.777	77.473	132.95
	hrealhdi	60312.404	3097.695	53654.754	66811.75
	hnrc	0.854	0.024	0.804	0.915
	hnrm	1.93	0.099	1.624	2.044
	hnld	1.286	0.051	1.228	1.41
Penghu County	$p^{gasoline}$	27.275	5.466	18.2	36.052
	hgas	58.184	8.263	40.756	79.42
	hrealhdi	57530.699	5705.323	48468.133	69602.266
	hnrc	0.622	0.046	0.491	0.704

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Region	Variable	Mean	Std. Dev.	Min.	Max.
	hnrm	1.999	0.077	1.856	2.113
	hnld	1.007	0.028	0.969	1.095
Keelung City	$p^{gasoline}$	27.275	5.466	18.2	36.052
	hgas	81.741	6.886	67.485	103.944
	hrealhdi	68276.59	4269.966	59451.574	75631.359
	hnrc	0.551	0.019	0.504	0.578
	hnrm	1.256	0.05	1.171	1.327
	hnld	1.113	0.037	1.057	1.209
Hsinchu City	$p^{gasoline}$	27.275	5.466	18.2	36.052
	hgas	132.444	14.712	100.224	159.534
	hrealhdi	96434.388	5515.933	84584.039	107727.031
	hnrc	0.911	0.022	0.884	0.954
	hnrm	1.817	0.067	1.626	1.908
	hnld	1.406	0.071	1.187	1.477
Chiayi City	$p^{gasoline}$	27.275	5.466	18.2	36.052
	hgas	116.958	11.636	95.529	145.801
	hrealhdi	67294.346	8318.674	56186.652	86755.531
	hnrc	0.848	0.024	0.799	0.887
	hnrm	2.063	0.079	1.841	2.147
	hnld	1.513	0.137	1.378	1.748

4.B Dummy Variable Setting

As the government's price regulation policy, the price adjustment formula, was implemented in September 2006, which is the 69^{th} month in our monthly dataset, the effect of the government's policy on the demand side needs to be discussed. Therefore, we set a dummy variable of the implementation of the price adjustment formula which is algebraically defined as

$$PAF_t = \begin{cases} 1 & \text{if } t \geq 69 \\ 0 & \text{, otherwise,} \end{cases}$$

where PAF_t is a dummy of 1 after the transparent price regulation policy was implemented by the government at period t.

For capturing the effect of price information sharing on household gasoline demand, we suppose that households would make a comparison of gasoline price between period t and $t1$, and this comparison is defined as current conduct price information sharing. Current conduct price-change information can be defined as two dummy variables which are expressed as:

$$PositiveChange_t = \begin{cases} 1 & \text{if } p_t > p_{t-1} \\ 0 & \text{, otherwise,} \end{cases}$$

and

$$NegativeChange_t = \begin{cases} 1 & \text{if } p_t < p_{t-1} \\ 0 & \text{, otherwise,} \end{cases}$$

where $PositiveChange_t$ is a dummy variable of 1 if there exists a positive change in gasoline price at period t, and $NegativeChange_t$ is a dummy variable of 1 if there exists a negative change in gasoline price at period t.

Next, we consider the sharing of future conduct price information. Since the state-owned enterprise's new gasoline price is publicly disclosed through the price adjustment formula, households can obtain the new retail gasoline price. New retail price-change information is written as two dummies

$$PositiveChange_{t+1} = \begin{cases} 1 & \text{if } p_{t+1} > p_t \\ 0 & \text{, otherwise,} \end{cases}$$

and

$$NegativeChange_{t+1} = \begin{cases} 1 & \text{if } p_{t+1} < p_t \\ 0 & \text{, otherwise,} \end{cases}$$

where $PositiveChange_{t+1}$ is a dummy variable of 1 if retail gasoline price increases at period $t+1$, and $NegativeChange_{t+1}$ is a dummy variable of 1 if retail gasoline price declines at period $t+1$.

Thus, the future conduct price information sharing to consumers is defined as the interaction terms between two dummy variables, price adjustment formula and new price change information, which are given by

$$PAF_{t+1} \times PositiveChange_{t+1},$$

and

$$PAF_{t+1} \times NegativeChange_{t+1},$$

where $PAF_{t+1} \times PositiveChange_{t+1}$ is a dummy variable of 1 if future positive price change information is available to consumers, and $PAF_{t+1} \times NegativeChange_{t+1}$ is a dummy variable of 1 if future negative price change information is available to consumers.

