AN ANALYSIS OF UNCERTAINTY IN INVENTORY OF PETROLEUM PRODUCTS

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การวิเคราะห์ความไม่แน่นอนของระดับน้ำมันสำเร็จรูปคงคลัง

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วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรดุษฎีบัณฑิต
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วีรวิชย์ ฤกษ์จำนง : การวิเคราะห์ความไม่แน่นอนของระดับน้ำมันสำเร็จรูปคงคลัง. (AN ANALYSIS OF UNCERTAINTY IN INVENTORY OF PETROLEUM PRODUCTS) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: รศ. ดร.พงศา พรชัยวิเศษกุล, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: อ. ดร.อนันต์ เจียรวงศ์, 76 หน้า.

วิทยานิพนธ์ฉบับนี้ศึกษาความไม่แน่นอนของระดับน้ำมันสำเร็จรูปคงคลังโดยประยุกต์ใช้ตัวแบบจำลองทางเศรษฐศาสตร์และการเงินเพื่ออธิบายพฤติกรรมการเคลื่อนไหวของระดับน้ำมันสำเร็จรูปคงคลังวิเคราะห์ร่วมกับตัวแปรต่างๆ วัตถุประสงค์ของงานศึกษาคือ การพิจารณาผลกระทบของความไม่แน่นอนของราคาหน้าโรงกลั่น ค่ากองทุนน้ำมันเชื้อเพลิง ราคาฟิวเจอร์ส และค่าการตลาด ต่อการบริหารและความไม่แน่นอนของระดับน้ำมันสำเร็จรูปคงคลังที่เกี่ยวกับการบริโภคเพื่อการขนส่ง ซึ่งประกอบด้วยกลุ่มน้ำมัน แก๊สโซฮอล์ เบนซิน และดีเซลหมุนเร็ว การวิเคราะห์ของวิทยานิพนธ์จะแบ่งออกเป็น 2 ส่วนหลักตามคุณลักษณะของตัวแปรที่ศึกษา

การวิเคราะห์ในส่วนแรก ผู้วิจัยนำเสนอแนวทางในการวิเคราะห์ความไม่แน่นอนของการบริหารระดับน้ำมันสำเร็จรูปจากตัวแบบจำลองทางเศรษฐมิติที่สามารถใช้อธิบายผลกระทบของความไม่แน่นอนของตัวแปรตลาดได้แก่ ราคาหน้าโรงกลั่น ค่ากองทุนน้ำมันเชื้อเพลิง และราคาฟิวเจอร์ส ต่อความไม่แน่นอนของระดับน้ำมันสำเร็จรูปคงคลัง ไปพร้อมกับการวิเคราะห์ผลกระทบของความไม่แน่นอนต่อการบริหารระดับน้ำมันคงคลัง ผลลัพธ์จากการใช้แบบจำลองกับข้อมูลรายเดือนของน้ำมันสำเร็จรูป พบว่า ความไม่แน่นอนของราคาหน้าโรงกลั่นและค่ากองทุนน้ำมันมีผลทำให้ระดับน้ำมันคงคลังมีความไม่แน่นอนเพิ่มมากขึ้น ในขณะที่ความไม่แน่นอนของราคาฟิวเจอร์สส่งผลให้ความไม่แน่นอนของระดับน้ำมันคงคลังลดลง ทั้งนี้ ความไม่แน่นอนดังกล่าวยังส่งผลให้ผู้ประกอบการเพิ่มระดับการเก็บน้ำมันคงคลังมากขึ้นอีกด้วย การวิเคราะห์ความอ่อนไหวโดยใช้ข้อมูลความไม่แน่นอนที่ประมาณการจากแบบจำลองพบว่า ความไม่แน่นอนของราคาหน้าโรงกลั่นมีผลต่อความไม่แน่นอนของระดับน้ำมันคงคลังมากที่สุด ในขณะที่ผลกระทบจากความไม่แน่นอนของค่ากองทุนน้ำมันต่อความไม่แน่นอนของระดับน้ำมันคงคลังนั้นน้อยกว่ามาก

การวิเคราะห์ในส่วนที่สอง ผู้วิจัยศึกษาความสัมพันธ์ระหว่างความไม่แน่นอนต่อการบริหารจัดการน้ำมันคงคลังโดยได้นำแนวคิดที่ว่าการตัดสินใจทางธุรกิจเกี่ยวกับระดับน้ำมันคงคลังและระดับค่าการตลาดนั้นกระทำไปในเวลาที่พร้อมกันเข้าไปรวมในแบบจำลอง และได้จำลองค่าความไม่แน่นอนของค่าการตลาดเข้าไปในโครงสร้างของแบบจำลองแบบพร้อมกันอีกด้วย ผลลัพธ์จากการประยุกต์ใช้แบบจำลองกับข้อมูลน้ำมันสำเร็จรูปพบว่า ระดับน้ำมันคงคลังและค่าการตลาดมีความสัมพันธ์ต่อกันในเชิงบวกสำหรับน้ำมันแก๊สโซฮอล์และน้ำมันดีเซลหมุนเร็ว ความไม่แน่นอนของระดับน้ำมันคงคลังส่งผลให้ธุรกิจเพิ่มระดับการจัดเก็บน้ำมันทุกประเภทที่ศึกษา นอกจากนี้ ความไม่แน่นอนของค่าการตลาดยังส่งผลให้ธุรกิจเพิ่มระดับการจัดเก็บน้ำมันเบนซินและดีเซลหมุนเร็วคงคลัง

ผลลัพธ์จากแบบจำลองและการวิเคราะห์ทั้งสองส่วนช่วยระบุตัวแปรที่สามารถช่วยลดความไม่แน่นอนของระดับน้ำมันสำเร็จรูปคงคลัง อีกทั้งยังช่วยให้สามารถประเมินค่าความไม่แน่นอนที่เกิดขึ้นได้อย่างสมเหตุสมผล ส่งผลให้การบริหารจัดการและการวางแผนการผลิตมีประสิทธิภาพและช่วยลดต้นทุน และเป็นข้อมูลประกอบการกำหนดนโยบายที่เกี่ยวข้อง

สาขาวิชา การจัดการด้านโลจิสติกส์	ลายมือชื่อนิสิต ....
ปีการศึกษา 2556	ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์หลัก ....
	ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์ร่วม ....

5387810020 : MAJOR LOGISTICS MANAGEMENT
KEYWORDS: UNCERTAINTY / INVENTORY MANAGEMENT / PETROLEUM PRODUCTS / OIL FUND / MARKETING MARGIN / FUTURES PRICE

WEERAWICH ROEKCHAMNONG: AN ANALYSIS OF UNCERTAINTY IN INVENTORY OF PETROLEUM PRODUCTS. ADVISOR: ASSOC. PROF. PONGSA PORNCHAIWISESKUL, Ph.D., CO-ADVISOR: ANANT CHIARAWONGSE, Ph.D., 76 pp.

This dissertation studies the relationship between uncertainties and inventory management in the context of Thai's petroleum market. The main objective of the study is to examine the effects of interested factors on inventory management, defined as an inventory to sale ratio; and on uncertainty in inventory management of petroleum products related to transportation purpose, including Gasohol (GSH), Unleaded Gasoline (ULG), and High Speed Diesel (HSD). The factors of interests include uncertainties in ex-refinery price, oil fund, futures price, and marketing margin. The analysis of the dissertation is divided into two parts regarding the factors being studied.

The first part of this dissertation examines (i) the relationship between uncertainty and inventory management and (ii) the impacts of uncertainties in ex-refinery price, oil funds, and futures price on uncertainty in inventory management, measured as a conditional variance of the IS ratio. A Generalized Autoregressive Conditional Heteroskedasticity in Mean (GARCH-M) framework is employed and fitted with the monthly data from January 2008 to June 2013. The results indicated that uncertainty induces businesses to hold more of the IS ratio than required as expected. The sensitivity analysis reported that uncertainty in ex-refinery price contributes mostly to the uncertainty in inventory management, while the impact of uncertainty in the oil fund on uncertainty in inventory management is relatively small. Interestingly, the result indicated that uncertainty in futures price can help mitigate uncertainty in inventory management and give support to the existence of the futures market.

The second part employs a system of simultaneous GARCH-M equations for inventory management and marketing margin to investigate how marketing margin and its uncertainty affect inventory management. The interrelationship of inventory management and marketing margin is incorporated into the analysis of uncertainties. Using weekly data, the results suggested positive interrelationships between inventory and marketing margin in general cases of GSH and HSD. For ULG, the interrelationship is reported to be negative and is expected to be as a result of the government promotion on the usage of GSH. Shocks in marketing margin positively affect uncertainty in inventory management that, in turn, gives rise to inventory holding. The effects of uncertainty in marketing margin on inventory management are found to be positive for ULG and HSD and negative for GSH. The policy implications involve the control of marketing margin within bands that required a periodic adjustment of taxes and/or oil funds.

The model framework in this study allows for estimation of the uncertainty that helps the businesses to more efficiently manage and plan their inventory accordingly. The results of this study contribute to a better understanding of petroleum product inventory behavior in Thailand and also have implications for uncertainty management of oil.

Field of Study: Logistics Management	Student's Signature ....
Academic Year: 2013	Advisor's Signature ....
	Co-Advisor's Signature ....

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Any errors or inadequacies that may remain in this dissertation is entirely my own responsibility.

CONTENTS

Page

LIST OF TABLES

Page

LIST OF FIGURES

Page

LIST OF ABBREVIATIONS

ARCH	Autoregressive Conditional Heteroskedasticity
DOEB	Department of Energy Business
EPPO	Energy Policy and Planning Office
FO	Fuel Oil
GARCH	Generalized Autoregressive Conditional Heteroskedasticity
GARCH-M	Generalized Autoregressive Conditional Heteroskedasticity in Mean
GDP	Gross Domestic Products
GSH	Gasohol
HSD	High Speed Diesel
IS	Inventory to Sale
JF	Jet Fuel
LPG	Liquid Purified Gas
OLS	Ordinary Least Squared Methods
SA	Stock-Adjustment Model
TA	Target-Adjustment Model
ULG	Unleaded Gasoline

Chapter I

INTRODUCTION

The consumption of energy in Thailand amounted to 2,139 billion baht, accounted for 19% of the country's Gross Domestic Products (GDP) in 2012. The consumptions of petroleum products shared 61% of the total energy consumptions in that year. The value of energy imported in 2012 was 1,423 billion baht or 12.5% of GDP and the ratios of energy imported to GDP have increased steadily over time. Since Thailand cannot sufficiently produce oil to serve the domestic consumptions, the domestic petroleum market depends on crude oils from the world market, mostly from the Middle East. This implies that the country is subject to uncertainty from the world market, especially uncertainty in the price of oil. The uncertainty from the world market directly affects domestic oil price and, of course, demand and supply in the market. In case of Thailand, energy price uncertainty affects key macroeconomic variables, such as unemployment rate, interest rate, and trade balance (Rafiq, Salim et al. 2009). There have been government attempts to stabilize the domestic oil price with mechanisms such as excise taxes and oil funds. For security purpose, oil businesses are required to hold Strategic Petroleum Reserves (SPR) in response to the market uncertainty. Generally, inventories of petroleum product are crucial in stabilizing the domestic oil market.

Inventory is held at many points in a petroleum products supply chain and plays beneficial roles. Crude oil inventory is needed for refinery operation purpose and the inventories of refined products are essential in moderating the imbalance of domestic demand and supply. Holding inventory serves as an economic method of meeting customers demand as compared to more timely and costly increase of production or import the products from the world market. Inventory may also serve as a financial opportunity when an inventory agent expects that future price will be substantially different from the current price. The nature of the present petroleum market is such that supply chain members seek to maintain their competitive advantage in the market environment with an increasing in demand and volatile oil prices. It is imperative for oil companies to optimally manage their inventories to be able to meet requirements and to avoid over or under stocking that can affects their performance.

Inventory management involves a determination of an optimal inventory to sale ratio (hereafter the IS ratio) that reflects a business decision and control over both inventory and sales (Bechter and Pollock 1980). An analysis of the IS ratio is also crucial in understanding inventory behavior and the business cycles (Bassin, Marsh et al. 2010). The historical data on inventory and sale levels and the IS ratios of petroleum products of the Thai market are shown in figure 1.

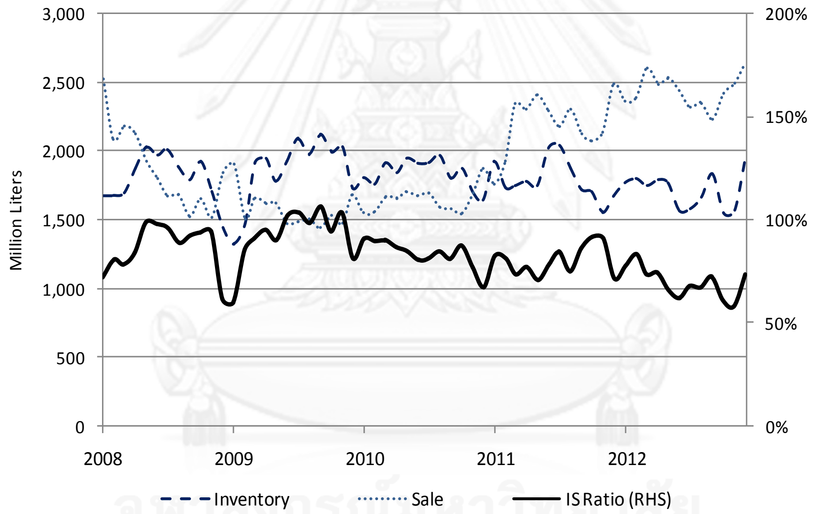

Figure 1 Inventories, sales, and the IS ratios

Source: Department of Energy Business

As of the end of 2012, inventories for petroleum products in Thailand, including (i) Unleaded Gasoline Products (ULG)[1], (ii) Gasohol Octane Number 95 E10 (GSH95), (iii) Gasohol Octane Number 95 E20 (GSH95E20), (iv) Gasohol Octane Number

[1] ULG product composes of ULG octane number 91 (ULG91) and ULG octane number 95 (ULG95). The service of ULG91 was, however, discontinued in March 2013.

91 E10 (GSH91), and (v) High Speed Diesel (HSD), amount to 1,915 million liters with the value of 54,700 million baht. The sales figure for the month of December 2012 was 2,630 million liters or the value of 76,820 million baht. The HSD product contributed to approximately 60% of the total sales, followed by ULG products with a share of 20%, and the GSH products contributed for the remaining 20%. The IS ratios have fluctuated in the range between 50% and 100% over the period. As of the end of December 2012, the IS ratio was approximately 73%.

As seen from Figure 1, the actual IS ratio is fluctuated, but it is difficult to determine whether the actual ratio deviates from the optimal level that was actually planned. The first task is then to identify the optimal level of inventory. The basic stock-adjustment models (hereafter the SA model), introduced by Metzler (1941), Lovell (1961), and others, can be regarded as a simplified form of the full inventory optimization models that provide a useful framework for empirical works on inventory behavior. The advantage of the framework is that it allows for analysis of inventory behavior in relations with interested factors. Typical factors include interest rates, sale expectations, firm specific financial constraints, price expectations, and uncertainty in demand. The SA model has been extensively used in inventory studies and modifications of the SA model have been made to improve the fitness of the model. Among these modifications are the Target-Adjustment model by Feldstein and Auerbach (1976) and the IS model by Bechter and Pollock (1980).

Uncertainty is relevant in the model because uncertainty makes it difficult for businesses to maintain the IS ratio at its optimal level. Bechter and Pollock (1980) pointed out that uncertainty in sales affects the IS ratio because businesses cannot fully control sales. It is also arguable that businesses cannot also fully control inventory because uncertainty in supply can have an impact on inventory. Thus, market uncertainties make both sale and inventory uncertain and cause the deviation of the actual ratio from its optimal level. This situation is defined as uncertainty in inventory management. Specifically, uncertainties cause the business to over or under stocking inventory from the planned or desired level, which is illustrated in Figure 2 below. Another importance of uncertainty in inventory studies is that it directly affects inventory behavior. Empirical evidences show that an increase in uncertainty in sale leads to an increase in inventory holding [see for example, Rubin (1980), Bo (2001), and Caglayan, Maioli et al. (2012)]. Excess holding of petroleum inventory to ensure adequate supply can generate significant carrying costs, while failing to meet the clients’ demand because inadequate supply may lead to loss of sales that would otherwise gain from sales. Considering the size of the petroleum market, the costs could be economically significant that motivates the investigation of the relationship between uncertainty and inventory management.

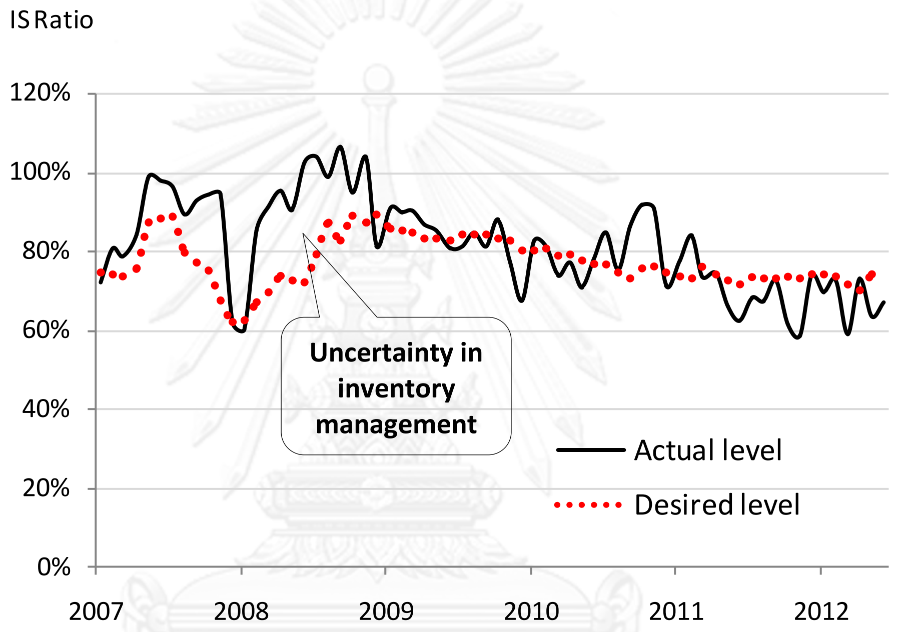

Figure 2 Illustration of uncertainty in inventory management concept

Despite numbers of research regarding the relationship between uncertainty and inventory, how market uncertainties affect uncertainty in inventory management and how uncertainty in inventory management affects inventory behavior have not been given attention. To the author’s knowledge, there is no existence research regarding the relationship between uncertainty and petroleum inventories in the context of Thailand. The main objectives of this dissertation are (i) to examine how uncertainties in ex-refinery price, oil fund, and futures price affect uncertainty in inventory management and inventory behavior, and (ii) to investigate whether marketing margin and its uncertainty affect inventory management in the context of Thai’s petroleum market. The scope of the study is on the above mentioned uncertainties and the focus is on the products related to transportation purpose including Gasohol (GSH), Unleaded Gasoline (ULG), and High Speed Diesel (HSD).

The analysis of this study can be divided into two parts serving the two main objectives. The first part involves the investigation of the effects of uncertainties in ex-refinery price, oil fund, and futures price on uncertainty in inventory management and inventory behavior. These uncertainties are considered exogenous to inventory management. The ex-refinery price is determined by the oil refinery based on the Singapore market price using import parity basis. It accounts for the largest component of the domestic retail price and represents the movement of the oil price in the world market. It is then expected that uncertainty in ex-refinery price has a strong effect inventory management. The oil fund is a government tool to stabilize the domestic retail price and the operation of oil funds can lead to uncertainty in the product price. In that sense, the variations of the oil fund affect inventory management. The futures price traded in the exchange market reflects the expectations and views on price of oil by market participants. The information contained in the futures price and the futures market can then help the oil business to manage their inventories.

