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The Effects of Uncertainties on Inventory Management of Petroleum Products: A Case Study of Thailand[1]

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ABSTRACT: This paper employed a Generalized Autoregressive Conditional Heteroskedasticity in Mean framework to examine (i) the relationship between uncertainty and inventory management, defined as an inventory to sale (IS) ratio; 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. Using monthly data for five petroleum products from January 2008 to June 2013, the results indicate that uncertainty induces businesses to hold more of the IS ratio than required. The sensitivity analysis reports 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 indicates that uncertainty in futures price can help mitigate uncertainty in inventory management and gives support to the existence of the futures market.

Keywords: Petroleum products; uncertainties; inventory management.
JEL Classifications: D89; G31; Q41

1. Introduction

Inventory is held at many points in a petroleum supply chain and plays beneficial roles. Crude oil inventory is necessary for refinery operation and the inventory of refined products is crucial in moderating the demand and supply imbalance. Oil inventory management plays a crucial role in stabilizing the oil market. The nature of the present petroleum market is imperative for producers to optimally manage their inventories. Inventory management often 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 (Bassin et al., 2010). The historical data on inventory and sale levels and the IS ratios of petroleum products for the Thai market are shown in Figure 1.

According to the data as of the end of 2012 from Department of Energy Business, Ministry of Energy, inventories for petroleum products in Thailand, including (i) Unleaded Gasoline Products (ULG)[3], (ii) Gasohol Octane Number 95 E10 (GSH95), (iii) Gasohol Octane Number 95 E20

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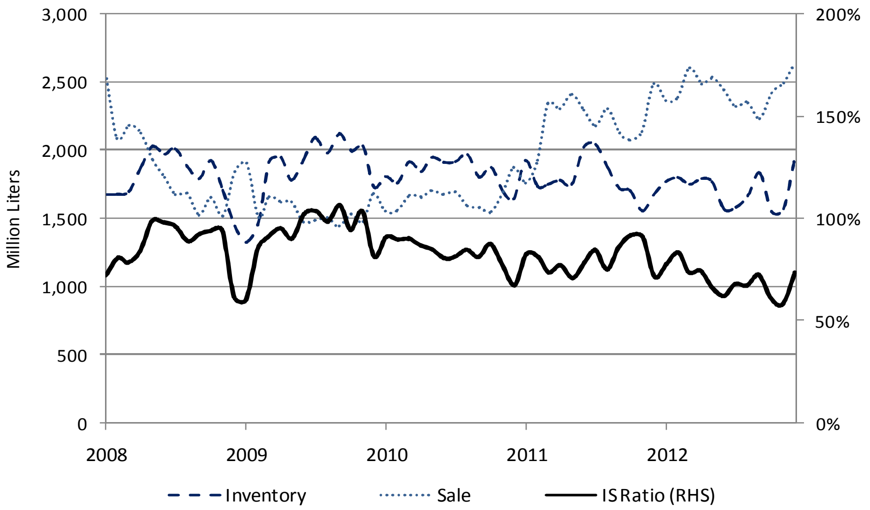
[3] ULG products compose of ULG octane number 91 (ULG91) and ULG octane number 95 (ULG95). The price structure of ULG91 was, however, discontinued in March 2013. All the price component information of the ULG group is weighted average using sale values.

(GSH95E20), (iv) Gasohol Octane Number 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 rest 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 hard 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 (TA) model by Feldstein and Auerbach (1976) and the IS model by Bechter and Pollock (1980).

Figure 1. Inventories, Sales, and the IS Ratios of Petroleum Products 2008-2012



Remark: The authors' calculation from Department of Energy Business (DOEB) Data

Uncertainty is relevant in inventory management 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. Another importance of uncertainty in inventory studies is that it directly affects inventory behavior. Empirical evidences show that uncertainty in sale leads to an increase in inventory holding (see for example, Rubin, 1980; Bo, 2001; Caglayan et al., 2012). Excess holding of petroleum inventory to ensure adequate supply can generate significant carrying costs. Considering the size of the petroleum market, the costs could be economically significant that motivate us to investigate the relationship between uncertainty and inventory management.

This paper 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 the variables. Related literatures are reviewed in the next section. The development of econometrics models for the IS ratio is then presented, followed by the empirical results and sensitivity analysis. The last section concludes the study.

2. Literature Review

The basic SA models, developed 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 models postulated that inventories change because businesses partially close the gap between the current and desired inventory levels, and because of unanticipated sales. A partial SA model can be written as:

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

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 (1) states that the 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 ($S_t^e = S_{t-1}$), a partial SA model might be represented as:

$$I_t = \lambda\gamma_0 + \lambda\gamma_1 S_t + \delta\left(S_{t-1} - S_t\right) + (1-\lambda)I_{t-1} \quad (2)$$

Early works in the field have shown that the framework did not perform well empirically because estimates of parameters were not reasonable. As discussed in Krol and Svorny (1987), 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[4]. 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 and Pollock (1980) introduced an IS model that reflects recognition of the fact that both sales and inventories are jointly controlled by businesses.

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 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

[4] The basic partial SA model is preliminary tested with the petroleum inventory dataset. The results show that the adjustment speed λ is very small around 3%, while the estimate of the adjustment to unexpected sales δ is approximately 20% (Appendix 1).