4.C Monthly Effects: Semiparametric Estimates with Possible Endogeneity

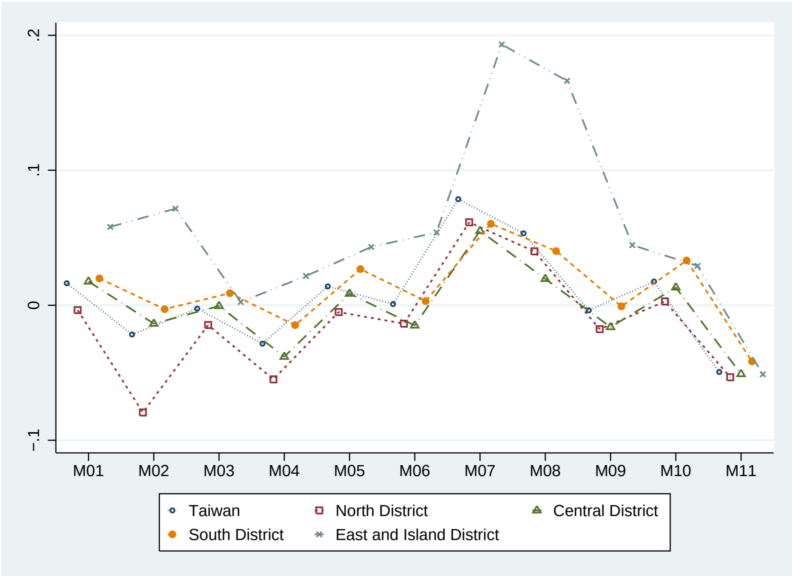

Figure 4.C.1: Monthly Effects in Fixed Effects Model with Possible Endogeneity

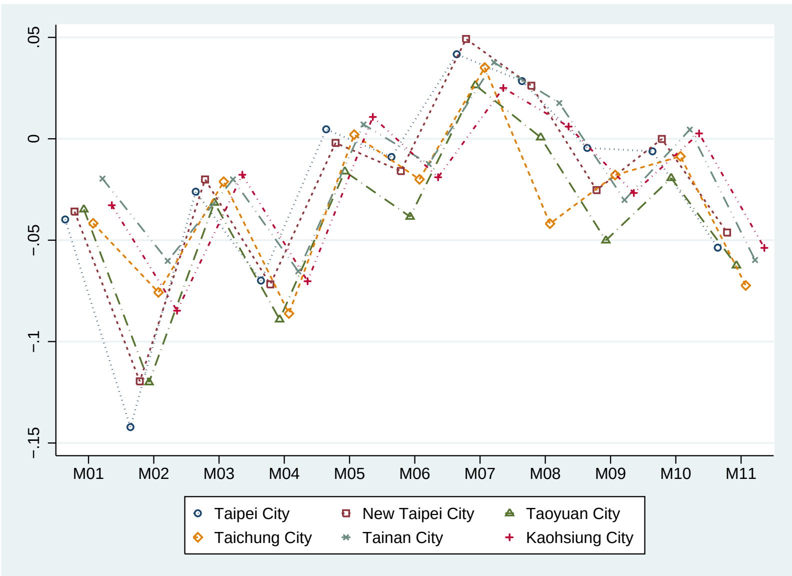

Figure 4.C.2: Monthly Effects in Six Special Municipalities with Possible Endogeneity