The analysis, therefore, applies a modification of the IS ratio model of Bechter and Pollock (1980) with a Generalized Autoregressive Conditional Heteroskedasticity in Mean (GARCH-M) framework to explore (i) the relationship between inventory management and uncertainty in inventory management; and (ii) the effects of uncertainties in ex-refinery price, oil fund, and futures price on uncertainty in inventory management in the context of Thai petroleum market. The impacts of the uncertainties on inventory holding are estimated and sensitivity analysis is provided to help identify the contribution of variables.

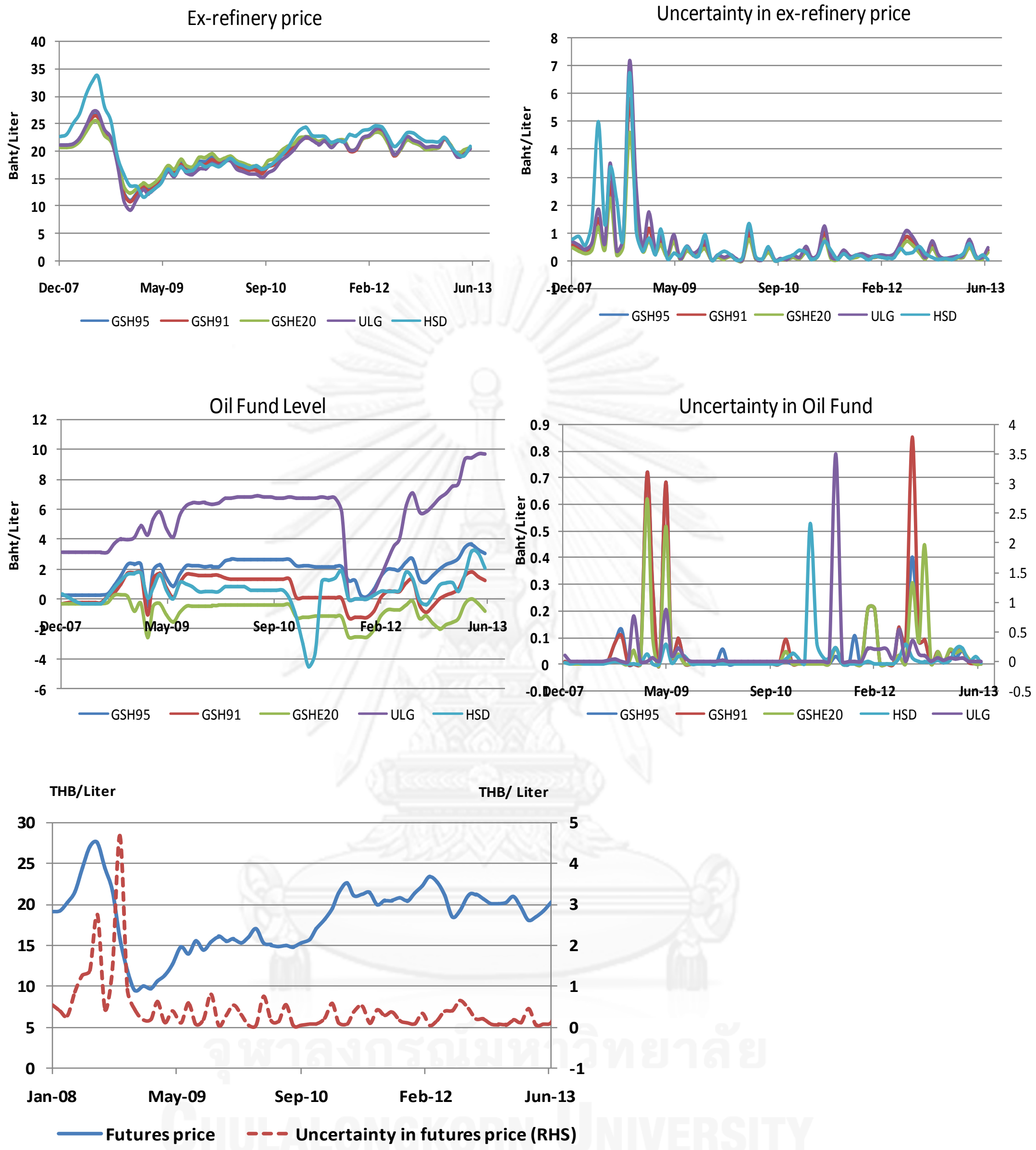

Figure 3 Historical level and uncertainty of ex-refinery price, oil fund and futures price.

Source: Energy Policy and Planning Office and the author's calculation

The second part of the analysis considers whether marketing margin and its uncertainty affect inventory management. This study requires separate analysis because, like inventory, marketing margin is also determined by the oil businesses. Specifically, marketing margin is set by the major oil companies with an intention to cover operational costs, including storage, overhead, distribution and normal profit. The marketing margin represents revenue of both the oil trading companies and retail service stations. Since marketing margin of petroleum products represents the profitability of the businesses, uncertainty in the profitability can affect the management of product inventories. Figure 4 plots historical marketing margin over the period of study. The relatively low margin since 2009 is because of increasing market competition that forces the oil companies to maintain their market share by keeping the margins low.

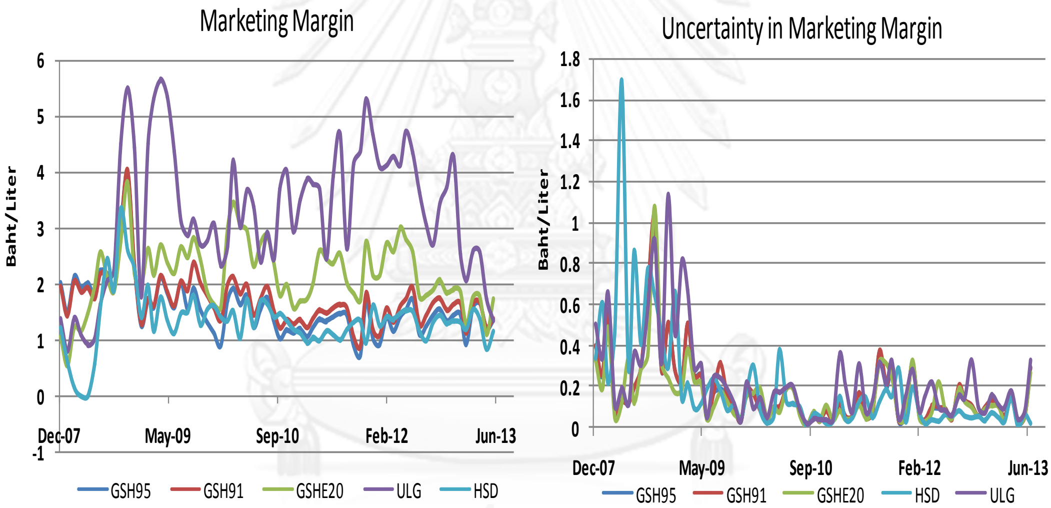

Figure 4 Marketing margin and its uncertainty

Source: Energy Policy and Planning Office and the author's calculation

The decision on marketing margin cannot, however, be done without taking other business factors into account. One important factor is, of course, inventory. Literatures in operation management and retail supply chain suggest a simultaneous relationship of business decisions involving the determination of inventory level and the setting of margin (price). Specifically, the literatures suggest that higher margins give rise to inventory holding, while higher inventory likely leads to future markdowns. The observations on the Thai's market are, however, not consistent with the claim in the literatures.

Figure 5 plots the change in marketing margin and inventory to sale ratio for petroleum products using the monthly data from January 2008 to June 2013. The points represent the changes in marketing margin against the change in the IS ratio at the certain time period and the straight line represents the trend line of the data. The figure suggests that the interrelationship between marketing margin and the IS ratio are positive. Specifically, a positive change in marketing margin is associated with a positive change in the IS ratio, and vice versa.

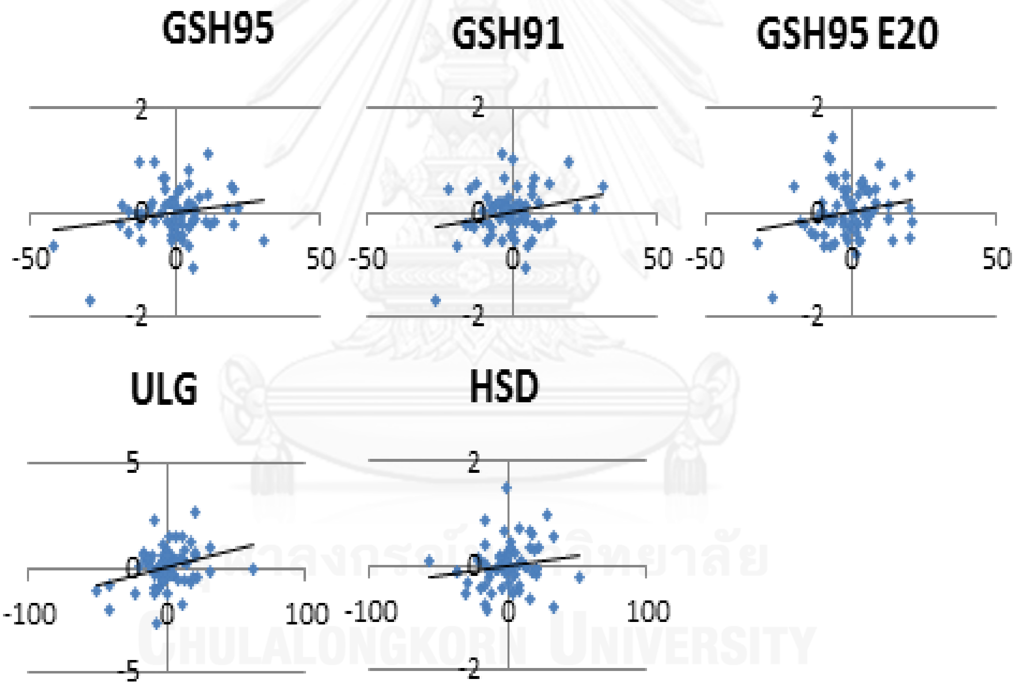

Figure 5 Changes in marketing margin and the IS ratio

Source: Energy Policy and Planning Office and Department of Energy Business

It is arguable that the inconsistent results of the interrelationship between the marketing margin and the IS ratio arises from the specific structure of the petroleum market. Petroleum inventories are hold mostly by refineries and major oil trading companies that also own retail businesses. Because the market power of the oil companies, they are price-setting agents and other retailers in the market are price-takers. Therefore, an increase in marketing margin tends to induce the oil companies to increase their inventory holdings in response to anticipated higher profits. An increase in inventory holding, in turn, tends to induce an increase in marketing margin. Since the storage of petroleum product requires specific storage facilities that are, at least in the short run, fixed in capacity level, oil companies are discouraged to raise the product inventories toward its capacity level. The overstocking of petroleum products incurs expensive holding cost arising from building additional storage capacity and this gives incentives for the oil companies to liquidate the stocks by reducing the refining margin. Given that the retail price remains constant, this results in a higher marketing margin. This induces oil traders and retailers to purchase the products and is also to give incentives for other retail petroleum stations to put their efforts on promotion and raise demand for the products and to compensate for their stocking of the products. This argument suggests that inventory and marketing margin are mutually endogenous and a study of the relationship between inventory and marketing margin requires a model framework that is able to incorporate this nature.

In addition, research studies regarding the impact of uncertainties on inventory and margin behavior have not been given much attention on the interrelationship between the two variables. Because inventory and margin are interrelated, the uncertainty in marketing margin will have an impact on inventory holdings and vice versa. In particular, the uncertainty in marketing margin represents the uncertainty in the profitability of the oil companies and it tends to make sale uncertain and make it difficult for businesses to maintain their inventories at optimal level. This part of the analysis contributes to current inventory studies by incorporating the interrelationship between marketing margin and inventory into the analysis of uncertainty. A system of simultaneous Generalized Autoregressive Conditional Heteroskedasticity in Mean (GARCH-M) equations for inventory and marketing margin for Thai's petroleum products, including Gasohol (GSH), Unleaded Gasoline (ULG), and High Speed Diesel (HSD) is employed and the sensitivity analysis is performed to give a clearer picture on the direct and marginal effects of uncertainties.

Addressing the empirical linkages between uncertainties and inventory management is important because uncertainties imply inventory holdings and excess holding of inventory to buffer uncertainties generates significant holding cost, which in turn affects marketing margin and hence the retail price. Considering the size of the petroleum market, the costs could be economically significant that motivates the investigation of the relationship between uncertainties and inventory management. The ability to reasonably estimate the uncertainty is, therefore, of great benefit because it enables the businesses to more efficiently manage and plan their inventory accordingly. An analysis of uncertainties also contributes to better understanding of the inventory management of petroleum products.

The next chapter briefly discusses the petroleum market in Thailand and related literatures. The chapter III describes the methodology and empirical model specification. The statistical results from the model are then presented in the chapter IV. The last chapter provides discussion and concludes the study.

Chapter II

LITERATURE REVIEW

This chapter starts by the review of petroleum market in Thailand. The structure of Thai's petroleum market is first discussed, following by the review of retail pricing structure of oil and related literatures regarding the Thai market. The basic SA model is presented with related results from literatures. The concept of the interrelationship between margin and inventory is reviewed. Finally, related literatures regarding the effects of uncertainty on inventory behavior are reviewed and the application of a GARCH model to uncertainty modeling is provided.

2.1 Review of petroleum market in Thailand

Thailand relies heavily on imports of crude oil, because the capacity to produce oil domestically is limited. According to the Thailand Energy Situation Report in 2012 by Ministry of Energy, the country imported crude oil amounting to 860 thousand barrels a day, while the domestic production was 149 thousand barrels a day. As shown in Figure 6, crude oil is major input of the production of petroleum products for refining companies. The majority of refined products include High Speed Diesel (HSD), Liquid Purified Gas (LPG), Unleaded Gasoline Octane 91 and 95 (ULG91 and ULG95), Gasohol (GSH91 E10, GSH95 E10, GSH95 E20, GSH95 E85), Jet Fuel (JF), and Fuel Oil (FO).

There are currently seven refineries in Thailand, including 1) ESSO (Thailand) Co., Ltd., 2) Bangchak Petroleum Public Co., Ltd., 3) Thai Oil Public Co., Ltd., 4) PTT Aromatics and Refining Public Co., Ltd., 5) Star Petroleum Refining Co., Ltd., 6) IRPC Public Co., Ltd., and 7) Rayong Purifier Public Co., Ltd. The refining production in the year was 1,082 thousand barrels a day, accounting for 90% of the total domestic refining capacity. Most of refined products were consumed domestically, with the amount of 709 thousand barrels a day and the import and export of refined products were netted to the export value of 158 thousand barrels a day.

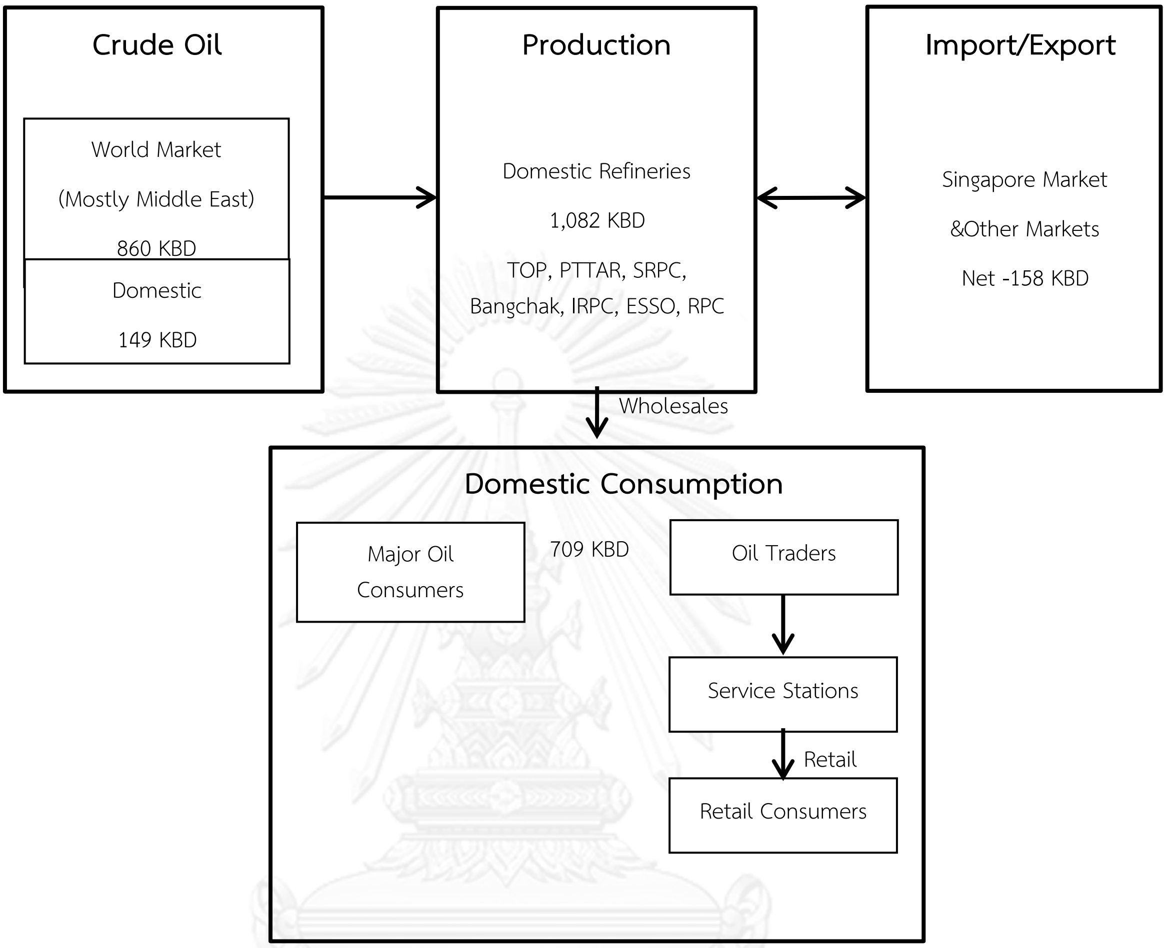

Figure 6 Structure of Thai petroleum market

According to the market structure, the refining companies wholesale their refined products to the major consumers for agricultural, transportation, and industrial purposes and oil traders. According to the article 7 of the Fuel Trade Act B.E.2543 (2000), there are currently 41 oil traders with trade volume of each or all type of product exceeding one hundred thousand metric tons per year or trade volume of LPG exceeding fifty thousand metric tons. The major oil trader companies include PTT Public Co., Ltd.; Bangchak Petroleum Public Co., Ltd.; ESSO (Thailand) Co., Ltd.; Shell (Thailand) Co., Ltd.; and Chevron (Thailand) Ltd. The oil traders sell the refined products through their retail network of service stations to retail energy consumers. As of November 2013, there are over 22,000 of service stations in the market that are registered with the Ministry of Energy. PTT Public Co. Ltd. is the market leader in price setting and accounted for the largest share of the sale volume in the market in 2012 as shown in Figure 7 below.

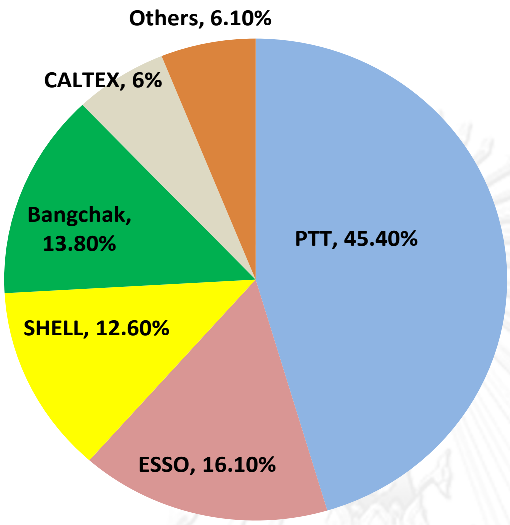

Figure 7 Market share by sale volume through services stations (January-September 2012)

Source: Jarurungsipong and Rakthum (2013)

Annual production, import, export and consumption of petroleum products from 2009 to 2012 are summarized in Table 1. Overall production of refined products has increased in response to increasing in demand for domestic consumption and export during the period. HSD shared the largest portion of 43% of the production in 2012, followed by LPG (21%), fuel oil (11%), jet fuel (10%), ULG (8%), GSH products (7%), and kerosene (0.15%). Decreasing in production of premium gasoline during the period was because of increasing demand for substitute products, namely GSH products. Import figures for refined products were only 466 million liters, which is much smaller compared to the production number. The largest share of product imported was fuel oil with the import value of 395 million liters. One fifth of 2012 refined products supply was exported. The amount exported was 11,641 million liters. HSD shared 47% of the total export volume, followed by FO (33%) and ULG91 (13%).

Overall domestic consumption of petroleum products has increased steadily over the 4-year period. Consumption of petroleum products in 2012 was 44,198 million liters, an increase of 5.12% from previous year. The majority of products consumed were HSD (47%), LPG (19%), GSH products (10%), and ULG (7%). The consumption of HSD in 2012 was at 20,584 million liters, an increase of 11.17% from the previous year. The increase in HSD consumption was as a result of economic growth and the government policy attempting to stabilize the diesel price by reducing the excise taxes.

LPG consumption shows an increasing trend over the period. In 2012, the LPG consumption was equivalent to 2,975 million liters, an increase of 6.26% from previous year. LPG was consumed by the residential and commercial sector (41%), followed by petrochemical industry (35%), and transport sector (14%). The consumption of ULG products (octane 91 and octane 95) decreased by 3.11% from the previous year and was recorded at 3,021 million liters in 2012. The ULG91 was discontinued in March 2013 to encourage the consumption in gasohol product instead of regular gasoline. The government policy to promote use of gasohol consumption via pricing with subsidy has boosted the consumption of GSH products, mainly E10 and E20 in 2012. The total consumption of gasohol products increased 9.39% from the previous year and was recorded at 4,609 million liters in 2012. GSH95 E10 shared the largest portion of 52% of the total gasohol consumptions, followed by GSH91 E10 (42%), GSH95 E20 (5.5%), and GSH95 E85 (0.5%).

Table 1 Production/ import/ export/ and consumption of petroleum products in million liters

Year	LPG	ULG91	ULG95	Gasohol	Jet Fuel	Kerosene	HSD	HSD B5	Fuel Oil	Total
1	Production									
2009	9,147	3,778	618	4,455	5,975	103	14,349	8,149	6,920	53,495
2010	10,522	3,748	623	4,371	6,196	476	16,275	7,040	6,031	55,282
2011	11,696	3,841	276	4,208	6,293	161	22,434	673	5,846	55,428
2012	12,231	4,586	158	4,353	5,786	89	24,900	0	6,154	58,257
2	Import									
2009	-	14	-	0	11	-	385	-	83	493
2010	16	-	-	0	3	-	62	-	101	182
2011	45	18	-	0	11	-	56	-	332	462
2012	5	46	-	0	3	-	17	-	395	466
3	Export									
2009	28	904	447	0	1,609	19	4,797	-	3,878	11,682
2010	46	805	540	0	1,405	426	5,517	-	3,234	11,973
2011	30	730	238	0	1,202	107	4,705	-	3,483	10,495
2012	18	1,484	108	1	742	34	5,439	-	3,815	11,641
4	Consumption									
2009	6,450	2,877	177	4,470	4,432	18	10,318	8,156	2,762	39,661
2010	7,194	2,957	77	4,382	4,712	15	11,443	7,053	2,646	40,479
2011	7,936	3,077	41	4,213	5,077	13	18,516	690	2,482	42,045
2012	8,433	2,975	46	4,609	5,335	16	20,584	-	2,200	44,198

Source: Energy Statistics of Thailand 2013, Energy Policy and Planning Office.

Inventories data for petroleum products are obtained from the Department of Energy Business, Ministry of Energy. The monthly data are available for ULG, GSH, HSD, LPG, palm oil, JF, and FO. While the inventory levels of gasohol products show an upward trend, the inventory level for ULG products appears to decline over time as a result of increasing usage of alternative GSH products. As of December 2012, inventories of all petroleum products summed up to the amount of 2,428 million liters, which is approximately 53.22% of the sales volume in the same month. Inventories of HSD accounted for 57% the total petroleum inventories, followed by GSH products (16%), FO (14%), and ULG (7%).

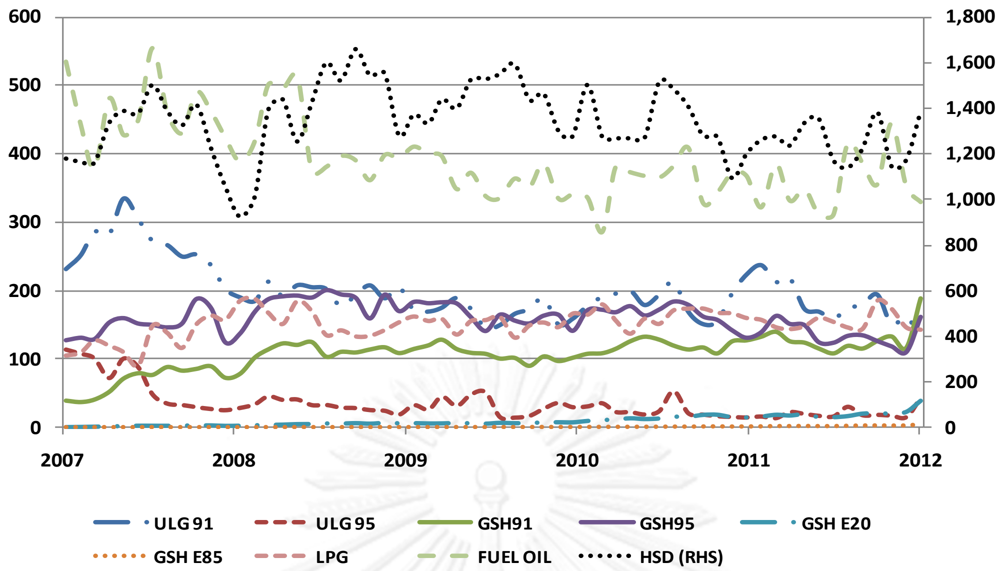

Figure 8 Ending inventory level for petroleum products in million liters

Source: Department of Energy Business

Refined product price structure can be divided into three parts: ex-refinery price, wholesale price, and retail price. The ex-refinery price is determined by the refineries using the import parity basis based on Singapore market as the reference market. Singapore market is the largest export market in the region with large trading volume that makes it difficult to speculate on the price. The Singapore market price movement is consistent with the movement of oil prices in other markets and the price volatility in the Singapore market is relatively low. Moreover, the market is the nearest market place to Thailand and hence represents the lowest import cost for oil traders. The ex-refinery price, then, depends on the Singapore price and the exchange rate, which constitutes the value of product import, adjusted with the adjustment in different product quality, logistics cost, insurance and refinery margin.

The wholesale price of each product is given by the following structure;

$$\text{Wholesale price} = \text{Ex-refined price} + \text{Excise Tax} + \text{Municipal Tax} + \text{Oil Fund} + \text{Conservation Fund} + \text{VAT} \quad (1)$$

The retail price of each product is then determined by the following;

Retail price = Wholesale price + Marketing Margin + VAT (2)

Before deregulation of retail oil price in 1991, the retail price remains relatively unchanged as compared to the movement of world market price because the government used taxes and the oil fund mechanisms to stabilize the domestic oil prices. After the price deregulation, the retail price movement is more closely in line with the movement of the ex-refinery price. However, the price structure still allows the government to control retail price via setting of tax rates and the oil fund. The conservation fund component is constant and is collected by the government and will be used to finance an energy conservation projects. The marketing margin is set by an oil company with an intention to cover operational costs, including storage, overhead, distribution and normal profit. Figure 9 below shows examples of ex-refinery prices and retail prices of ULG91 and ULG95. It can be seen from the graph that the gaps between the two prices represent the components of taxes, oil fund, conservation funds, and marketing margin as shown in equation (1) and (2).

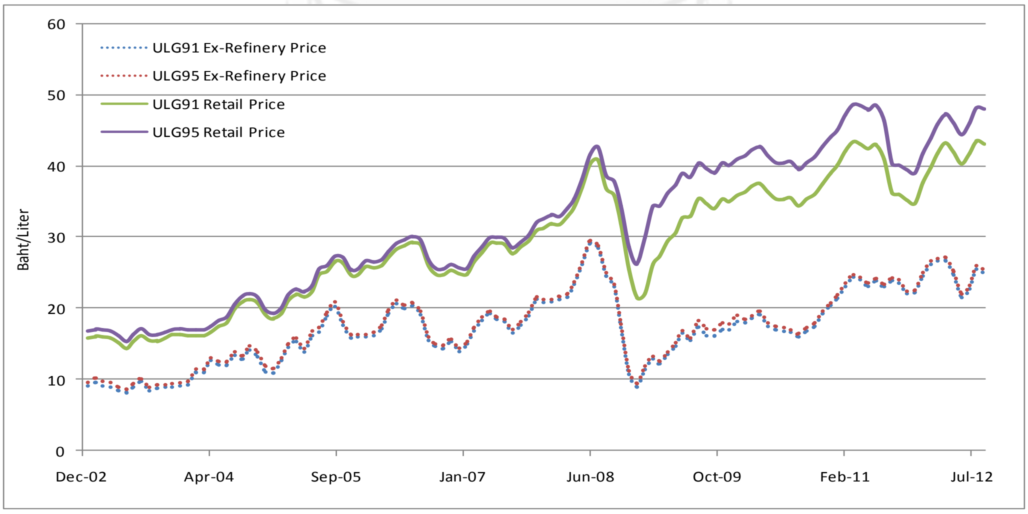

Figure 9 Ex-refinery price and retail price of ULG91 and ULG95

Source: Energy Policy and Planning Office

Table 2 Example of price structure of petroleum products in Bangkok as of 28 September 2012

UNIT : BATH/LITRE	EX-REFIN. (AVG)	TAX B./LITRE	M. TAX B./LITRE	OIL FUND (1)	CONSV. FUND	WHOLESALE PRICE(WS)	VAT	WS&VAT	MARKETING MARGIN	VAT	RETAIL PRICE
ULG 95R ; UNL	25.3626	7	0.7	7.4	0.25	40.7126	2.85	43.563	4.0538	0.2838	47.9
ULG 91R ; UNL	24.924	7	0.7	6.1	0.25	38.974	2.728	41.702	1.2596	0.0882	43.05
GASOHOL95 E10	25.0795	6.3	0.63	1.7	0.25	33.9595	2.377	36.337	1.2087	0.0846	37.63
GASOHOL91	24.861	6.3	0.63	-0.6	0.25	31.441	2.201	33.642	1.4375	0.1006	35.18
GASOHOL95 E20	24.7104	5.6	0.56	-0.9	0.25	30.2204	2.115	32.336	1.7236	0.1207	34.18
GASOHOL95 E85	21.4589	1.05	0.105	-11.8	0.25	11.0639	0.775	11.838	9.4782	0.6635	21.98
HIGH SPEED DIESEL(0.035%S)	25.8606	0.005	0.0005	0.2	0.25	26.3161	1.842	28.158	1.525	0.1067	29.79
FO 600 (1) 2%S	20.7496	1.1545	0.1154	0.06	0.07	22.1495	1.551	23.7			
FO 1500 (2) 2%S	20.092	1.1065	0.1107	0.06	0.07	21.4392	1.501	22.94			

UNIT:BAHT/KILO	EX-REFIN. (AVG)	TAX B./KILO	M. TAX B./KILO	OIL FUND (1)	CONSV. FUND	WHOLESALE PRICE(WS)	VAT	WS&VAT	OIL FUND (2)	MARKETING MARGIN	VAT	RETAIL
LPG (COOKING)	10.5057	2.17	0.217	0.7936	0	13.6863	0.958	14.644		3.2566	0.228	18.13
LPG (AUTOBILE)	10.5057	2.17	0.217	0.7936	0	13.6863	0.958	14.644	3.0374	3.2566	0.4406	21.38
LPG (INDUSTRY)	10.5057	2.17	0.217	0.7936	0	13.6863	0.958	14.644	11.22	3.2566	1.0134	30.13

Source: Energy Policy and Planning Office

There are several related academic studies regarding the petroleum market in Thailand. Most of study focuses on modeling consumption of petroleum products and the relationship with economic growth. Asafu-Adjaye (2000) estimated the causal relationships between energy consumption and income for four Asian developing countries, including India, Indonesia, the Philippines, and Thailand. Cointegration and

Error Correction Model (ECM) techniques were employed to analyze the time-series properties of the data. The estimations for Thailand, like that of the Philippines, showed bidirectional Granger causality runs from energy to income. For the long-run, energy, income, and energy price were mutually casual.

Leesombatpiboon and Joutz (2010) examined the short-run and long-run determinants of energy consumption in seven major economic sectors, namely agriculture, construction, electricity, manufacturing, mining, residential and commercial, and transport sectors. Their research approach was to first develop a dynamic panel data method for the aggregate consumption of the economy and then separately employ Autoregressive Distributed Lag (ADL) equilibrium correction framework to model the oil demand for each sector. The model includes standard demand variables, which are price, income, price of substitute product, and labour and capital as production function input determinants. The main result from aggregate consumption model was that the long-run responses, derived from ADL, were larger than the short-run responses, derived from Error Correction Model (ECM), for all variables. The results for each sector indicated that the own-price elasticities were negative in both short-run and long-run. The short-run estimates were less elastic than the long-run estimates for the price. The income elasticities were positive and inelastic. The long-run labour elasticities were approximately unity.

Tongchuang and Thoongsuwan (Undated) analyzed the factors affecting gasohol E20 consumption and developed a forecasting model for gasohol consumption in Thailand. The study indicated that consumption of gasohol E20 rose steadily over 2008-2009 because of the government strategic plan and policy to promote the usage of gasohol E20. Using multiple regressions, they found that, at the significant level of 0.05, the retail price of gasohol E20, the retail price of gasoline 95, and the retail price of gasoline 91 were factors that help determine gasohol E20 consumption. As expected, the retail price of gasohol E20 was negatively correlated with its consumption, while the retail price of gasoline 95 and gasoline 91, which are considered substituted products, were positively correlated with gasohol E20 consumption. The elasticity of prices were estimated and reported to be -22.6435, 9.2085, and 7.0456, for retail prices of gasohol E20, gasoline 95, and gasoline 91, respectively.

Recent paper by Tansawat, Pochan et al. (2012) developed a transport energy consumption model for Thailand provinces using linear and log-linear relationship. They utilized historical data in 2007 and cross-sectional data on Gross Provincial Product, number of vehicles, number of gas station for each province were used to analyze the relationship with energy consumption. Bangkok data was excluded from the analysis as there was remarkable variation in figures between Bangkok and other provinces. The results from linear regression showed that all the variables, except the dummy variables for North and North East, have a positive relationship with energy consumption. The log-linear regression model also confirmed the positive relationship, but the income variable, GPP, being the most influential factor.

Academic researches regarding price structure of petroleum products in Thailand focus on the current inefficient price structure that generated welfare lost to the economy. Vikitset (Undated) examined the retail pricing structures of ULG and HSD that were characterized by cross-price subsidy from ULG consumers to the HSD consumers. The author estimated the demand functions of ULG and HSD and then calculated the welfare loss from the estimation. The optimal pricing policy was obtained using Linear Programming (LP) technique to find solution to Lagrangean welfare loss function that would generate the same amount of tax revenue as existing structure but minimize welfare loss and economic costs. The welfare-loss, estimated from demand equations, showed that the cross price subsidy from ULG to HSD increased the welfare gain to HSD consumers at the expense of ULG consumers. The policy, however, increased economic costs of the two products. The optimal pricing policy was found to be the pricing structure that would equalize the retail price ratios of ULG and HSD to their marginal economic cost ratios. Given that the tax rates remained unchanged, this can be achieved by the variation of oil funds.

Chenphuengpawn (2012) studied the price structure of Biodiesel B5 during 2007-2011, the period in which the retail price was subsidized by taxes and oil fund of HSD. Similar to Vikitset (Undated) study, the paper estimated variations in demand and supply of both HSD and Biodiesel B5 using Ordinary Least Squared (OLS) regressions and calculated the economic loss arising from the cross-price subsidy policy. The simulation of pricing policy was obtained using Linear Programming (LP) technique. The economic loss was estimated to be 11,497 million Baht for the whole period, mainly occurred in the HSD market, and was found to be an increasing function of Biodiesel B5 consumption. The economic model was simulated and the results were consistent with that of Vikitset (Undated) in that the author supported the continuity of taxes collection, but not the cross-price subsidy. The tax collected should, however, be a function of social cost of externalities arising from fuel usage. The oil fund should play a role to stabilize the retail prices only. Finally, to avoid for the loss, the government should monitor and utilize the tax rates as a tool to make the proportions of retail prices and cost of the two fuel equal.

Vikitset (2013) recently studied the role of oil funds in stabilizing the price of petroleum products before and after the introduction of alternative energy products, namely GSH and Bio Diesel in 2007. Using linear regression for each period, the author found that the oil funds acted as a tax instruments for gasoline and HSD products. The oil fund rates were directly varied according to the cost of the products. After 2007, the regression results reported that the oil funds operations help stabilize the domestic retail prices of all products. The cross-subsidy feature was reported and it is found that the GSH91 consumers were the major contributors to the oil funds and the GSH95 E85 consumers were the major receivers of the funds. The balance of the fund account can be both in surplus or deficit depending on the degree of price subsidy in that period.

2.2 Review of the Stock-Adjustment model

The basic SA models, developed by Metzler (1941), Lovell (1961), and others, has been regarded as a simplified form of the optimization models of inventory problem that provide a useful framework for empirical works on inventory behavior. The models postulated that inventories change because (i) businesses partially close the gap between the current inventory level and the desired inventory level, and (ii) because of unanticipated sales. A partial SA model can be written as:

$$I_t\text{-}I_{t\text{-}1} = \lambda\left(I_t^*\text{-}I_{t\text{-}1}\right) + \delta(S_t^e\text{-}S_t) \tag{3}$$

where I_t and I_t^* denote the actual and desired stock of inventories at the end of period t, S_t and S_t^e denote actual and expected sales during period t, and λ is referred to as the speed of adjustment coefficient. Equation (3) states that one period change in inventory stock is a fraction, λ, of desired change in inventory and a fraction, δ, of the difference in expected and actual sales. Assuming the desired stock level depends linearly on sales $(I_t^* = \gamma_0 + \gamma_1 S_t)$ and expected sales are measured by previous period sales $(S_t^e = S_{t\text{-}1})$, a partial SA model might be represented as:

$$I_t = \lambda\gamma_0 + \lambda\gamma_1 S_t + \delta\left(S_{t\text{-}1}\text{-}S_t\right) + (1\text{-}\lambda)I_{t\text{-}1} \tag{4}$$

Early works in the field have shown that the framework did not perform well empirically because estimates of parameters were not reasonable. Specifically, the speed of adjustment to desired stocks (λ) estimates were unbelievably small, implying that the adjustment costs of inventories to its desired level are expensive. These results did not coincide with the large estimates of δ, which imply an immediate adjustment of inventories in response to unanticipated sales[2]. Despite the critiques on its performance, the framework provides a foundation of various useful analysis of inventory behavior that follows. Feldstein and Auerbach (1976) proposed a target-adjustment model of immediate inventory adjustment to a slowly changing inventory target, but the inventories adjust immediately to change in target level. They showed empirically that the model is better consistent with the estimated parameters and with the characteristics of inventory and sales expectations. Bechter

[2] The basic partial SA model was preliminary tested with petroleum inventory dataset. The results show that the adjustment speed λ is very small around 3%, while the estimate of δ implies that around 80% of the effect of unanticipated sales is adjusted within a month. These results are consistent with the claim in literatures (Appendix 1).

and Pollock (1980) introduced an IS model that reflects recognition of the fact that both sales and inventories are jointly controlled by businesses. The model is consistent with the target-adjustment model of Feldstein and Auerbach (1976).