4.D Household Gasoline Demand in Remaining 14 Regions

Figure 4.D.1: Nonparametric Price Effect in 14 Regions

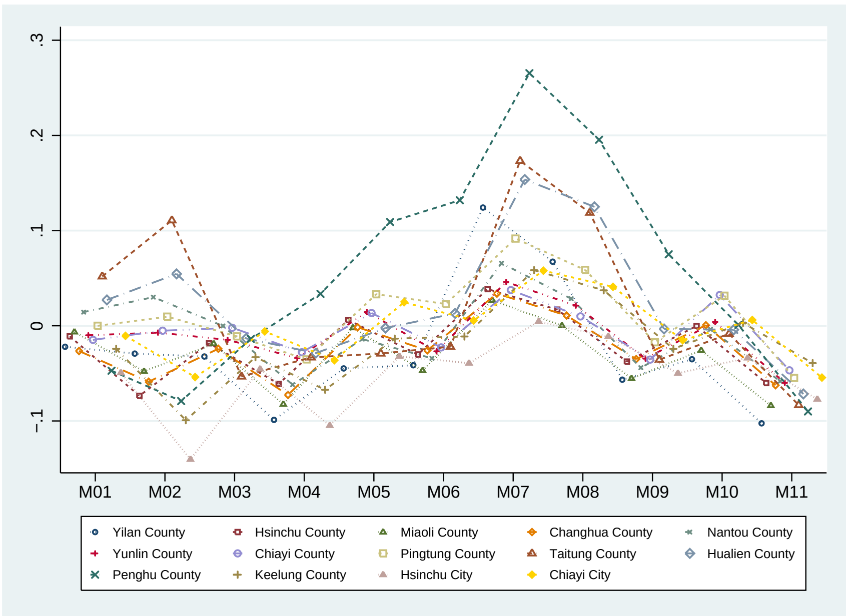

Figure 4.D.2: Monthly Effects in 14 Regions

Table 4.D.1: Household Gasoline Demand in Remaining 14 Regions

Region	Yilan County	Hsinchu County	Miaoli County	Changhua County	Nantou County	Yunlin County	Chiayi County
Dependent Variable	Log of Household Gasoline Consumption						
Period	All Periods						
Log of Real Household Disposable Income	-0.048	0.157	-0.015	0.400**	-0.051	-0.016	-0.145
	(0.119)	(0.119)	(0.164)	(0.195)	(0.130)	(0.098)	(0.151)
Log of # of Registered Cars/Per Household	1.483**	0.569*	0.374	0.776**	1.601***	1.437***	2.201***
	(0.571)	(0.313)	(0.312)	(0.330)	(0.299)	(0.282)	(0.481)
Log of # of Registered Motorcycles/Per Household	-0.434	-0.568***	-0.578***	-0.116	0.025	0.412	0.210
	(0.321)	(0.165)	(0.206)	(0.229)	(0.187)	(0.275)	(0.299)
Log of # of Licesed Drivers/Per Household	0.415	-0.106	-0.026	0.532	0.570***	1.501***	0.471
	(0.416)	(0.076)	(0.155)	(0.380)	(0.154)	(0.458)	(0.354)
Current Conduct Information Sharing							
PositiveChange	-0.018	-0.025	-0.015	-0.019	-0.024	-0.016	-0.014
	(0.024)	(0.016)	(0.020)	(0.021)	(0.022)	(0.019)	(0.021)
NegativeChange	0.006	-0.012	0.006	-0.007	-0.003	-0.001	-0.005
	(0.024)	(0.016)	(0.021)	(0.021)	(0.022)	(0.019)	(0.021)
Future Conduct Information Sharing							
PAF×PostiveChange	0.138***	-0.023	0.032*	-0.010	0.017	0.018	-0.023
	(0.023)	(0.020)	(0.018)	(0.021)	(0.019)	(0.017)	(0.019)
PAF×NegativeChange	0.093***	-0.051**	-0.010	-0.061***	-0.025	-0.023	-0.064***
	(0.023)	(0.021)	(0.019)	(0.021)	(0.019)	(0.018)	(0.021)
Monthly Effects							
Observations	174	174	174	174	174	174	174
R^2	0.623	0.572	0.403	0.432	0.499	0.433	0.516
Significance Test for Price Effect							
V_{stat}	1.159	2.342	3.086	1.751	3.214	2.837	3.888
$p-value$	0.123	0.010	0.001	0.040	0.001	0.002	0.000

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Region	Pingtung County	Taitung County	Hualien County	Penghu County	Keelung City	Hsinchu City	Chiayi City
Dependent Variable	Log of Household Gasoline Consumption						
Period	All Periods						
Log of Real Household Disposable Income	-0.115	-0.048	-0.124	-0.124	-0.027	-0.021	0.041
	(0.169)	(0.143)	(0.180)	(0.121)	(0.082)	(0.107)	(0.059)
Log of # of Registered Cars/Per Household	0.839***	1.233***	1.694***	0.778**	2.005***	0.990***	0.266
	(0.179)	(0.283)	(0.550)	(0.298)	(0.163)	(0.319)	(0.237)
Log of # of Registered Motorcycles/Per Household	-0.087	0.008	0.125	-0.044	0.357**	-0.082	-0.223
	(0.181)	(0.302)	(0.373)	(0.548)	(0.163)	(0.144)	(0.179)
Log of # of Licesed Drivers/Per Household	-0.024	0.822**	0.552	-0.007	0.760***	-0.225	0.215
	(0.380)	(0.341)	(0.504)	(0.543)	(0.145)	(0.161)	(0.172)
Current Conduct Information Sharing							
PositiveChange	-0.012	-0.019	-0.013	-0.031	-0.014	-0.009	-0.026
	(0.021)	(0.028)	(0.026)	(0.034)	(0.014)	(0.015)	(0.016)
NegativeChange	-0.003	-0.010	-0.002	-0.008	-0.024*	0.002	-0.011
	(0.021)	(0.028)	(0.026)	(0.034)	(0.014)	(0.015)	(0.016)
Future Conduct Information Sharing							
PAF×PostiveChange	-0.023	0.049**	0.044*	0.008	0.025*	0.015	-0.009
	(0.020)	(0.024)	(0.024)	(0.028)	(0.013)	(0.017)	(0.023)
PAF×NegativeChange	-0.065***	0.009	0.022	-0.057*	0.015	-0.010	-0.039*
	(0.022)	(0.024)	(0.027)	(0.029)	(0.013)	(0.018)	(0.022)
Monthly Effects							
Observations	174	174	174	158	174	174	174
R^2	0.471	0.592	0.507	0.631	0.744	0.712	0.546
Significance Test for Price Effect							
V_{stat}	3.026	2.394	2.335	1.161	3.174	2.499	3.802
$p-value$	0.001	0.008	0.010	0.123	0.001	0.006	0.000

Note: Significant test of nonparmetrically price effect is based on Yatchew's significance test procedure (2003). Significance Test statistic as follows $V_{stat} = (m \times n)^{1/2}\frac{(s^2_{nopeffect}-s^2_{diff})}{s^2_{diff}} \xrightarrow{D} N(0,1)$, where m denotes the order of differencing, n denotes sample size, $s^2_{nopeffect}$ denotes the estimator of the residual variance without price effect, s^2_{diff} denotes the m-th order differencing estimator of the residual variance. More details, see Proposition 4.3.1, Yatchew (2003). For monthly effects, see figure 4.D.2. Standard erros are presented in parentheses. Standard errors are presented in parentheses. *** Statistically significant level at 0.01, ** Statistically significant level at 0.05 and * Statistically significant level at 0.1.

Table 4.D.2: Household Gasoline Demand in Remaining 14 Regions with Possible Endogeneity

Region	Yilan County	Hsinchu County	Miaoli County	Changhua County	Nantou County	Yunlin County	Chiayi County
Dependent Variable	Log of Household Gasoline Consumption						
Period	All Periods						
Log of Real Household Disposable Income	-0.044	0.170	-0.021	0.418**	-0.099	-0.013	-0.151
	(0.122)	(0.130)	(0.163)	(0.196)	(0.136)	(0.098)	(0.151)
Log of # of Registered Cars/Per Household	1.504**	0.596*	0.293	0.832**	1.728***	1.556***	2.323***
	(0.581)	(0.331)	(0.323)	(0.341)	(0.319)	(0.298)	(0.500)
Log of # of Registered Motorcycles/Per Household	-0.400	-0.546***	-0.675***	-0.035	0.169	0.585*	0.343
	(0.361)	(0.187)	(0.231)	(0.258)	(0.228)	(0.310)	(0.338)
Log of # of Licesed Drivers/Per Household	0.420	-0.109	-0.036	0.565	0.565***	1.616***	0.535
	(0.417)	(0.077)	(0.155)	(0.382)	(0.153)	(0.466)	(0.361)
Current Conduct Information Sharing							
PositiveChange	-0.019	-0.024	-0.015	-0.020	-0.024	-0.017	-0.015
	(0.024)	(0.016)	(0.020)	(0.021)	(0.022)	(0.019)	(0.021)
NegativeChange	0.007	-0.011	0.001	-0.004	0.003	0.004	-0.002
	(0.025)	(0.017)	(0.021)	(0.021)	(0.023)	(0.020)	(0.021)
Future Conduct Information Sharing							
PAF×PostiveChange	0.138***	-0.023	0.035*	-0.013	0.009	0.014	-0.025
	(0.023)	(0.020)	(0.018)	(0.021)	(0.020)	(0.017)	(0.020)
PAF×NegativeChange	0.094***	-0.050**	-0.010	-0.063***	-0.031	-0.025	-0.064***
	(0.023)	(0.021)	(0.019)	(0.022)	(0.020)	(0.018)	(0.021)
residuals	0.041	0.037	-0.155	0.121	0.219	0.199	0.150
	(0.206)	(0.145)	(0.169)	(0.181)	(0.199)	(0.168)	(0.179)
Monthly Effects							
Observations	174	174	174	174	174	174	174
R^2	0.623	0.572	0.407	0.434	0.504	0.440	0.519
Significance Test for Price Effect							
V_{stat}	1.008	2.309	2.534	1.599	3.349	2.972	3.890
$p-value$	0.157	0.010	0.006	0.055	0.000	0.001	0.000