The flexibility of the SA framework also allows researchers to conveniently study the relationships between interested factors and inventory. Cost of holding inventories is one of the main research topics in the field. Examples of studies include Bechter and Pollock (1980), Rubin (1980), and Louri (1996). Empirical works also employ different financial variables and econometric approaches using panel data at the firm level. The empirical results show a linkage between financial variables and firms' inventory investments. Generally, more financially constrained firms tend to have difficulty in using inventory to deal with market uncertainties (See for example, Guariglia (1999) for the UK., Caglayan, Maioli et al. (2012) for European countries, and Sangalli (2013) for Italian manufacturing industry).

The relevance of spot and futures prices on oil inventory management is increasingly studied in inventory literatures. Oil spot price is relevant to inventory management as it directly affects demand and supply. Economics theory states that demand and supply are functions of price; inventory must then also be a function of price. Lovell (1961) pointed out that manufacturers adjust their inventory position in response to expected price increase or decrease. They hold more inventory when price is rising and less when price reductions are anticipated. A problematic issue of the price anticipation is that exact data on expected price is not available for various commodities. Potential representatives for the expected prices include a naive projection of the past price, average or moving average of its lags and so forth. In case of oil industry, the existence of oil futures markets help provide significant informative perceptions on expected future oil price of the market participants including hedgers, speculators, and arbitrageurs. For an oil company, futures contracts can be used to hedge against price change and manage customer demands. Oil futures are traded in exchanges in various countries. In Thailand, Brent crude oil futures are available for trade at Thailand Futures Exchange (TFEX). More discussions on the relationship between futures price and oil inventory can be found in Balabanoff (1995); Stevans and Sessions (2010); and Ederington, Fernando et al. (2012).

2.3 Review of the interrelationship between margin and inventory

The determination of optimal inventory has been one of major topics in operation management filed. The traditional newsvendor problems, introduced by Edgeworth (1888), presented an appealing solution of optimal inventory decision under demand uncertainty that is crucial for the studies of inventory behavior that follows. However, the original newsvendor models treat demand and other market parameters, such as a product price, as exogenous variables. It is, however, arguable that the decisions on price and on inventory are set simultaneously. The newsvendor model is adapted to link price policy and inventory control policy together by Whitin (1955). The selling price was incorporated in the model through the demand function and was determined in the problem rather than treated as an exogenous variable. Petruzzi and Dada (1999) suggested that incorporating demand and selling price into the model can provide a merit mean of examining how those variables interact with marketing issues to make business decision. For other reference in inventory research under joint pricing of inventory and margin, readers are referred to Federgruen and Heching (1999), Elmaghraby and Keskinocak (2003), and Chen and Simchi-Levi (2004).

The application of those optimization studies to this study is that inventory and prices are interrelated and the business decisions regarding the two variables are simultaneous determined. Gaur, Fisher et al. (2005) postulated that, based on the observation of managerial practices and results in academic literatures, the decisions regarding business target of a retail firm are based on trade-off between inventory turnover, which is the ratio of cost of goods sold over inventory, and gross margin. Specifically, products with higher margin are given lower turnover targets than the products with lower margin. Thus, the inventory turnover is negatively correlated with the gross margin and inventory is positively correlated with the gross margin. Roumiantsev and Netessine (2007) also pointed out that higher margin is associated with higher product inventories because the under-storage cost is increased with margins.

Inventories, in turn, affect margin. The study by Cosidine (2001) provided an analysis of markups in the US refined petroleum products, including gasoline, distillate, jet fuel, and other product, The results suggested that markups for all products increase with lower price of crude oil and propane inputs and with lower product inventory. Other research in the retail supply chain, such as Petruzzi and Dada (1999) and Gaur, Fisher et al. (2005) also found that a higher inventory level is associated with a lower margin because the sellers are forced to mark down in order to liquidate or adjust their inventory positions. Recognizing the simultaneous nature of margin and inventory, Kesavan, Gaur et al. (2010) postulated that the decision of setting marketing margin and determining level of inventory are interrelated. An increase in inventory level tends to be associated with future mark down, while an increase in profit margin increases the level of optimal inventory. They adopted a system of simultaneous equations for sales, inventory, and gross margin. The results reported strong statistical evidence that inventories negatively affect margin, while the effect of margin on inventories can be negative or positive depending on types of the stores. With the system of equations, the authors showed that the data on inventory and margin can help improve the quality of sale forecasts.

2.4 Review of the effects of uncertainties on inventory behavior

Uncertainty is relevant in a study of inventory because uncertainty affects inventory behavior by inducing businesses to hold more inventories to smooth production and sales. This implies that the return on holding inventories increases with uncertainty. Past studies applied various proxies of uncertainty, including (i) uncertainty in demand or sale (Bechter and Pollock 1980, Rubin 1980, Lee and Koray 1994, Bo 2001, Caglayan, Maioli et al. 2012), (ii) uncertainty in price (Pindyck 2004, Pietola, Liu et al. 2010), and (iii) uncertainty in inventory (Lee and Koray 1994). The empirical works mostly focus on effects of uncertainties in sales or demand on inventory behavior. Rubin (1980) stated that firms must carry sufficient inventory to meet an unusual robust demand since the long-run consequences of failure in meeting customer demand could be serious. The study found that an increase in demand uncertainty induces firms to hold more inventories stock to buffer any shocks as hypothesized. Other studies also reported a positive relationship between inventory and uncertainty in sale Bo (2001), and Caglayan, Maioli et al. (2012). In contrary, Bechter and Pollock (1980) found a negative relationship between uncertainty in sale and inventory. They argue that firms may maintain a tighter IS ratio policy with increasing uncertainty. The only study that includes uncertainty in inventory in addition to the uncertainty in sales into the analysis of inventory behavior is the study by Lee and Koray (1994). The authors adopted a bivariate GARCH-M framework to measure the impact of uncertainty in sales and inventories on the U.S. wholesale and retail trade sectors. The empirical evidence showed, however, that both uncertainty in sale and uncertainty in inventory do not affect inventory holding behavior in both sectors.

The relationship between uncertainty and petroleum inventory behavior has been studied based on the theory of storage, which implies that spot and futures price volatilities are negative functions of inventories. Empirical results confirmed the application for the crude oil and petroleum products, see Ng and Pirrong (1996); Geman and Ohana (2009); Symeonidis, Prokopczuk et al. (2012) for examples. In contrast, the study by Pindyck (2004) reported that, for the U.S. petroleum complex including crude and heating oil, spot and futures price volatility cannot be predicted by market variables, including inventories. In contrast, the price volatilities affect inventory holding because volatilities affect the marginal value of storage, price, and production. For gasoline product, the author found, however, that the price volatility is a function of spot price and convenience yield. Since the Thai petroleum market is small compared to the world market, it is unlikely that Thai's petroleum inventories will impact oil spot and futures prices and it is, therefore, intuitive to study the impact of oil prices uncertainty on inventory.

Uncertainties may also affect price and margin. Federgruen and Heching (1999) pointed out that, for any given price, higher demand uncertainty leads to increases in required buffer stocks and expected under-storage costs. Therefore, when demand uncertainty is increased, the optimal reaction is to raise price that will in turn reduces the mean and standard deviation of the demand in the equivalent proportion. Pietola, Liu et al. (2010) also suggested that price volatilities affect prices level because higher uncertainty implies more inventory holding. Assuming production remains unchanged, the increase in inventory must be as a result of the reduction in sales, which requires a higher price. They provide statistical results for the Wheat market, which suggested that price volatility further increases the price, but only in the short run. Over time, the effects of price volatility on price level diminished and high volatility may also lead to a decline in price.

A practical issue in an empirical study is to generate uncertainty measures. Potential choices include historical volatility, forecast error of sales or demand, and conditional variance from Autoregressive Conditional Heteroskedasticity (ARCH) and Generalized-ARCH (GARCH) models. Modeling uncertainty with the GARCH models has attracted popularity from researchers because the basic assumption of the least square model of homoskedaticity of the error terms (constant error terms) tends to be violated. The modeling of time-varying errors terms is of considerable interest to researchers and practitioners, especially those in the financial market field. The ARCH and GARCH models the dynamic of the variance so that the deficiencies of the least squares estimation are corrected and, in addition the variance of the error term can be computed and predicted. Under the ARCH model (Engle 1982), the volatility is a time-varying, positive and modeled in terms of past observation. The ARCH(p) model is presented by:

$$h_t = \alpha + \beta_1 \varepsilon_{t-1}^2 + \cdots + \beta_p \varepsilon_{t-p}^2 \tag{5}$$

where h_t denotes the uncertainty at period t and ε_{t-1} is the shocks at time t-1. Equation (5) states that the variance today depends conditionally on the innovation, which is the variability of past observations, up to period p. Bollerslev (1986) suggested a generalized version of the Engle (1982)'s ARCH model by adding the lagged value of h_t into the model. The equation (5) becomes:

$$h_t = \alpha + \beta_1 \varepsilon_{t-1}^2 + \cdots + \beta_p \varepsilon_{t-p}^2 + \gamma_1 h_{t-1} + \cdots + \gamma_q h_{t-q} \quad (6)$$

This is so-called Generalized ARCH [GARCH(p,q)] model. Equation (6) states that the variance today depends conditionally on the innovations up to period p and its lags up to period q. Both ARCH and GARCH model are powerful tools of describing the history of conditional volatilities and, because of their application to risks and returns, are widely employed in studies of financial markets. The application of the GARCH model family to the energy market is to model the volatility of energy price as an input to macroeconomic models, portfolio selection, and oil derivatives pricing (Cabedo and Moya 2003, Sadorsky 2006). The GARCH type models also have implications on inventory studies. For example, Lee and Koray (1994) apply a multivariate GARCH-M approach to evaluate the effects of uncertainties in inventory and uncertainty in sale on inventory level. Bo (2001) employed GARCH model to evaluate the impacts of volatility in sales on inventory investment for Dutch firms. Ginama (1996) employed MGARCH model to validate the production smoothing hypothesis.

This dissertation employs a variation of the SA model, namely the IS ratio model to describe the inventory behavior over time. The GARCH concept is utilized to model the uncertainty of inventory management. Specifically, a type of GARCH model family, called the GARCH in Mean model is employ to study the effects of uncertainties in focused variables on inventory management. The development of the empirical models will be discussed in the next chapter.

Chapter III

EMPIRICAL MODEL SPECIFICATIONS

The empirical model specifications of this study are divided in two parts regarding the two main objectives. The first part involves the modeling of a GARCH-M model to investigate the effects of uncertainties in ex-refinery price, oil fund, and futures price on uncertainty in inventory management and inventory behavior. This part starts by describing the derivation of the model from the IS ratio model by Bechter and Pollock (1980). The application of the heteroskedasticity assumption is discussed and validated from the actual uncertainty data. The second part of the chapter involves the setting of a system of simultaneous GARCH-M model to investigate the effects of marketing margin and its uncertainty on inventory management. Finally, the information on the data used to fit the models is provided.

3.1 A GARCH-M model for the analysis of market uncertainties on inventory management

Because the focus of this research is on inventory management, the IS ratio model of Bechter and Pollock (1980) provides a good starting point for a model specification. The IS model can be represented as:

$$\mathrm{IS_t} = \mathrm{IS_t^*} + \zeta(\mathrm{S_t^e} - \mathrm{S_t}) \tag{7}$$

where $\mathrm{IS_t}$ and $\mathrm{IS_t^*}$ denote the actual and desired IS ratio at the end of period t, respectively. The IS model states that the actual IS ratio at any period t equals the desired IS ratio and the fraction ζ of unanticipated sales in that period. The IS model is consistent with the assumption of TA model by Feldstein and Auerbach (1976) that complete adjustment of the actual IS ratio to the desired IS ratio is achieved within the period t. However, the objectives of the study are not to estimate or discuss about the adjustment speed of the IS model, but to study the relationship between uncertainties and inventory management and to incorporate prices and price volatilities in the model.

To estimate the IS model, a functional relationship between the desired IS ratio and interested variables is specified. At any period t, the desired IS ratio is assumed to depend on interest cost of holding inventories (C_t), expected sales (S_t^e), and the degree of uncertainties in the IS ratio (U_t^{IS}).[3] This can be written as:

$$IS_t^* = \alpha\text{-}\vartheta C_t + \gamma S_t^e + \mu U_t^{IS} \tag{8}$$

Putting equation (8) into equation (7) and setting $\omega = \gamma + \zeta$ yield;

$$IS_t = \alpha\text{-}\vartheta C_t + \omega S_t^e\text{-}\zeta S_t + \mu U_t^{IS}. \tag{9}$$

Basic economics theory states that sales are negative functions of price. To investigate the relationships between price and inventory management, the prices information is incorporated by further assuming current sales to be a linear function of current retail prices (RP_t) and the expected sales to be a linear function of expected retail price (RP_t^e). This can be written as:

$$S_t = a\text{-}bRP_t \tag{10}$$

$$S_t^e = c\text{-}dRP_t^e \tag{11}$$

From this assumption, equation (9) then becomes

[3] The original IS model focused on uncertainty in sales and the use uncertainty in inventory to sale ratio is proposed in this study.

$$IS_t = \beta_0 - \beta_1 C_t + \beta_2 RP_t - \beta_3 RP_t^e + \beta_4 U_t^{IS}. \quad (12)$$

where $\beta_0 = \alpha + \omega c - \zeta a$, $\beta_1 = \vartheta$, $\beta_2 = \zeta b$, $\beta_3 = \omega d$, and $\beta_4 = \mu$.

Equation (12) states that an increase in the IS ratio is associated with; (i) a decrease in holding cost (ii) increase in retail selling price (iii) decrease in expected retail price, and (iv) increase in uncertainty in inventory management. As inventory holding cost increases, the IS ratio tends to decline. The IS ratio should be a positive function of retail price. Businesses would be more willing to hold inventory when price increase as its value of inventory to the businesses also increase. Sales also tend to fall when retail price increases, without any change in production, there will then be more inventories in this period and the IS ratio will increase.

In order to obtain a proper estimate of expected retail price (RP_t^e), the petroleum price structures are again reviewed. Thai's petroleum product price structure can be divided into ex-refinery price, wholesale price, and retail price. The ex-refinery price is determined by the refineries using the import parity basis based on Singapore market as the reference market. The ex-refinery price, then, depends on the Singapore price and the exchange rate, adjusted by differences in product quality, logistics cost, insurance and refining margin. The wholesale price is obtained by adding the ex-refinery price with taxes, conservation funds, and the oil fund. The final retail price is obtained by further adding the wholesale price with marketing margin and value added tax.

Given the price structure above, the major determinant of the variation of petroleum price is the ex-refinery price. The existence of crude oil futures market allows for reasonable estimations of the expected ex-refinery prices for the next period. Despite the fact that there is no exact futures contract for specific petroleum products, the crude oil futures represents an expected price of the cost of input for refined product that should allow us to reasonably estimate the expected ex-refinery price (EP_t^e) for the next period. Assuming naive expectation of the spread between the retail price and the ex-refinery price, the expected retail price at time t (RP_t^e)

equals the futures price in baht at time t-1 maturing at time t $(F_{t\text{-}1,t})$ plus the difference between retail price at time t-1 and ex-refinery price at time t-1, or

$$RP_t^e = F_{t\text{-}1,t} + \left[RP_{t\text{-}1}\text{-}EP_{t\text{-}1}\right] \quad (13)$$

To summarize, it is assumed that the retail price for each product next period is reasonably estimated by adding the futures price in Thai baht maturing next month with the current spread between retail and ex-refinery prices[4].

Uncertainty plays a role in the model because it affects the behavior of the IS ratio. The uncertainty in the IS ratio may not, however, be constant over time, leading to heteroskedastic residuals in the regression model. This implies that the OLS assumption of constant variance of the error term may suffer from loss of efficiency. In order to examine the validity of the constant variance assumption, a series of standard deviation of the historical IS ratio is calculated for each product group using 20-month data points. With the total of 66 monthly data points for each product, a series of 46 standard deviations for each product group is obtained and is shown in Figure 10 below. It is obvious from the figure that the standard deviation of the IS ratio of each product is not constant over time and it is appropriate to model the uncertainty in the IS ratio as a dynamic process with the GARCH framework.

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[4] In order to validate the concept for any product j, the actual spot retail price is regressed on the intercept and the expected retail price $(RP_{j,t} = \tau_{j,0} + \tau_1 RP_{j,t}^e + \epsilon_{j,t})$. The regression results show that the coefficient of the expected price, τ_1, is largely positive and statistically significant (Appendix 2). The overall R-square is 85%. This partly confirms that the approach provides a good approximation of the future retail prices.

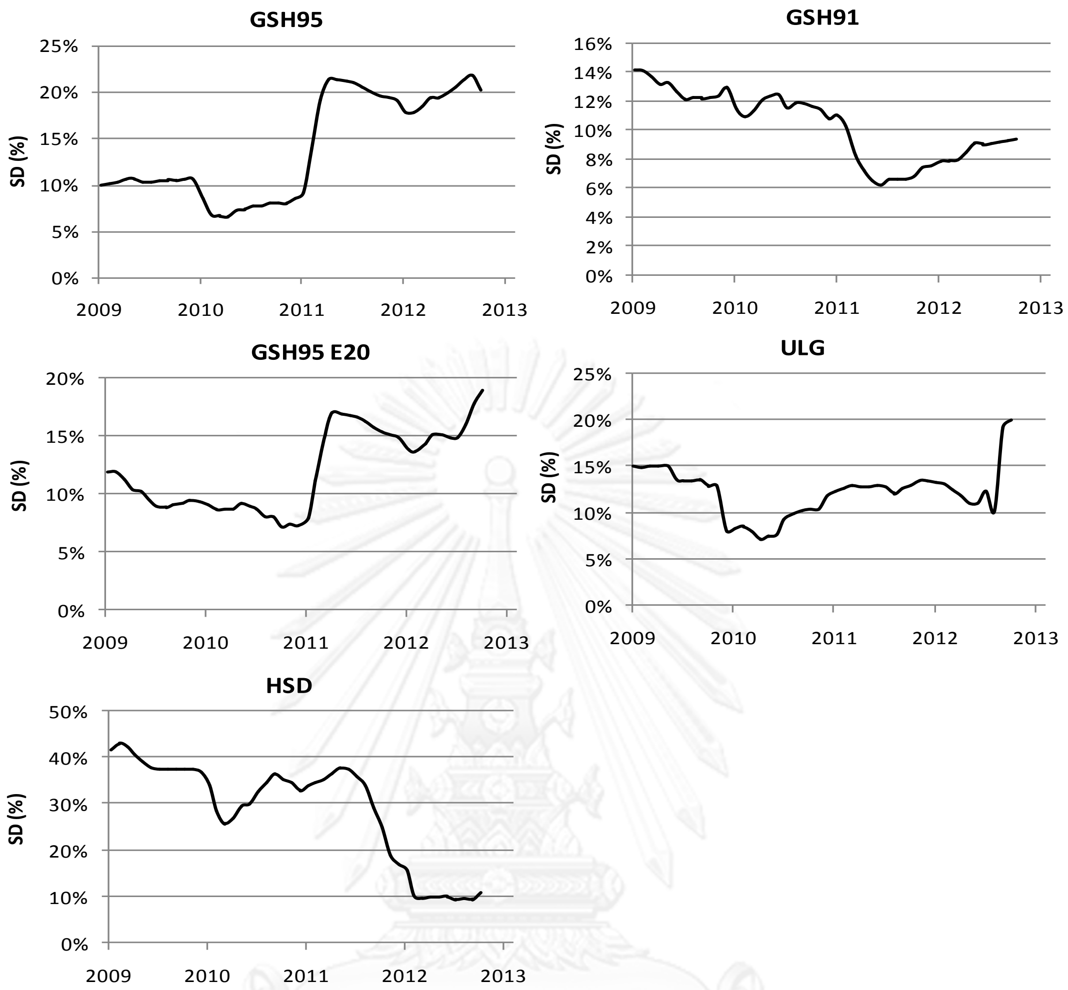

Figure 10 Actual standard deviation of the IS ratio by group of product

The variance process of the IS ratio is, therefore, assumed to follow a GARCH process that treats heteroskedasticity as a variance to be modeled. Specifically, the conditional variance, calculated from the model, is a measure of the deviation of the IS ratio from its rational expectations. This property makes the conditional variance from the GARCH an appropriate model to analyze the role of IS ratio as a buffer stock. In order to estimate the buffer inventory level in response to uncertainty, the calculated conditional variance will directly appear in the mean equation (12). This is called GARCH in Mean (GARCH-M) model.