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Region	Pingtung County	Taitung County	Hualien County	Penghu County	Keelung City	Hsinchu City	Chiayi City
Dependent Variable	Log of Household Gasoline Consumption						
Period	All Periods						
Log of Real Household Disposable Income	-0.111	-0.059	-0.155	-0.151	-0.032	-0.017	0.038
	(0.170)	(0.143)	(0.180)	(0.122)	(0.084)	(0.106)	(0.061)
Log of # of Registered Cars/Per Household	0.845***	1.255***	1.882***	0.712**	2.011***	1.039***	0.254
	(0.180)	(0.284)	(0.563)	(0.300)	(0.165)	(0.320)	(0.246)
Log of # of Registered Motorcycles/Per Household	-0.056	0.075	0.347	0.293	0.382*	-0.155	-0.243
	(0.198)	(0.316)	(0.405)	(0.600)	(0.195)	(0.155)	(0.208)
Log of # of Licesed Drivers/Per Household	-0.025	0.818**	0.619	0.055	0.756***	-0.172	0.220
	(0.380)	(0.340)	(0.502)	(0.541)	(0.147)	(0.166)	(0.173)
Current Conduct Information Sharing							
PositiveChange	-0.012	-0.020	-0.013	-0.032	-0.014	-0.008	-0.026
	(0.021)	(0.028)	(0.025)	(0.033)	(0.014)	(0.015)	(0.016)
NegativeChange	-0.002	-0.006	0.007	-0.000	-0.024*	-0.002	-0.011
	(0.021)	(0.028)	(0.026)	(0.034)	(0.014)	(0.015)	(0.017)
Future Conduct Information Sharing							
PAF×PostiveChange	-0.026	0.043*	0.041*	-0.003	0.024	0.014	-0.009
	(0.021)	(0.025)	(0.024)	(0.029)	(0.015)	(0.017)	(0.023)
PAF×NegativeChange	-0.066***	0.004	0.023	-0.063**	0.014	-0.012	-0.039*
	(0.022)	(0.025)	(0.026)	(0.029)	(0.014)	(0.018)	(0.022)
residuals	0.067	0.163	0.298	0.343	0.028	-0.152	-0.026
	(0.178)	(0.233)	(0.219)	(0.259)	(0.119)	(0.122)	(0.140)
Monthly Effects							
Observations	174	174	174	158	174	174	174
R^2	0.472	0.593	0.515	0.637	0.744	0.716	0.546
Significance Test for Price Effect							
V_{stat}	2.728	2.374	2.545	1.389	2.853	2.135	3.266
$p - value$	0.003	0.009	0.005	0.082	0.002	0.016	0.001

Note: For monthly effects, see figure 4.D.4. Standard errors are presented in parentheses. *** Statistically significant level at 0.01, ** Statistically significant level at 0.05 and * Statistically significant level at 0.1.