Another advantage of the GARCH-M model is that it allows for the analysis of the determinants of the uncertainty in inventory management. The researchers' interests are on the effects of uncertainties in ex-refinery price, in oil funds, and in futures price on the uncertainty in inventory management. A variation in ex-refinery price is the major determinant of variations in spot retail price that reflects the volatility of the crude oil price in the world market and uncertainty in the current value of inventory.

Although the primary objectives of the oil fund are to stabilize price and to promote usage of the alternative energy products, the variation of the oil fund directly affects the product value. In this sense, uncertainty in oil fund might have an impact on uncertainty in inventory management. Higher volatility in the futures market would reflect uncertainty in the future price of crude oil and thus uncertainty in the future value of the petroleum products. On the other hand, variation in the futures price provides information regarding the future expectation of the market participants, including the hedgers that might use a futures contract to manage inventory position and help reduce uncertainty in inventory management. To reduce a risk of having a negative term of variance in the left hand side of equations, the study assumes the multiplicative heteroskedasticity form for the variance equation. Introducing index j for each product group, the GARCH-M (1,1)[5] model can be represented as;

$$IS_{j,t} = \beta_0 - \beta_1 C_t + \beta_2 RP_{j,t} - \beta_3 RP^{e}_{j,t} + \beta_4 U^{IS}_{j,t} + \varepsilon_{j,t} \tag{14}$$

$$U^{IS}_{j,t} = \exp(\lambda_0 + \lambda_1 U^{XP}_{j,t} + \lambda_2 U^{OF}_{j,t} + \lambda_3 U^{F}_{j,t}) + \alpha_1 \varepsilon^2_{j,t-1} + \alpha_2 U^{IS}_{j,t-1} \tag{15}$$

where $U^{IS}_{j,t}$ is the conditional variance of the IS ratio, $U^{XP}_{j,t}$ is the variance of ex-refinery price, $U^{OF}_{j,t}$ is the variance of oil fund, and $U^{F}_{j,t}$ is the variance of futures price

[5] To determine the lag of ARCH and GARCH terms, the models with different lags are estimated and considered for the robustness of the results. It appears that adding more lags for both ARCH and GARCH terms into the model does not improve the results. The author then decides to use lag 1 for both terms in the study.

at time t. The subscript j is an index of product group (j = 1, 2, 3, 4, 5). The model is estimated using the Maximum Likelihood Estimation for the pool of five petroleum product group. As can be seen from model specifications in the equations (14) and (15), any change in uncertainties in ex-refinery price, oil fund, and futures price affects inventory management through their impacts on uncertainty in inventory management as shown in Figure 11 below.

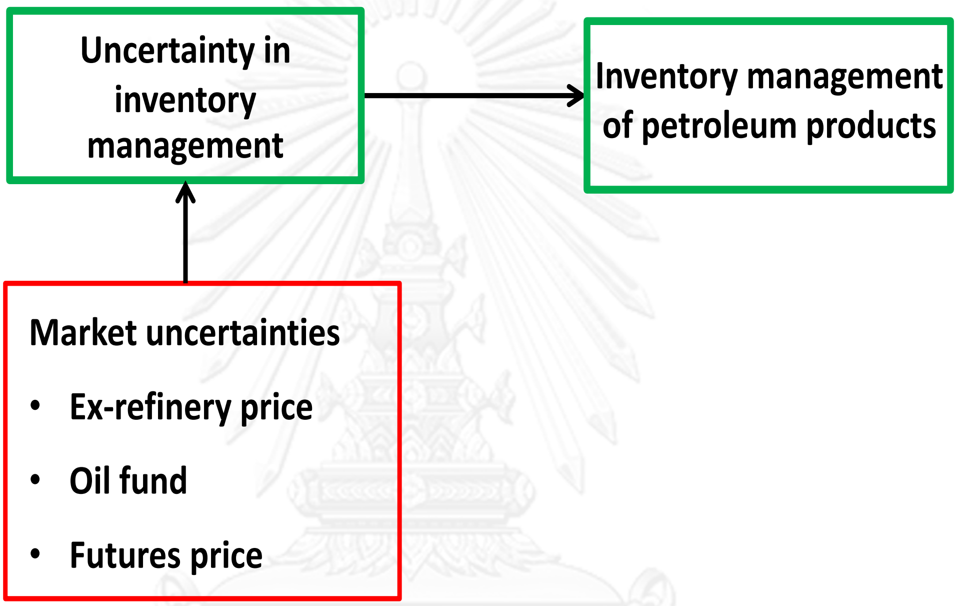

Figure 11 Effects of market uncertainties on inventory management

3.2 A system of simultaneous GARCH-M models for the analysis of marketing margin on inventory management

This part of model specification attempts to answer the question whether the marketing margin and its uncertainty affect inventory management of petroleum products. This empirical model builds on the interrelationship nature of inventory and marketing margin and the modeling of uncertainty. A system of simultaneous GARCH-M equations is employed for inventory management and margin. For the inventory equation, a variation of the IS ratio model in equation (14) is applied.

Basically, the IS ratio is assumed to be a function of real interest rate (C_t), retail price (RP_t), uncertainty in inventory management (U_t^{IS}), and uncertainty in marketing margin (U_t^{MM}). To link the effect of marketing margin on inventory, the retail price is decomposed into the wholesale price and marketing margin, i.e. $\mathrm{RP}_t = \mathrm{WHP}_t + \mathrm{MM}_t$. Because the marketing margin is determined in the system of equation, it enters the inventory equation as expected terms $(\widehat{\mathrm{MM}}_t)$.

The marketing margin is assumed to be a function of the expected IS ratio $(\widehat{\mathrm{IS}}_t)$, the Singapore price (SP_t), uncertainty in inventory management, and own-uncertainty in marketing margin. The expected IS ratio is determined in the system of equation. Any significant increase in the Singapore price (in baht) would trigger an increase in retail price, otherwise the margin becomes negative. However, retail price needs not to response immediately to the increase in Singapore price. Generally, the retail prices remain at the same level until the marketing margin reduces to a certain level that triggers the oil companies to increase the marketing margin and hence the retail price rises. Uncertainties tend to give rise to marketing margin as suggested by Federgruen and Heching (1999) and Pietola, Liu et al. (2010).

The variance processes of the IS ratio and marketing margin are also assumed to follow a GARCH process. The possibility that the uncertainties of inventory management and marketing margin may be correlated by inserting the cross-shock (ARCH) terms is incorporated into the conditional variance equations. To reduce a risk of having a negative term of variance in the left hand side of equations, the study assumes the multiplicative heteroskedasticity form and, for simplicity, only the ARCH term in the conditional variance equations is considered. The system of simultaneous GARCH-M equations can be represented as followings:

$$IS_t = a_0 + a_1 C_t + a_2 WHP_t + a_3 \widehat{MM}_t + a_4 U_t^{IS} + a_5 U_t^{MM} + \varepsilon_{IS,t} \quad (16)$$

$$U_t^{IS} = \exp(\beta_0 + \beta_1 \varepsilon_{MM,t-1}^2) + \beta_2 \varepsilon_{IS,t-1}^2 \quad (17)$$

$$MM_t = b_0 + b_1 \widehat{IS}_t + b_2 SP_t^S + b_3 U_t^{IS} + b_4 U_t^{MM} + \varepsilon_{MM,t} \quad (18)$$

$$U_t^{MM} = \exp(\gamma_0 + \gamma_1 \varepsilon_{IS,t-1}^2) + \gamma_2 \varepsilon_{MM,t-1}^2 \tag{19}$$

where exp denotes an exponential function. $\mathrm{U_t^{IS}}$ and $\mathrm{U_t^{MM}}$ are the conditional variances (uncertainty) of inventory management and marketing margin, respectively. $\varepsilon_{IS,t}$ and $\varepsilon_{MM,t}$ are the residuals from the inventory management and marketing margin equations, respectively. The coefficients a_4 and b_4 represent own-uncertainty effects on level, while the coefficients a_5 and b_3 represent the cross-uncertainty effects on the level of other variable. The own-shock effect on uncertainties are evaluated with the coefficients β_2 and γ_2, while the cross-shocks effects on uncertainties are presented by the coefficients β_1 and γ_1. The analysis of own- and cross- uncertainty effects are illustrated in Figure 12 below.

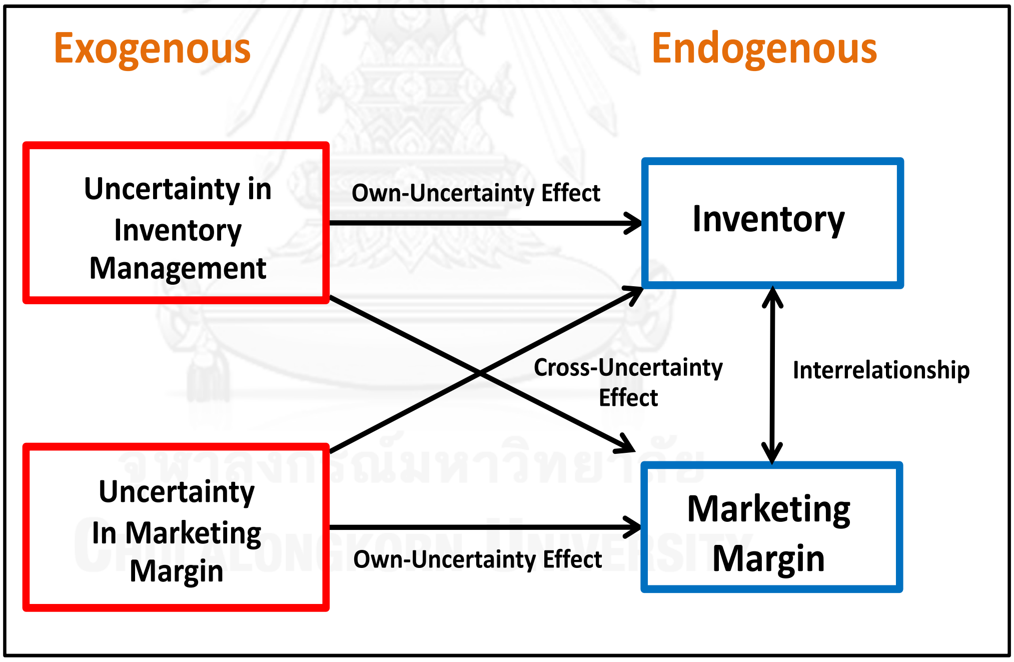

Figure 12 Own-uncertainty and cross-uncertainty effects

3.3 Data

The data used in the first part of the analysis is monthly data from January 2008 to June 2013 for five petroleum product groups, including (i) ULG, (ii) GSH95, (iii) GSH95E20, (iv) GSH91, and (v) HSD. The IS ratio is computed from inventories and sales data from the Department of Energy Business (DOEB). The inventory data are available from January 2008 to December 2012. The inventory data for January 2013 onward are calculated using an inventory identity from available production, import, sales, and export data from DOEB, with inventory as of end December 2012 as a base inventory.

The carrying cost (C_t) is represented by the real corporate bond yield computed by subtracting the 1-month corporate bond yield with the inflation from Consumer Price Index (CPI) data (December 2007 = 100). Data for bond yields and nominal spreads are from Thai Bond Market Association (ThaiBMA). The spot price (RP_t) data series are monthly-average data from daily retail price structure data available at Energy Policy and Planning Office (EPPO). All prices are converted into real terms. The futures price data is the 1-month Brent crude oil futures price, converted into THB per liter using a real exchange rate and a conversion factor of 158.9873[6]. The spreads between the retail price and the ex-refinery price are calculated directly from monthly-average EPPO price structure data. Uncertainties of spot ex-refinery prices, oil funds, and futures prices are monthly historical variance calculated from daily observations of each variable.

[6] 1 Barrel = 158.9873 Liters

Table 3 Descriptive statistics of data for GARCH-M model

Variable	**Description**	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
$IS_{j,t}$	IS Ratio	0.810826	0.296503	0.234995	2.177189
C_t	Real Interest Rate	-0.0064	0.022375	-0.05487	0.062792
$RP_{j,t}$	Retail Price	30.27225	5.078294	15.6703	43.23544
$RP_{j,t}^{e}$	Expected Retail Price	28.68526	5.577846	12.81838	42.74263
$U_{j,t}^{XP}$	Variance of Ex-refinery Price	0.500462	0.899049	0.006502	7.178427
$U_{j,t}^{OF}$	Variance of Oil Fund	0.129302	0.625146	0	8.919054
$U_{j,t}^{F}$	Variance of Futures Price in THB	0.442913	0.680831	0.027947	4.675738

For the analysis of the marketing margin, the model estimation will be based on the weekly data basis. Because the use of monthly data may lead to a problem in studying adjustment mechanism that may be felt within a month, the monthly data are converted into weekly interval using the cubic spline method. This conversion is common in economic studies and allows the IS ratio data to match the other data that are available on weekly basis. The base inventory data is monthly data from January 2008 to June 2013 for three petroleum product groups, including (i) Unleaded Gasoline (ULG) (ii) Gasohol (GSH), and (iii) High Speed Diesel (HSD). The ULG group consists of ULG octane number 91 and octane number 95, while the GSH consists of GSH91, GSH95 E10, GSH95 E20, and GSH95 E85. The data for each product group is combined using sale value as weights and is decomposed into weekly interval using the cubic spline approach. The spot wholesale price (WHP_t) and marketing margin (MM_t) data series are weekly-averaged from daily price structure data available at Energy Policy and Planning Office (EPPO). The Singapore price (SP_t) data are weekly-averaged from the daily data reported for ULG and HSD at the Department of Energy Business (DOEB). All prices are converted into real terms.

Table 4 Descriptive statistics of data for a system of simultaneous GARCH-M model

Product / Factor	Variable	Definition	Obs	Mean	Std.Dev.	Min	Max
Gasohol (GSH)	IS_t	IS ratio	287	0.788	0.102	0.494	1.114
	WHP_t	Wholesale Price	287	25.665	3.762	12.133	31.193
	MM_t	Marketing Margin	287	1.662	0.565	0.246	4.426
	SP_t	Singapore Price	287	19.685	4.152	7.938	29.529
Unleaded Gasoline (ULG)	IS_t	IS ratio	287	0.624	0.131	0.405	1.107
	WHP_t	Wholesale Price	287	30.238	3.874	16.822	36.012
	MM_t	Marketing Margin	287	1.897	0.667	0.106	4.869
	SP_t	Singapore Price	287	19.685	4.152	7.938	29.529
High Speed Diesel (HSD)	IS_t	IS ratio	287	0.666	0.115	0.384	0.897
	WHP_t	Wholesale Price	287	23.467	3.416	15.1	36.784
	MM_t	Marketing Margin	287	1.299	0.701	-2.828	4.104
	SP_t	Singapore Price	287	20.571	4.841	10.217	35.748
Interest Rates	C_t	Interest Rate	287	-0.001	0.022	-0.056	0.063

Chapter IV

EMPIRICAL RESULTS

The empirical results are reported in this chapter. The first part presents and focuses on the results on the effects of uncertainties in ex-refinery price, oil fund, and futures price on uncertainty in inventory management and inventory behavior. The model performance and sensitivity analysis based on the model results are provided. The second part reports the statistical results for the effects of marketing margin and its uncertainty on inventory management. The skewness tests for normality of the residuals are performed to help explain the results and the sensitivity analysis is also provided.

4.1 The effects of uncertainty in ex-refinery price, oil fund, and futures price on inventory management

The model estimation with the GARCH-M approach of five petroleum product groups are summarized in table 5 below.

Table 5 Estimated GARCH-M with multiplicative heteroskedasticity model

$$IS_{j,t} = \underset{(7.87)^{***}}{0.7096} \; \underset{(-3.22)^{***}}{-1.6794C_t} + \underset{(2.56)^{***}}{0.0096RP_{j,t}} \underset{(-3.58)^{***}}{- 0.0101RP^{e}_{j,t}} + \underset{(2.47)^{**}}{1.1104U^{IS}_{j,t}}$$

$$U^{IS}_{j,t} = \exp(\underset{(-11.80)^{***}}{-6.1673} + \underset{(6.23)^{***}}{1.3017U^{XP}_{j,t}} + \underset{(2.29)^{**}}{0.2333U^{OF}_{j,t}} \underset{(-4.58)^{***}}{- 1.1430U^{F}_{j,t}}) + \underset{(4.03)^{***}}{0.4521\varepsilon^2_{j,t-1}} + \underset{(3.72)^{***}}{0.48935U^{IS}_{j,t-1}}$$

Log pseudolikelihood = 134.9912 Wald chi-squared (4) = 42.12

Note: The z-values are in (). *** and ** indicate statistically significant at the level of 1% and 5%, respectively.

4.1.1 Effects of holding cost, price, expected price, and uncertainty in inventory management on inventory behavior

All variables in the mean equation are statistically significant at 95% confidence interval with proper signs as hypothesized. The IS ratio is negatively influenced by the real interest rate, supporting the general claim that the interest cost of holding inventories adversely affect the inventory holding. The coefficient implies that for a 1 percentage increase in real interest rate, the IS ratio would move around 1.6794% in the opposite direction. The spot and expected price incorporated in the model provides significant coefficients with correct signs as expected. The spot retail price variable has a significant positive parameter in the mean equation. The coefficient of the spot retail price variable suggests that one baht increase in the retail price leads to a growth of 0.96% of the IS ratio. The expected future price is negatively correlated with the IS ratio as predicted by the model. It is implied from the coefficient that for one baht increase in the expected retail price, the IS ratio is decreased by 1.01%.

The test result shows a significant positive relationship between uncertainty in inventory management $(U_{j,t}^{IS})$ and the IS ratio, which is in contrast with the original IS model by Bechter and Pollock (1980) that reported a negative relationship between uncertainty in sales and the IS ratio. The result is consistent with other inventory studies (Rubin, 1980; Bo, 2001; Caglayan et al., 2012) and supports the view that businesses tend to hold more inventories when they foresee higher level of uncertainty. Fitted value of uncertainty in inventory management is plotted in figure 13. Over the period, uncertainty in inventory management fluctuated between 11.46% and 28.23% with an average of 19.39% over the period of study. The effects of uncertainty in inventory management on the IS ratio can be estimated using the coefficient of 1.1104 for the GARCH-M.