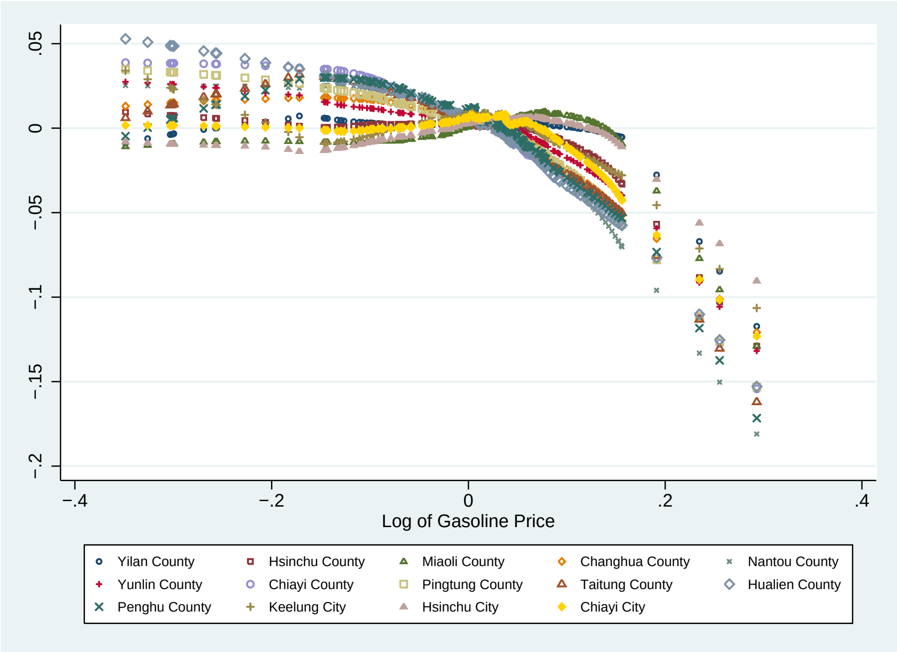


Figure 4.D.3: Nonparametric Price Effect in 14 Regions with Possible Endogeneity

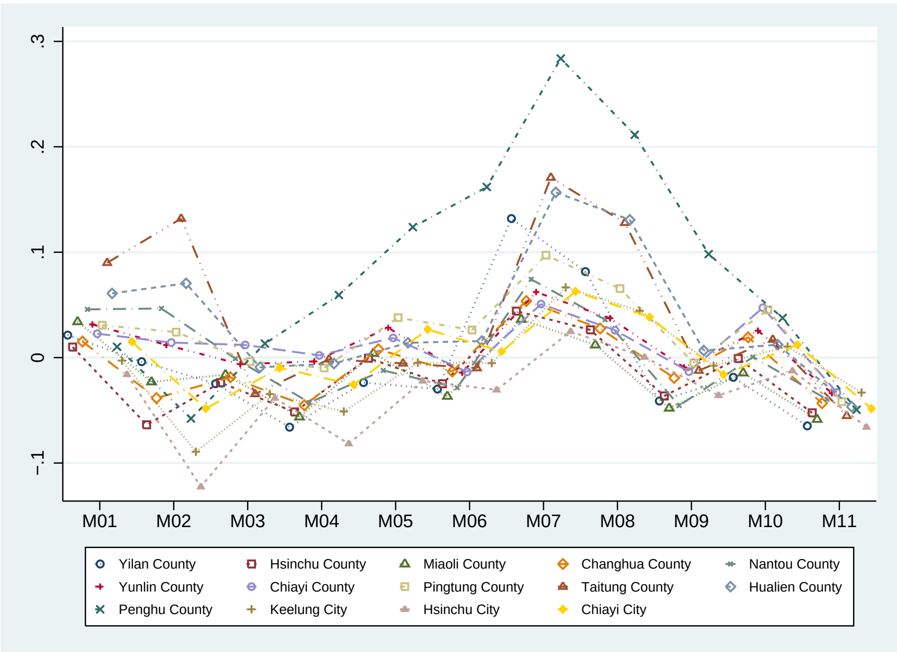
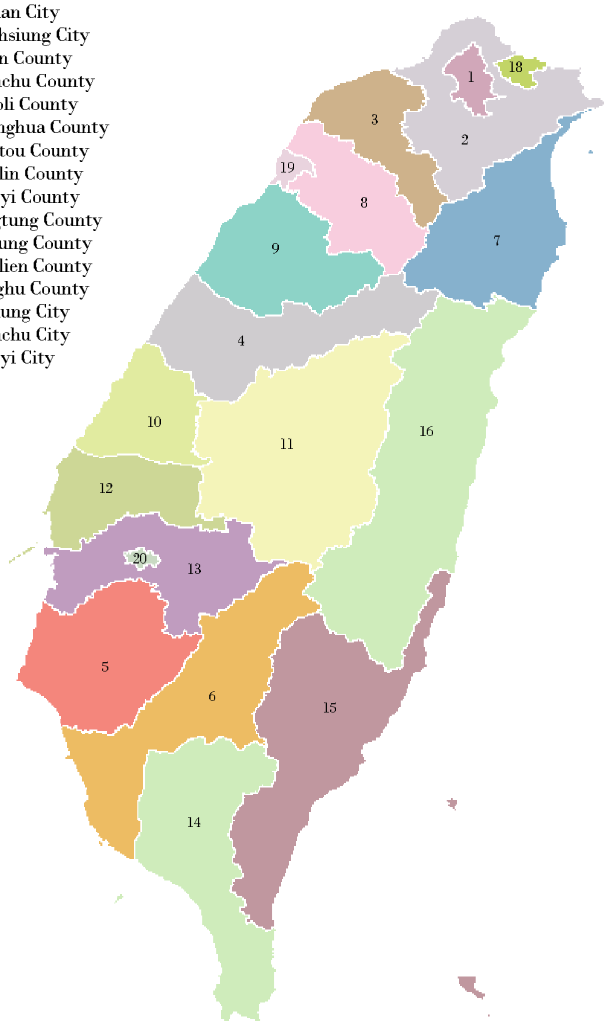