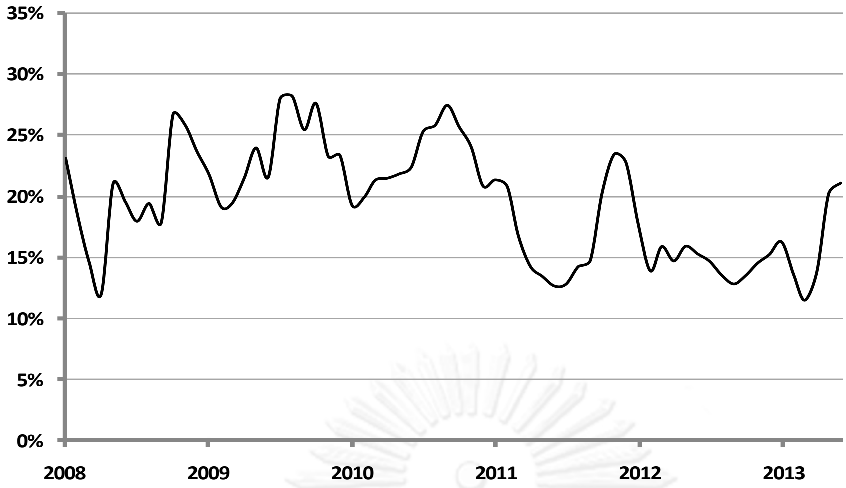

Figure 13 Estimated uncertainty in inventory management

4.1.2 Effects of uncertainties on inventory management

The model framework developed in this study differs from other studies in that it allows for simultaneous investigation of the effects of uncertainty in certain factors on uncertainty in inventory management. The authors found that a higher level of the uncertainty of ex-refinery price and oil fund give rise to uncertainty of the IS ratio. A fluctuation of ex-refinery price makes current product values and sales uncertain, raises the uncertainty in inventory management, and, therefore, leads to more inventory holdings. The oil fund variable also receives positive parameter but less statistically significant than the other two variables. This is likely because the oil fund did not much volatile over the period of study. Despite this fact, a greater uncertainty in the oil fund still raises uncertainty in inventory management and inventory holding. Interestingly, the coefficient of the futures volatility has a negative sign, signifying that variations in futures price help mitigate uncertainty in inventory management. A variation in futures price provides additional information regarding expected movements of the oil price. Producers can then better manage their inventory position and customer demand with a futures contract, and hence lessen the uncertainty of inventory management. Businesses may also maintain tighter inventory management policy when future product value is hard to anticipate. Finally, the coefficients of the ARCH and GARCH terms are statistically significant and positive. Shocks and inventory management uncertainty in the previous period induce an increase in inventory management uncertainty this period, confirming the validity of the heteroskedasticity assumption.

4.1.3 Model Performance

The model is tested for the performance by comparing the resulting uncertainty in inventory management with the actual variation in the IS ratio shown in Figure 10. Figure 14 plots the uncertainty in inventory management in standard deviation terms for each product against the actual standard deviation of the IS ratio. As seen from the figure, the overall movement of the fitted value of uncertainty in IS ratio are in line with the actual standard deviation estimated. It seems that the model tends to produce higher level of uncertainty relative to the actual level, especially for the ULG and HSD products. The relatively poor performance of those products is expected to be as a result of omitted uncertainty variables that are not included in the model. This may also be considered a limitation of the study arising from the model's assumption that all product inventories are managed in the same fashion and the factors being studied have the same effects on the IS ratio and hence the uncertainty in the IS ratio of the products[7].

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[7] The model was actually tested for each product group. However, due to the complexity of the model estimation, the estimation faced numerical calculation problems and the final results for each group are not obtained.

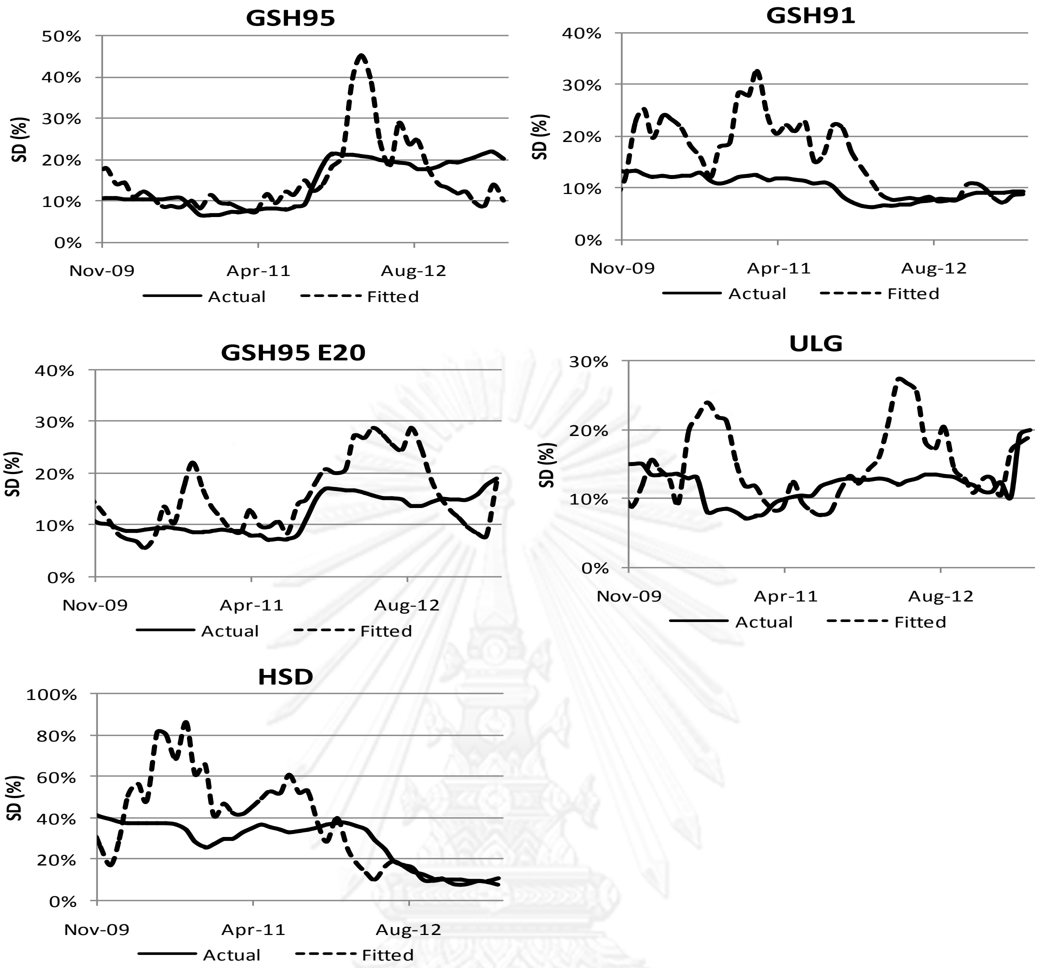

Figure 14 Actual S.D. and fitted S.D. of the IS ratio

The model is then tested for out-of-sample performance by comparing the fitted uncertainty with the actual uncertainty. Because the data for testing the out of sample performance is available from January 2008 to September 2013, the model is re-estimated with the data from January 2008 to March 2013 and the resulting coefficients are used to forecast the uncertainty in inventory management by plugging in the actual value of endogenous variables[8]. The forecasted series of uncertainty in inventory management are then compared to the series of actual uncertainty using Mean Absolute Percentage Error (MAPE) and Root Mean Square Errors (RMSE).

[8] This is to assume that the values of those variables are perfectly known by an agent.

The MAPE is a measure of forecast accuracy of a model in term of percentage difference between forecasted and actual value. The MAPE formula can be written as:

$$MAPE_j = \frac{100\%}{n} \sum_{t=1}^{n} \left| \frac{A_{t,j} - F_{t,j}}{A_{t,j}} \right| \tag{20}$$

where $A_{t,j}$ is actual standard deviation value of the IS ratio, $F_{t,j}$ is the forecasted value of uncertainty in inventory management obtained from the model, and n is number of observations.

The RMSE also measures the differences between forecasted values and the actual values in terms of standard deviation. The RMSE is defined as:

$$RMSE_j = \sqrt{\frac{\sum_{t=1}^{n} (F_{t,j} - A_{t,j})^2}{n}} \tag{21}$$

Both MAPE and RMSE are often employed in evaluating the out-of-sample performance. The results of both measurements are reported in Table 6 and Table 7. As reported in table 6, the forecasting performance varies across product. The results for GSH95, GSH91 and ULG are satisfactory. The reported MAPE indicates that the forecasting errors are different from the actual value by approximately 10%-30%. However, it seems that the model gives poor forecasting performance of uncertainty for GSH95 E20 and HSD products. It is estimated that the forecast values are, on average, different from the actual value by approximately 100%, which is again expected to be as a result of model limitation discussed above. Further investigation of square errors (residuals) of each forecasting month reveals that forecasting errors are quite steady for most products. However, the forecasting errors of both GSH95 E20 and HSD tend to be larger after 3-month forecasting period. When forecasting performance is a major concern, it is, therefore, suggestible that the model should be frequently re-estimated when the data is available.

Table 6 Out-of-sample performance of uncertainty in inventory management

Product	MAPE	RMSE
GSH95	0.30201	0.07101
GSH91	0.11782	0.01121
GSH95 E20	1.03290	0.23222
ULG	0.08079	0.01744
HSD	0.95005	0.11302

Source: the author's calculation

Table 7 Square-errors of the forecast by month

Date	GSH95	GSH91	GSH95 E20	ULG	HSD
Apr-13	0.00381	0.00001	0.00056	0.00011	0.00181
May-13	0.01160	0.00008	0.00902	0.00004	0.00461
Jun-13	0.01209	0.00027	0.03407	0.00018	0.01817
Jul-13	0.00253	0.00015	0.07152	0.00059	0.02325
Aug-13	0.00016	0.00010	0.10106	0.00066	0.01543
Sep-13	0.00007	0.00014	0.10734	0.00025	0.01338

Source: Author's calculation

4.1.4 Sensitivity Analysis

The sensitivity of the contributions of the uncertainties on the values of inventory holding is now performed by back-testing the model with the actual volatility data from the previous year (July 2012 – June 2013). The analysis is conducted by shocking up and down each volatility variable by certain percentage between one and minus one standard deviation of the corresponding historical volatilities. For example, shocking up the actual standard deviations by 100% is equivalent to allowing one standard deviation increase from the original standard deviation. This implies more fluctuation of the level of shocked variables within the corresponding month and hence higher uncertainty of that variable. On the other hands, shocking down by -100% implies no fluctuation (no uncertainty) of the shocked variable. Figure 15 illustrates the case where the uncertainty is shocked up by 100% or 1 standard deviation. The impact of changes in those volatility variables on the IS ratio can be obtained through the change in the conditional variance term in the mean equation. As the base case, it is estimated that uncertainties drive up the IS ratio by 2.75%, amounting to 23,232 million baht over the last year.

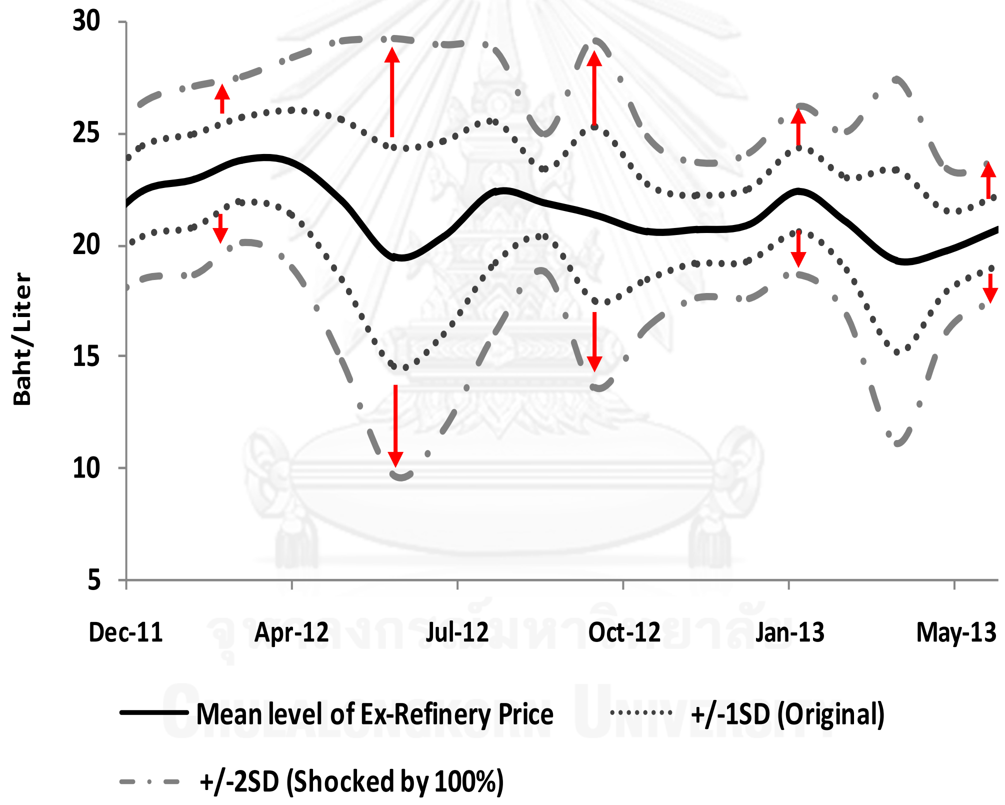

Figure 15 Illustration of the sensitivity analysis in case of shock up by 1 standard deviation

Figure 16 presents the sensitivity analysis on the impacts of increase and decrease market uncertainties on buffer inventory holding value[9]. The estimation illustrates that the contribution of changes in uncertainty in ex-refinery prices on the inventory management is stronger than the other two uncertainty variables. A 100% growth in the uncertainty of ex-refinery price would raise value of inventory holdings by 1,117 million baht, an increase of 4.81% from its original value. On the contrary, controlling the uncertainty of the ex-refinery price to the value of zero would help subside inventory holding by 2.68% or a reduction of 622 million baht in the inventory value. On average, businesses could cut down 60 million baht of inventory for every 10% fall in uncertainty in ex-refinery price. The uncertainty in oil fund has less contribution to the IS ratio. A 100% growth in the uncertainty of oil fund from its actual value would give a rise to the inventory holding by only 0.65% or 150 million baht, while controlling the variance of the oil fund to zero would reduce the IS ratio by 0.56% or 129 million baht.

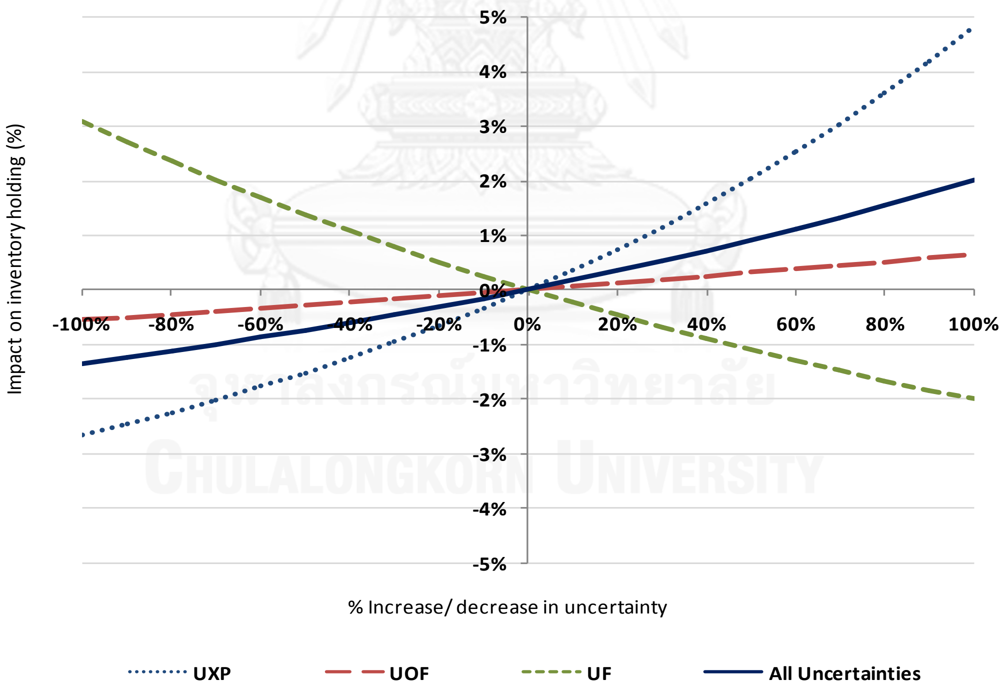

Figure 16 Sensitivity analysis of increase/decrease in uncertainties on the IS ratio

[9] Due to the model specification of multiplicative heteroskedasticity with the exponential term, the effect of increase in uncertainty of a variable with positive coefficient will have more marginal impact on the IS ratio than the effect of decrease in that variable.

The adverse impact of the uncertainty in futures market is that a rise of 100% in futures price uncertainty results in a decline of inventory holdings by 2.01% or 466 million baht, while a fall of 100% drive up a higher inventory holding by 3.08% or 714 million baht. The combination effect is tested by shocking all the uncertainties with the same percentage. The testing results show that every 10% growth in market uncertainties would cause businesses to hold, on average 0.20% additional inventory or approximately 47 million baht, while businesses could cut down inventory holding by 0.14% or approximately 32 million baht for every 10% decline in market uncertainties from its original value.

4.2 Effects of marketing margin and its uncertainty on inventory management

Because the model in the second part is simultaneous in nature, the estimation requires iterative procedure. The estimation procedure starts with the initial estimates of conditional variance using the GARCH models for IS ratio and marketing margin without exogenous variables. The fitted values of conditional variance are then included into the equations and the model is re-estimated with the exogenous variables. Finally, the fitted value of IS ratio $(\widehat{IS}_t)$ and marketing margin $(\widehat{MM}_t)$ are incorporated into the estimations of each corresponding model. The final estimation results are reported in Table 8 below.

Table 8 Results for a system of simultaneous GARCH-M equations

Equation	Variable	GSH		ULG		HSD	
		Coefficient	SE	Coefficient	SE	Coefficient	SE
IS Mean Equation							
Constant	Constant	0.1576**	0.062	1.9951***	0.249	0.2743	0.179
R_t	Interest rate	1.6198***	0.057	0.7775*	0.452	-5.59***	1.104
WHP_t	Wholesale price	0.0188***	0.001	-0.0160***	0.003	-0.0002	0.005
$\widehat{MM}_t$	Marketing Margin	0.1674***	0.026	-0.5143***	0.098	0.258***	0.057
U_t^{MM}	Uncertainty in margin	-0.0851***	0.017	0.0927***	0.020	0.0441***	0.011
U_t^{IS}	Uncertainty in inventory Management	0.3829*	0.206	0.7928**	0.333	1.4231***	0.280
IS Variance Equation							
Constant	Constant	-8.8853***	0.372	-7.6588***	0.219	-8.0708***	0.664
$\epsilon_{MM,t-1}^2$	Shock in margin (t-1)	1.245**	0.574	0.315884	0.462	0.5545***	0.114
$\epsilon_{IS,t-1}^2$	Shock in inventory (t-1)	1.1049***	0.076	0.9959***	0.097	1.0488***	0.180
Marketing Margin Mean Equation							
Constant	Constant	1.3187***	0.461	3.5044***	0.210	0.8896*	0.458
$\widehat{IS}_t$	IS ratio	1.0876***	0.660	-1.6951***	0.459	1.4774***	0.462
SP_t	Singapore Price	-0.0269***	0.009	-0.0340***	0.012	-0.024*	0.013
U_t^{IS}	Uncertainty in inventory management	0.8538	0.610	4.1896***	1.209	-1.9302***	0.557
U_t^{MM}	Uncertainty in margin	0.0048	0.096	0.1622**	0.077	-0.1862***	0.063
Marketing Margin Variance Equation							
Constant	Constant	-2.1027***	0.151	-1.9447***	0.135	-2.2993***	0.135
$\epsilon_{MM,t-1}^2$	Shock in margin (t-1)	0.4927***	0.096	0.5754***	0.092	0.8063***	0.193
$\epsilon_{IS,t-1}^2$	Shock in inventory (t-1)	-1.4821	1.269	-7.0429*	3.975	-15.9569***	5.091

Remark: *** indicates statistical significance at 1% level. ** indicate s statistical significance at 5% level. * indicates statistical significance at 10% level.

4.2.1 General results

Table 8 suggests that overall results of the models are statistically significant. Consider first the results regarding the interrelationship between inventories and marketing margin. The statistical evidence confirms a positive interrelationship between inventory and marketing for GSH and HSD products. A one baht increase in marketing margin induces an increase in the IS ratio by 16.7% and 25.8% for GSH and HSD, respectively. The positive effects of marketing margin on inventories are consistent with other studies, such as Gaur, Fisher et al. (2005) and Roumiantsev and Netessine (2007). On the other hands, an increase of 1% in the IS ratio is associated with an increase in marketing margin of around 0.01 baht for both products.