Figure 4.D.4: Monthly Effects in 14 Regions from Semiparametric Estimates with Possible Endogeneity

4.E Taiwan Administrative Regions Map

City/County ID	City/County Name
1	Taipei City
2	New Taipei City
3	Taoyuan City
4	Taichung City
5	Tainan City
6	Kaohsiung City
7	Yilan County
8	Hsinchu County
9	Miaoli County
10	Changhua County
11	Nantou County
12	Yunlin County
13	Chiayi County
14	Pingtung County
15	Taitung County
16	Hualien County
17	Penghu County
18	Keelung City
19	Hsinchu City
20	Chiayi City



Note: Taiwan map data source from National Land Surveying and Mapping Center, Ministry of the Interior, Taiwan (R.O.C.), and Taiwan map is plotted by R.

4.F Yatchew's Optimal Differencing Weights

m	$(d_0, d_1, \ldots, d_m)$
1	(0.7071,-0.7071)
2	(0.8090,-0.5000,-0.3090)
3	(0.8582,-0.3832,-0.2809,-0.1942)
4	(0.8873,-0.3099,-0.2464,-0.1901,-0.1409)
5	(0.9064,-0.2600,-0.2167,-0.1774,-0.1420,-0.1103)
6	(0.9200,-0.2238,-0.1925,-0.1635,-0.1369,-0.1126,-0.0906)
7	(0.9302,-0.1965,-0.1728,-0.1506,-0.1299,-0.1107,-0.0930,-0.0768)
8	(0.9380,-0.1751,-0.1565,-0.1389,-0.1224,-0.1069,-0.0925,-0.0791,-0.0666)
9	(0.9443,-0.1578,-0.1429,-0.1287,-0.1152,-0.1025,-0.0905,-0.0792,-0.0687,-0.0588)
10	(0.9494,-0.1437,-0.1314,-0.1197,-0.1085,-0.0978,-0.0877,-0.0782,-0.0691,-0.0606,-0.0527)

Note: Source from Yatchew (2003).

4.G Data Source of Chapter 4

Table 4.G.1: Data Source

Chapter 4		
Dataset	**Data Type**	**Source**
CPC's Retail Price of 95 Unleaded Gasoline, 2001M01-2015M09	Weekly Data	Bureau of Energy, Ministry of Economic Affairs, Taiwan
Price of Dubai Crude Oil, 2001M01-2015M09	Weekly Data	Bureau of Energy, Ministry of Economic Affairs, Taiwan
Price of Brent Crude Oil, 2001M01-2015M09	Weekly Data	Bureau of Energy, Ministry of Economic Affairs, Taiwan
Exchange Rate: USD-TWD, 2001M01-2015M09	Monthly Data	Central Bank of the Republic of China (Taiwan)
Regional Gasoline Consumption, 2001M01-2015M09	Monthly Data	Bureau of Energy, Ministry of Economic Affairs, Taiwan
Regional Household Disposable Income, 2001M01-2015M09	Annual Data	National Statistics, Taiwan
# of Registered Vehicles (Cars and Motorcycles), 2001M01-2015M09	Monthly Data	Ministry of Transportation and Communications, Taiwan
# of Licensed Drivers, 2001M01-2015M09	Monthly Data	Ministry of Transportation and Communications, Taiwan

Chapter 5

Conclusion

This concluding chapter summarizes the findings in each chapter and considers further directions of these three studies. This chapter is organized as follows: Section 5.1 summarizes our findings in each chapter and section 5.2 provides a consideration about future extensions in these three studies.