For ULG product, the interrelationship between IS ratio on marketing margin is reported to be negative, which is an unexpected outcome. It is arguable that this unexpected result is attributable to the fact that the nature of ULG product is different from the nature of GSH and HSD in that it is planned to fade out from the market. There have been government attempts since 2008 to promote the usage of alternative energy, such as the GSH products, in substitution of ULG by charging higher oil fund to the ULG price and lower oil fund to the GSH price. This resulted in price differential between the ULG and GSH products and most energy consumers have switched to GSH products. The policy discouraged businesses to stock the ULG products despite an increase in the margin (and wholesale price) and an increase in ULG inventories has resulted in a lower margin to liquidate the stocks.

It is also arguable that that there might be other variables, such as a government policy, that was ignored from the model an ignoring this may affect the results of ULG product. In order to account for that fact, the oil funds ratio into the model is included in the model. The oil fund ratio is calculated as the difference between oil funds charged to ULG and GSH over the oil fund of the GSH. Specifically, the oil fund ratio measures how much in percentage the ULG’s oil fund is greater or less than the GSH’s oil fund and the greater the ratio, the higher the degree of government promotion on the usage of GSH. The result of the model with oil fund ratio, reported in the Appendix 3, suggested that an increase in the oil fund ratio is associated with decreases in both inventory and marketing margin. In addition, other results remain relatively the same after controlling for the government policy and the study continues with the original results in Table 8.

The effects of other factors on inventories and marketing margin vary depending on product type. First, the effects of real interest rate on inventory management are reported to be positive for GSH and ULG; and negative for HSD. Other things being constant, an increase in real interest rate of 1% gives rise to the IS ratio by 1.61% and 0.7% for GSH and ULG, respectively; and leads to a fall in the IS ratio of 5.59% for HSD. The positive coefficient of real interest rate for GSH and ULG contradicts the results of other studies (Bechter and Pollock 1980, Rubin 1980, Louri 1996). It is arguable that the positive coefficient of real interest for GSH is because sales volume of the product has increased over time as a result of promotion and support for alternative energy usage. In particular, Bechter and Pollock (1980) provided an explanation for this event that businesses tend to hold more inventories when sales are strong. However, stronger sales strengthen the demand for credit, including loans or bonds, and the interest rate tends to rise. Therefore, the IS ratio tend to rise when interest rates rise. The positive effect of real interest rate for the ULG products tends to be attributable to the unusual nature of the product.

Second, the results suggest that the wholesale prices positively affect inventory management for GSH product only. For a 1 baht increase in the wholesale price, the IS ratio of GSH product will increase by 1.88%. The negative effect of the wholesale price on ULG inventory is as a result of the different nature of ULG product discussed above. In addition, there is no statistical evidence on the relationship between the wholesale price and inventory for HSD product. Finally, the statistical evidence confirmed the hypothesis of negative relationship between marketing margin and the Singapore price. An increase of 1 baht in the Singapore price lowers marketing margin by 2-3 satang for the products.

4.2.2 The effects of uncertainties on inventory holdings

As expected, own-uncertainty effects (the GARCH-M terms) have a positive impact on inventory management. The results are statistically significant for all the products. This evidence provides further support to the hypothesis that businesses increase their IS ratio as they are subject to increased uncertainty in inventory management. The cross-uncertainty effects of uncertainty in marketing margin on inventory management are different across products, reported to be negative for GSH and positive for ULG and HSD. In addition, the positive cross-ARCH effects of shocks in marketing margin on uncertainty in inventory management for GSH and HSD products are reported. The skewness test for normality of the residuals of both IS ratio and marketing margin equations are conducted to further examine the outcomes. The testing results are reported in Table 9 and the distributions of residuals from inventory management and marketing margin equations are shown in Figure 17 and 18 below.

Table 9 Skewness test for normality of the residuals

Variable	Definition	GSH	ULG	HSD
$\epsilon_{IS,t}$	Residuals from inventory management equation	2.71100 (0.0000)	-0.68761 (0.0000)	-1.73562 (0.0000)
$\epsilon_{MM,t}$	Residuals from marketing margin equation	0.243247 (0.0889)	0.366692 (0.016)	0.630378 (0.0000)

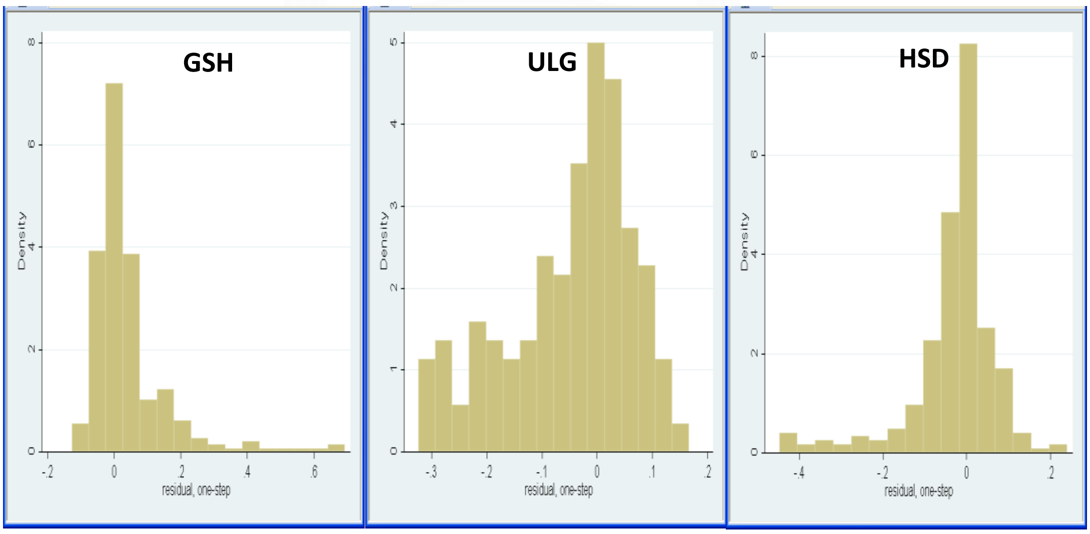

Figure 17 Distribution of residuals from inventory equations

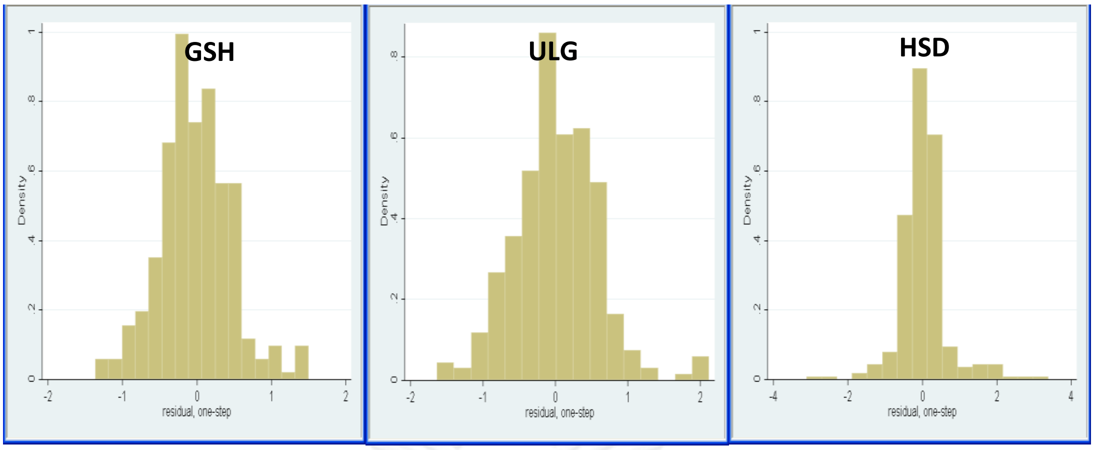

Figure 18 Distribution of residuals from marketing margin equation

The testing results for the residuals from inventory equation suggest that the hypothesis that the residuals are normally distributed for all products can be rejected. Specifically, the residuals for GSH inventories are found to skew to the right, while the residuals for ULG and HSD inventories are reported to skew to the left. These imply that the actual IS ratio for GSH tends to be above its rational expectation, while the actual IS ratio for ULG and HSD tend to be lower than their rational expectation levels. In general, uncertainties are likely to raise concerns regarding stock out and businesses raise their inventory. Combined with the right-skewed of the GSH residuals, this leads to a significant positive impact of uncertainty in inventory management on the IS ratio. Although the residuals of the IS ratio for ULG and HSD products are found to be left-skewed, the concern of safety stock cause the own-uncertainty effect to be positive. This is especially true for HSD product, which is considered strategic energy products that are not only consumed for transportation purpose, but are also used as intermediate input in industrial purpose. Thus, the concern of inventory shortage is stronger than other products.

The testing results for the residuals from marketing margin equation suggest that the hypothesis that the residuals from the marketing margin equation for ULG and HSD are normally distributed can be rejected. The skewness of the residuals for ULG and HSD products are reported to be positive (right-skewed), implying that the shocks in marketing margin tend to be positive, i.e. the actual marketing level tends to exceed its rational expectation value. Thus, the positive coefficients of cross-uncertainty effects for ULG and HSD products implies that businesses speculate an increase in the product value and hold more inventories. The hypothesis of normal distributions for GSH residuals is not, however, rejected at 5% level. This means that the above argument regarding skewness of the residuals does not apply for GSH. Thus, the explanation of the result for GSH concerns risk management. That is uncertainty in marketing margin induces more risk to the value of the product, and businesses manage the risks by maintaining a tighter IS ratio policy.

4.2.3 The effects of uncertainties on marketing margin

The results suggest that the effects of uncertainties on marketing margin vary across products. First, no evidence that uncertainties have a direct impact on marketing margin level of GSH products[10] is reported. Second, statistical results show that, for ULG product, both own-uncertainty and cross-uncertainty effects are reported to positively affect marketing level, which are consistent with other studies. Third, unexpected outcomes of negative own- and negative cross-uncertainty effect on marketing margin level is found for HSD product.

Some explanations for the unexpected outcomes of HSD are provided using the skewness testing results reported in Table 9. Consider first the unexpected negative own-uncertainty effect. While the right-skewness of marketing margin HSD residuals implies that the actual level of marketing margin tends to above its rational expectation, it also implies that, when uncertainty in marketing margin increases, businesses can set the marketing margin below its expectation level since the downside loss from setting margin too low is smaller than the upside gain from setting too high margin. Hence, uncertainty in marketing margin could negatively affect marketing margin, which is the case for HSD. Consider now the unexpected negative cross-uncertainty effect. The skewness testing result reported that the shocks in the IS ratio of HSD is skewed to the left, implying that over time businesses

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[10] The indirect impacts of uncertainties on marketing margin may exist via a change in inventory level as a result of uncertainties. This will be discussed in the sensitivity analysis experiments part.

tend to hold less inventories than the rational expectation level. An increase in inventory uncertainty implies the inventory level fall even lower and, hence, the effect on marketing margin is negative. This is in line with the positive coefficient of IS ratio in the HSD marketing margin equation.

4.2.4 Impacts estimations and sensitivity analysis

This section further investigates and quantifies the impact of uncertainties on inventory by back testing the models with the actual data. Sales are assumed to equal their actual values and any increase in uncertainty causes an increase in inventory level only. The fitted values of uncertainty in inventory management and uncertainty in marketing margin are shown in Figure 19 below.

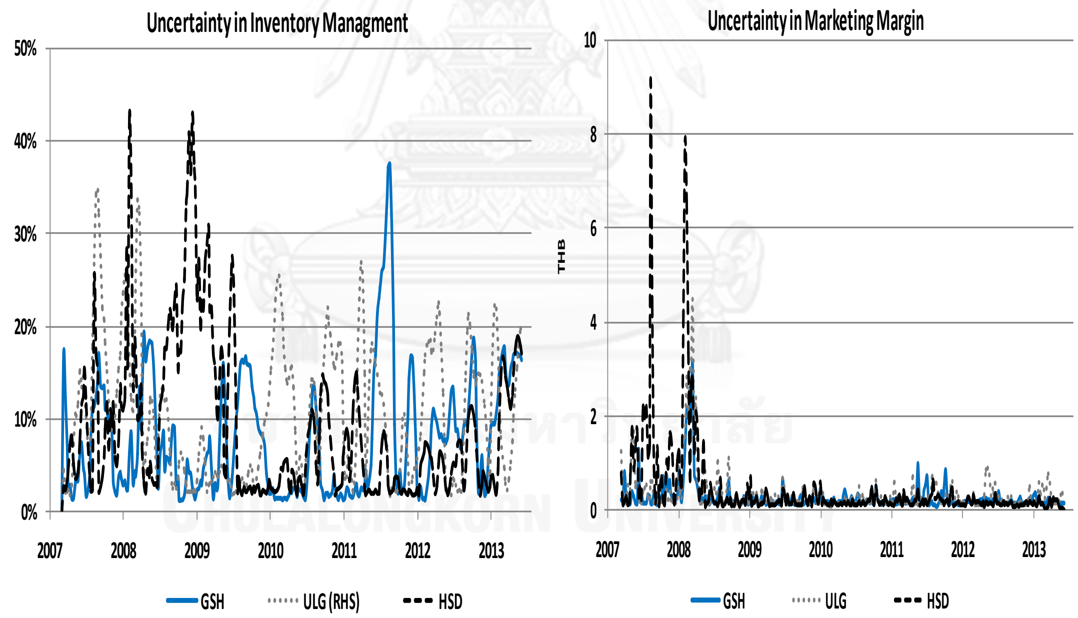

Figure 19 Uncertainties in inventory management and marketing margin

4.2.4.1 Direct impact of uncertainties on inventories

The direct effects of uncertainties on inventory according to the inventory equation are first calculated. The results are reported only for the estimated coefficients of uncertainty that are statistically significant in the inventory equations. Based on the calculations, the values of buffer inventory in response to uncertainties in inventory management averages to 15,342 million baht per year, or equivalent to 1.69% of the average sales per year. The estimated buffer inventory for HSD is the largest in term of value, reported to be 12,818 million baht per year or 2.04% of the average sales. Combined with the estimates for GSH, the buffer value contributed to around 1.47% of the average sales. The estimated effects of shocks in marketing margin on the uncertainties in inventory management are also provided. The estimated results suggest that shocks in marketing margin contributed to small portion of uncertainty in inventory management for both products. The direct effects of cross uncertainties in marketing margin on inventories are almost equal to the impact of own-uncertainty effect. For GSH product, the effect is much larger than the effects of uncertainty in inventory management on inventory, but is in opposite direction. For ULG product, the cross-uncertainty effect is larger than own uncertainty effect and is estimated to be around 2.97% of the average sale, while the effect for HSD product is almost equal to the effect from uncertainty in inventory management, reported to be 2.02% of the average sales.

Table 10 Direct effects of uncertainties on inventories

Uncertainty Effects	Inventory in baht				Inventory relative to sales			
	GSH	ULG	HSD	All Groups	GSH	ULG	HSD	All Groups
Own-Effect of $\mathrm{U}_{\mathrm{t}}^{IS}$	527	1,997	12,818	15,342	0.40%	1.33%	2.04%	1.69%
Effect of $\epsilon_{MM,t-1}^{2}$ on $\mathrm{U}_{\mathrm{t}}^{IS}$	3	-	820	823	0.003%	-	0.13%	0.09%
Cross-Effect of $\mathrm{U}_{\mathrm{t}}^{MM}$	-2,440	4,469	12,655	14,685	-1.87%	2.97%	2.02%	1.62%

4.2.4.2 Marginal impacts of change in uncertainties on inventories

The marginal impacts of changes in uncertainties on inventories and marketing margins levels are now examined. The analysis of marginal impacts needs to incorporate the simultaneity nature of the two variables into calculations. For example, an increase in uncertainty induces an increase in inventory holding, that also affects marketing margin. Any change in marketing margin, in turn, affects inventory holding behavior. To incorporate this interrelationship, the reduced form of the inventories and marketing margin equations is generated. The endogenous natures of both variables are eliminated by conducting a linear transformation of both equations. That is the IS ratio and marketing margin are written as a linear functions of all exogenous variables. For simplicity of the analysis environment, the effect of cross-shocks effects on uncertainties is ignored[11]. The reduced-form models are re-estimated and the calculated effects of uncertainties on inventories and marketing margin are considered in the scenarios that the uncertainties are shocked down by 50% from the actual values. The simulated effects are reported in Table 11 and Table 12.

Table 11 Marginal effects of changes in uncertainties on inventories

Scenarios	Inventory in baht				Inventory relative to sales			
	GSH	ULG	HSD	All Groups	GSH	ULG	HSD	All Groups
50% decrease in $\mathrm{U}_{\mathrm{t}}^{IS}$	-1,469	-4,644	-7,697	-13,809	-1.13%	-3.09%	-1.23%	-1.52%
50% decrease in $\mathrm{U}_{\mathrm{t}}^{MM}$	138	-402	-304	-568	0.11%	-0.27%	-0.05%	-0.06%
50% decrease in both $\mathrm{U}_{\mathrm{t}}^{IS}$ and $\mathrm{U}_{\mathrm{t}}^{MM}$	-1,331	-5,046	-7,393	-13,769	-1.02%	-3.35%	-1.18%	-1.52%

The marginal impact of 50% decrease in uncertainties in inventory management and uncertainty in marketing margin is estimated to reduce inventory holding by 13,809 million baht per year or 1.52% of the average sales value. The sensitivity analysis results suggest that changes in uncertainties in inventory management have much stronger effects on inventories holding of all products than

[11] This does not alter the presented sensitivity analysis results.

changes in uncertainty in marketing margin. The impacts in terms of value and percentage relative to average sale are strongest for the HSD product.

Table 12 Marginal effects of changes in uncertainties on marketing margin

Scenarios	Effects in baht			Effects in percentage		
	GSH	ULG	HSD	GSH	ULG	HSD
50% decrease in $\mathrm{U}_{\mathrm{t}}^{IS}$	-0.002	-0.03	0.003	-0.10%	-1.29%	0.27%
50% decrease in $\mathrm{U}_{\mathrm{t}}^{MM}$	-0.08	-0.05	0.37	-4.11%	-2.19%	6.68%
50% decrease in both $\mathrm{U}_{\mathrm{t}}^{IS}$ and $\mathrm{U}_{\mathrm{t}}^{MM}$	-0.081	-0.073	0.373	-4.21%	-3.48%	6.95%

The sensitivity results reported in Table 12 also suggest that the own uncertainty effects are stronger than the cross-uncertainty effects in all cases. Although the model results in Table 8 reported no direct uncertainty effects on marketing margin of GSH, the marginal effects of uncertainties on marketing margin for GSH arise from the change in inventory level in response to the change in uncertainties. Uncertainties in inventory management seem to have small impacts on marketing margin levels. Specifically, a 50% decrease in the uncertainty in inventory management leads to a change in marketing margin level of less than 2 satang for all products, while the effects of own-uncertainty in marketing margin on its level vary from -8 satang (GSH) to 37 satang (HSD).

Chapter V

DISCUSSION AND CONCLUSION

This chapter provides discussions on the major findings of the study. The model applications and policy implications are discussed with some numerical example. The last section concludes the major finding of the study. Limitations of the study and future research directions are provided.

5.1 Discussion on the effects of market uncertainties on inventory management

In line with the claim in inventory literatures, the model proposed in this study suggested that uncertainties give rise to inventory holding. From the model setting, market uncertainties have an impact on inventory management through increase or decrease in uncertainty in inventory management. The GARCH-M framework employed in the study allows for the estimation of uncertainty in inventory management from available market data. The ability to reasonably estimate the uncertainty is of great benefit because it enables the businesses to more efficiently manage and plan their inventory accordingly. The GARCH-M framework also allows for the investigation of how market uncertainties affect uncertainty in inventory management, which gives policy implications of the empirical paper that concern the hedging of ex-refinery price, the roles of the oil fund mechanism, and the existence of the futures market.

First, the effect of uncertainty in ex-refinery price is statistically significant and positive. Sensitivity analysis also reported that its effects are strongest among the three variables. Thus, this implies that the oil business can reduce uncertainty in inventory management by reducing the uncertainty in ex-refinery price. Since the ex-refinery price depends largely on the movement of crude oil and Singapore market prices, the reduction in uncertainty of ex-refinery price can be done via the hedging of the crude oil price, which is the major input of the refining process. Reducing uncertainty in inventory management via lower uncertainty in ex-refinery price can help reduce buffer inventory holding, which is clearly shown in the sensitivity analysis part.

Second, the oil fund mechanism did not much affect uncertainty in inventory management. The primary objectives of the oil fund are to stabilize petroleum price and promote usage of alternative energy products[12]. Although the uncertainty in the oil fund variable has a significant positive coefficient, the statistical significance is less than the other two variables (uncertainty in ex-refinery price and uncertainty in futures price) the sensitivity analysis demonstrates that its impact on the uncertainty management is not economically significant. In other words, the operation of the oil fund does not have much side effect on uncertainty in petroleum inventory management. The framework also delivers a technical tool for a policy agent to evaluate trade-off between the stabilized price policy and the cost of additional inventory holdings as a result of uncertainty.

Finally, the results of this study support the existence of futures market since it is reported that the variations in the futures market can diminish level of uncertainty in inventory management and the futures price is a biased predictor of future spot price. The futures market provides a hedging tool and information for producers to effectively plan and manage their inventories and sales. The hedging via futures contract also result in reduction of the uncertainty in the ex-refinery price, in which the sensitivity analysis highlights that a decline in ex-refinery price volatility can greatly reduce the degree of uncertainty in inventory management.

5.2 Discussion on the effects of marketing margin and its uncertainty on inventory management

The empirical results suggest that marketing margin and its uncertainty affect inventory management of petroleum products. In general case of GSH and HSD, a higher margin leads to higher inventory holding in anticipation of future higher

[12] It is not the objective to study the benefit of the oil fund on the economy. Instead, the focus is on its impact on uncertainty in inventory management.

profitability of the oil businesses, which is expected and in line with other studies in the field. The study also reported statistical evidence that uncertainty in marketing margin affects inventory management behavior. The effects are reported to be positive for ULG and HSD and to be negative for GSH. Regardless the signs of the coefficients, a higher uncertainty in marketing margin causes a fluctuation in inventory holding level, which in turn leads to higher in uncertainty in inventory management and inventory holdings. From this perspective, it is suggestible to control the level of marketing margin within an acceptable range, which could help reduce the degree of uncertainty in marketing margin and thus the uncertainty in inventory management.

Therefore, a policy implication of the study involves policy makers pay attention to uncertainty in marketing margin. Potential approach to help reduce uncertainty in marketing margin is to allow marketing margin to vary within given bands. Prior to deregulation of retail petroleum price in 1991, taxes and the oil fund were important government mechanisms to stabilize the domestic oil prices and thus the retail price remain relatively unchanged. After the price deregulation, the retail price movement is more closely in line with the movement of the ex-refinery price. However, the price structure still allows the government to control retail price via the setting of tax rates and the oil fund. For example, an increase in oil price in the world market leads to an increase of the ex-refinery price. Given that the marketing margin remains constant, a constant retail petroleum price can be achieved with the reduction in taxes and/or oil fund. Without the adjustments of taxes and oil fund, marketing margin would be volatile. Hence reduced uncertainty in marketing margin can be achieved with the periodic adjustments of withholding tax rates and the oil fund.

As an example, the experiment on the marketing margin targeting policy is simulated using the data period from January 2008 to June 2013. The standard deviation of marketing margin for each product is first calculated and the policy is to control the margin within +/- 1 standard deviation of the marketing margin of each product. The marketing margin is capped to be less than or equal to the upper bound and the excess of actual margin from the upper bound is compensated by the oil fund. The margin is also forced to be greater than or equal to the lower bound and the difference between the actual margin and the lower bound is paid to the oil fund. It should be noted that the operation of this policy does not affect the level of retail prices. Figure 20 plots the actual marketing margin and the targeting ban of +/- 1 standard deviation over the period of study and Table 13 reports the effects of the policy on inventory holdings.

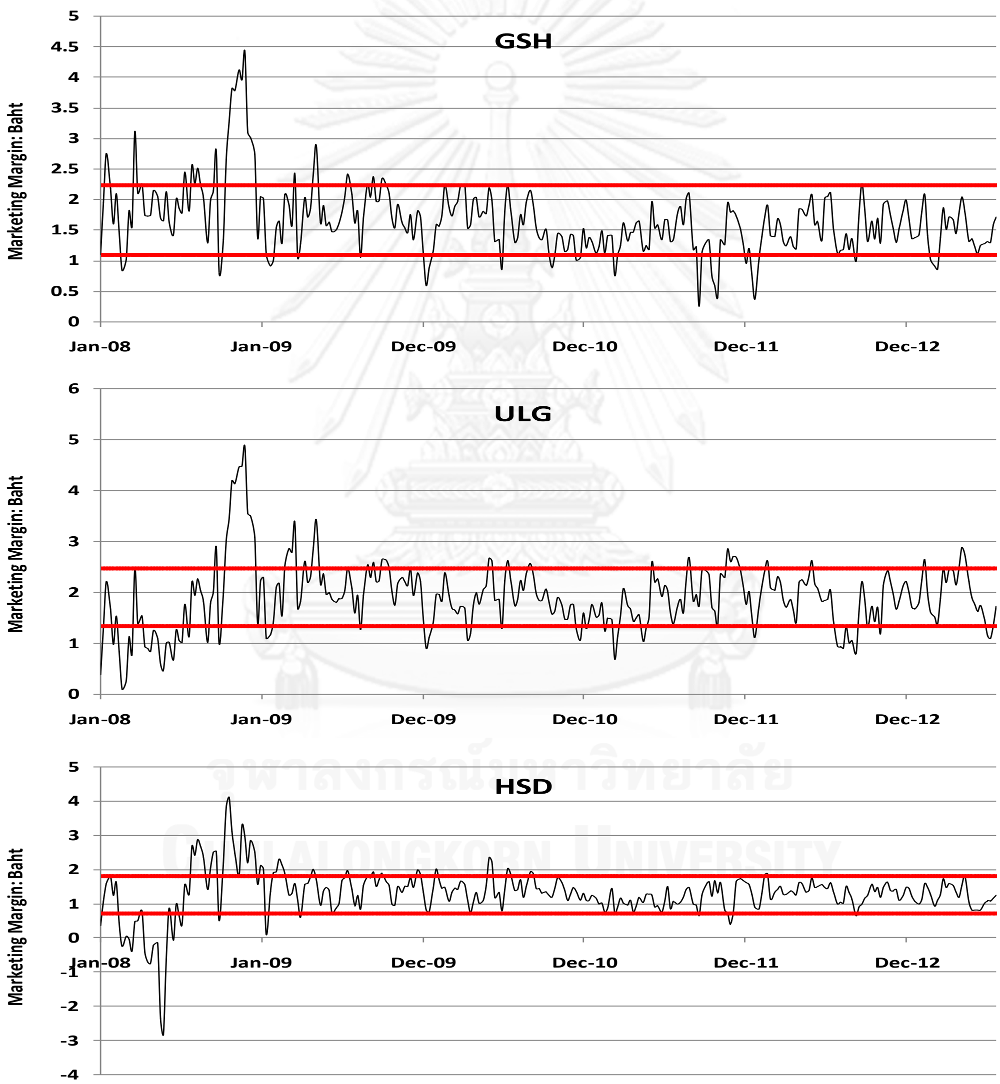

Figure 20 Example of marketing margin targeting policy

Table 13 Effects of marketing margin targeting policy on inventory

Estimation	Inventory in baht				Inventory relative to sale			
	GSH	ULG	HSD	All	GSH	ULG	HSD	All
Original estimation	-2,440	4,469	12,655	14,685	-1.87%	2.97%	2.02%	1.62%
Estimation with targeting policy	-1,231	2,258	3,679	4,705	-0.94%	1.50%	0.59%	0.52%
Changes in inventory	1,209	-2,211	-8,976	-9,980	0.93%	-1.47%	-1.43%	-1.10%

It is estimated from the simulation experiment that the marketing margin targeting policy could help reduce inventory holdings in response to uncertainty by 9,980 million baht or a reduction of on average 1.10% in the IS ratio. The reduced uncertainty in marketing margin directly affects the inventory holding and leads to a smoother IS ratios, which also implies a reduction in uncertainty in inventory management. It is estimated that the indirect impact of reduced uncertainty in marketing margin would help reduce the uncertainty in inventory management (in standard deviation terms), on average, for GSH by 1% and HSD by 2% (Appendix 4).

5.3 Conclusion

This dissertation analyzes uncertainty in inventory management of petroleum products related to transportation purposes, including GSH, ULG, and HSD. Instead of focusing on uncertainty in demand as other usual inventory studies, the study introduces the concept of uncertainty in inventory management, which is defined as the deviation of the actual IS ratio from its rational expectation level. A GARCH-M framework in the study of relationship between uncertainty in inventory management and inventory behavior is employed. The analysis of the study is divided into two parts according to the factors being studied. It can be generalized from both analyses that uncertainty in inventory management gives rise to inventory holding, which is in line with other results for uncertainty measures in inventory literatures.

The model proposed in the first part of the analysis suggested that market uncertainties have an impact on inventory management through increase or decrease in uncertainty in inventory management. The GARCH-M framework employed in the study allows for the estimation of uncertainty in inventory management from available market data. The ability to reasonably estimate the uncertainty is of great benefit because it enables the businesses to more efficiently manage and plan their inventory accordingly. The GARCH-M framework also allows for the investigation of how market uncertainties affect uncertainty in inventory management. The sensitivity analysis suggested that uncertainty in ex-refinery price has an economically significant positive impact on uncertainty in inventory management. Uncertainty in the oil fund also positively affects the uncertainty in inventory management, but its impact on inventory management is not economically significant. The study found an encouraging result that the uncertainty in futures price can help mitigate the inventory uncertainty and the empirical result gives support to the existence of futures market. The results of this study contribute to a better understanding of petroleum product inventory behavior in Thailand and also have implications for uncertainty management of oil.

The second part of the analysis contributes to inventory study in that the interrelationships between inventory management and marketing margin is incorporated into an analysis of uncertainties. It can be generalized from the results that, at least for GSH and HSD products, the effects of marketing margin on inventory management are positive in anticipation of higher future profits, while an increase in the IS ratio gives rise to marketing margin as the margin include storage costs and as the oil trading companies giving incentive to retailers. The results for ULG product suggest a negative interrelationship, which are unexpected outcomes. These are expected to be attributable to the fact that the ULG products have been increasingly substituted by the GSH products as a promotion of government policy.

Further evidence that uncertainty in inventory management positively affect inventory management is found. Shocks in marketing margin also have a positive impact on uncertainty in inventory management. The cross-uncertainty effects of uncertainty in marketing margin on inventory managements are found to be positive for ULG and HSD and negative for GSH. This implies that uncertainty in marketing margin causes the inventory management to be volatile. The sensitivity analysis experiments show how the buffer inventory holding behavior response to the uncertainties that leads to a policy implication of controlling marketing margin within pre-specified band, with the adjustment of taxes or oil fund, can help reduce uncertainty in inventory and, hence, lower buffer inventory holding.

The major limitation of the study regarding uncertainty in inventory management involves the scope of the study that focuses on the uncertainty in ex-refinery price, oil funds, futures prices, and marketing margin. Of course, there must be other uncertainties that affect inventory behavior, such as uncertainty in lead time and macroeconomic uncertainties that are not included in the analysis. It is, therefore, suggestible for future research study to incorporate the other uncertainty measures in the model. The limitation of the analysis in chapter III arises from the complication of the model estimation that requires adequate sample size. This study then decides to employ the pool regression technique using data for five groups of products in the study rather than running regression on each product. It implicitly assumes that all product inventories are managed in the same fashion and the factors being studied have the same effects on the IS ratio of the products. The model with the data for each product group is tested, but experienced the problems in estimation that is expected to be attributable to the inadequate of data. Although the technique provides satisfactory results, the analysis in chapter IV reported that the factors may have different effects on different product. This warranted for further study that might employ larger set of data or different model technique. It is also suggestible for relevant future research to analyze the relationship between uncertainty and inventory with different frameworks, e.g. Vector-Autoregressive model (VAR) or Multivariate-GARCH models. This would give further insights into the relationships. The trade-off between stabilize inventory and stabilized price is also an interesting topic for further study.

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APPENDIX 1

Estimated Partial Stock-Adjustment Model for Petroleum Products

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$$I_{j,t} = 2.10624 + 0.00692S_{j,t} + 0.19414\left(S_{j,t}^{e} - S_{j,t}\right) + 0.98190I_{j,t}$$

$$(0.49) \quad (0.46) \quad (3.48)^{***} \quad (63.73)^{***}$$

Number of observations = 325	F(3,321) = 6729.15	Prob>F = 0.000000
R-Square = 0.9843	Adj. R-Square = 0.9842	Root SME = 58.953

Note: The t-values are in (). *** indicates statistically significant at the level of 1%.

APPENDIX 2

Estimated Pooled Regression Model

$$RP_{j,t} = 6.1886 + 0.83958 RP_{j,t}^{e}$$

$$(10.89)^{***} \quad (43.18)^{***}$$

Number of observations = 330	F(1,328) = 1864.48	Prob>F = 0.000000
R-Square = 0.8504	Adj. R-Square = 0.8499	Root SME = 1.9672

Note: The robust z-values are in (). *** indicates statistically significant at the level of 1%.

APPENDIX 3

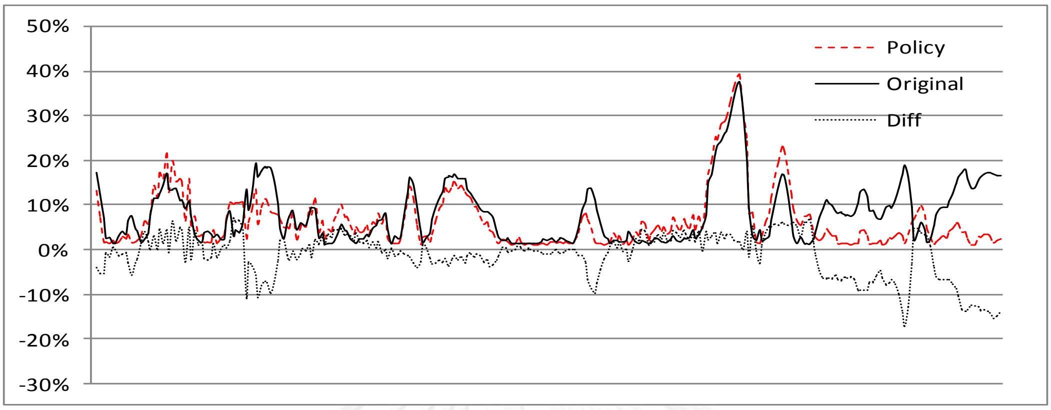
Comparisons of Results of ULG and ULG with OF ratio

Equation	Variable	ULG		ULG with OF ratio	
		Coefficient	SE	Coefficient	SE
IS Mean	$\mathrm{R_t}$	0.7775*	0.4527	0.7882**	0.3280
	$\mathrm{P_t^{WHS}}$	-0.0160***	0.0036	-0.0158***	0.0039
	$\widehat{\mathrm{MM}}_\mathrm{t}$	-0.5143***	0.0983	-0.5345***	0.0756
	OF Ratio			-0.0006***	8.35E-05
	$\mathrm{h_{MM,t}}$	0.0927***	0.0207	0.0953***	0.0192
	Constant	1.9951***	0.2499	2.0323***	0.2195
	$\mathrm{h_{IS,t}}$	0.7928**	0.3334	0.7398**	0.3310
IS Variance	$\epsilon_{MM,t-1}^2$	0.315884	0.4628	0.2714	0.6713
	Constant	-7.6588***	0.2191	-7.6502***	0.2186
	$\epsilon_{IS,t-1}^2$	0.9959***	0.0973	0.9980***	0.0993
MM Mean	$\widehat{\mathrm{IS}}_\mathrm{t}$	-1.6951***	0.4594	-1.6873***	0.4441
	$\mathrm{P_t^S}$	-0.0340***	0.0126	-0.0323***	0.0123
	OF Ratio			-0.0011***	0.0001
	$\mathrm{h_{IS,t}}$	4.1896***	1.2097	4.0788***	1.1947
	Constant	3.5044***	0.2105	3.4778***	0.2085
	$\mathrm{h_{MM,t}}$	0.1622**	0.0779	0.1595**	0.0782
MM Variance	$\epsilon_{IS,t-1}^2$	-7.0429*	3.9755	-7.0432	5.0114
	Constant	-1.9447***	0.1350	-1.9558***	0.1579
	$\epsilon_{MM,t-1}^2$	0.5754***	0.0924	0.5730***	0.0936

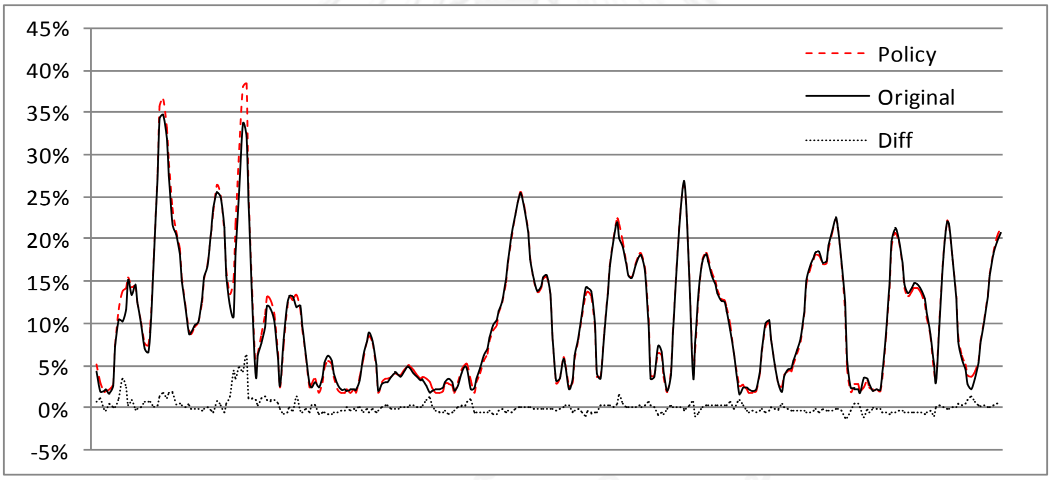
APPENDIX 4

Impacts of marketing margin targeting policy on uncertainty in inventory management

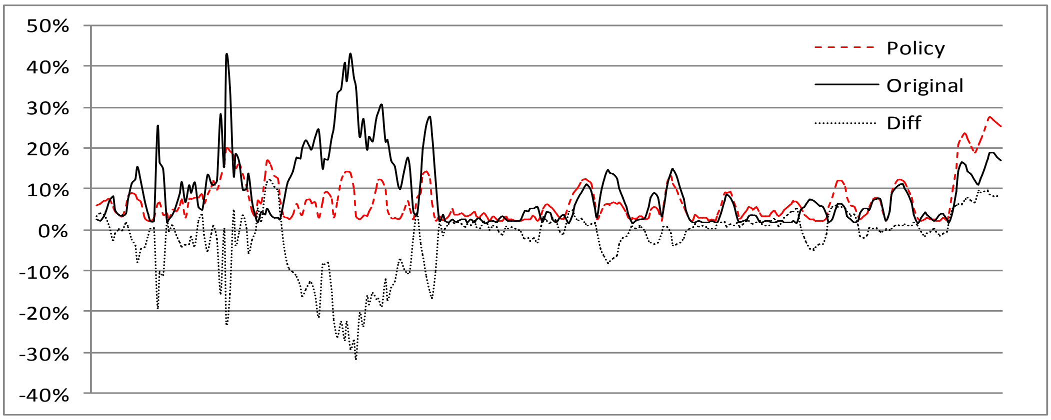
GSH



ULG



HSD



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