5.1 Summary of Chapters and Policy Implication

This thesis consists of three empirical analyses in the government's transparent price regulation policy, the price adjustment formula (PAF). Chapter 2 considers a concern in which the asymmetric pricing upward/downward adjustment is changed by the implementation of the price adjustment formula. In the later two chapters, we suppose that the government's transparent price policy has the effect of becoming a future method of information exchange. We focus our attention on investigating the effects of the government's transparent price on the supply side in Chapter 3 and on the demand side in Chapter 4, respectively.

The first empirical study is presented in Chapter 2 and investigates the role of the government's transparent price policy, the price adjustment formula, in a retail gasoline price setting. Using monthly data over 161 months from 1999 to 2012, we identify the response of retail gasoline prices to fluctuations of international crude oil prices. Our findings show that: (i) the price adjustment formula resulted in a quicker response of retail gasoline prices to changes in crude oil prices, but it delayed an increase in retail gasoline prices when crude oil prices rose; and (ii) due to indirect government intervention, the retail price adjustment in response to changes in crude oil prices is 'hot air balloons and bricks' rather than 'rockets and feathers'.

Chapter 3 investigates the effect of the government's transparent price policy on the supply side: firms' price setting mechanism, price leadership and potential anti-competitive outcomes. According to our results, we provide evidence that: (i) the leading firm's retail price response was most likely to be 'hot air balloons and bricks' when the price adjustment formula was adopted, which is consistent with the previous finding in Chapter 2; (ii) the price adjustment formula led to greater incidence of price leadership; and (iii) the price leadership frequently resulted in the competing firm's perfect price alignment, which lowers the degree of competition in the retail gasoline market.

In Chapter 4, we turn our attention to the effect of the government-regulated price transparency on the demand side. We investigate household gasoline demand across 20 Taiwan administrative regions by using a longitudinal dataset, and take into account a consideration of the government's policy on household gasoline demand. Our results present findings about disaggregate household gasoline demand by urban and rural regions, the effect of a future method of information sharing. First, household gasoline demand is inelastic in urban and rich regions, but is elastic in rural and poor regions. Second, future negative price change information sharing resulted in significant decreases in current household gasoline consumption, which suggests that future price information sharing may effectively generate intertemporal substitution on the demand side. In addition, we also provide an application of a semiparametric approach in a geographically small country.

Finally, the policy was designed to address one thing: that the stability of retail gasoline prices should be maintained, but the government needs to consider implications on both the supply and the demand sides. In the case of the price adjustment formula, this may have resulted in collusion, treated as a better intertemporal substitution by consumers. However, in the Taiwan gasoline market, the implications of the transparent price policy on the supply side seem to outweigh the demand side.

5.2 Further Research

Given empirical evidence from Chapters 2, 3 and 4, we understand the effects of the government's transparent price policy on the retail gasoline market. In particular, we suppose the government's transparent policy to be future practise of unilateral information sharing in this thesis, and investigate the effects of information sharing on the supply and demand sides. Nevertheless, there are some possible suggestions for natural directions of future research. First, we could investigate another country with a different type of government intervention, which could be deemed as a future conduct information sharing in petrol retailing. In addition, we could further investigate a consideration of a future method of information exchange on another Taiwan market, where the state-owned enterprise takes a dominant position and a similar type of government intervention is adopted, e.g., the telecommunications market.

Second, the government is taking two roles - a regulator and a leading firm - in the retail gasoline market. We restrict our attention to the second role, a leading firm, and have considered the government's transparent price regulation as a unilateral future method of information sharing in Chapters 3 and 4. We have not considered a regulator's view in these two chapters, which might not provide a representative argument on identifying the government's transparent price regulation. Hence, we might provide a clear explanation of why the government continues to implement the price adjustment formula in the petrol retailing market if a consideration of a regulator's view is taken into account. These suggestions are worth extending in future studies.

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