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 Balanbanoff (1995); Stevans and Sessions (2010); and Ederington, Fernando, Holland, and Lee (2012).

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. 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 that also reported a positive relationship between inventory and uncertainty in sale include Bo (2001) and Caglayan 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 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. This would require an appropriate model specification as will be discussed in the next session.

3. Empirical Model Specification

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 ratio model can be represented as:

$$IS_t = IS_t^* + \zeta(S_t^e - S_t) \tag{3}$$

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 to the desired IS ratio is achieved within the period t. However, our objectives 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 first 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}).[5] This can be written as:

$$IS_t^* = \alpha - \vartheta C_t + \gamma S_t^e + \mu U_t^{IS} \quad (4)$$

Putting equation (4) into equation (3) and setting $\omega = \gamma + \zeta yield$;

$$IS_t = \alpha - \vartheta C_t + \omega S_t^e - \zeta S_t + \mu U_t^{IS}. \quad (5)$$

Basic economics theory states that sales are negative functions of price. To investigate the relationships between price and inventory management, the prices information are incorporated by further assuming current sales to be a linear function of current retail prices ($S_t = a - bRP_t$) and the expected sales to be a linear function of expected retail price ($S_t^e = c - dRP_t^e$). From this assumption, equation (5) then becomes

$$IS_t = \beta_0 - \beta_1 C_t + \beta_2 RP_t - \beta_3 RP_t^e + \beta_4 U_t^{IS}. \quad (6)$$

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

Equation (6) states that an increase in the IS ratio is associated with; (i) a decrease in holding cost (ii) an increase in retail selling price (iii) a decrease in expected retail price, and (iv) an 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 willing to hold more inventories when price increases as the value of inventories 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 first discussed. 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. Further adding the wholesale price with marketing margin and value added tax, the final retail price is obtained. Before the 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.

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 at time t-1 maturing at time t ($F_{t-1,t}$) plus the difference between retail price at time t-1 and ex-refinery price at time t-1, or $RP_t^e = F_{t-1,t} + \left[RP_{t-1} - EP_{t-1}\right]$. 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[6].

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 identical overtime, leading to heteroskedastic

[5] The original IS model of Bechter and Pollock (1980) focused on uncertainty in sales and the researchers propose to use uncertainty in inventory to sale ratio in this study.

[6] In order to validate the concept for any product j, we run a pooled regression of spot retail price 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.

residuals of the regression model. This implies that the OLS assumption of constant variance of the error terms may suffer from loss of efficiency. The variance process of the IS ratio is, therefore, assumed to follow a Generalized Autoregressive Conditional Heteroskedasticity (GARCH) process that treats heteroskedasticity as a variance to be modeled. 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 measure to analyze the role of IS ratio as a buffer stock. The calculated conditional variance will also appear in the mean equation (6) and 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 uncertainty 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)[7] model can be represented as;

$$\mathrm{IS}_{j,t} = \beta_0 - \beta_1 \mathrm{C}_t + \beta_2 \mathrm{RP}_{j,t} - \beta_3 \mathrm{RP}^{e}_{j,t} + \beta_4 \mathrm{U}^{\mathrm{IS}}_{j,t} + \varepsilon_{j,t} \quad (7)$$

$$U^{IS}_{j,t} = \exp(\lambda_0 + \lambda_1 U^{XP}_{j,t} + \lambda_2 U^{OF}_{j,t} + \lambda_3 U^{F}_{j,t}) + \alpha_1 \varepsilon^2_{j,t-1} + \alpha_2 U^{IS}_{j,t-1} \quad (8)$$

where $\mathrm{U}^{\mathrm{IS}}_{j,t}$ is the conditional variance of the IS ratio, $\mathrm{U}^{\mathrm{XP}}_{j,t}$ is the variance of ex-refinery price, $\mathrm{U}^{\mathrm{OF}}_{j,t}$ is the variance of oil fund, and $\mathrm{U}^{\mathrm{F}}_{j,t}$ is the variance of futures price at time t. As can be seen from model specifications in equations (7) and (8), any changes in uncertainties in ex-refinery price, oil fund, and futures price affects inventory management through their impacts on uncertainty in inventory management.

4. Data

The data used in this study 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 (table 1).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 rate, calculated from the 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[8]. The spreads between the retail price and the ex-refinery price are calculated directly from monthly-average

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[7] To determine the lag of ARCH and GARCH terms, the model with different lags is 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 authors decide, therefore, to use lag 1 for both terms in the study.

[8] 1 Barrel = 158.9873 Liters

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.

Table 1. Summary of Statistics

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
$RP^e_{j,t}$	Expected Retail Price	28.68526	5.577846	12.81838	42.74263
$U^{XP}_{j,t}$	Variance of Ex-refinery Price	0.500462	0.899049	0.006502	7.178427
$U^{OF}_{j,t}$	Variance of Oil Fund	0.129302	0.625146	0	8.919054
$U^{F}_{j,t}$	Variance of Futures Price in THB	0.442913	0.680831	0.027947	4.675738

5. Empirical Results

The model estimation with the GARCH-M approach of five petroleum product groups are summarized in Table 2.

Table 2. Estimated GARCH-M with Multiplicative Heteroskedasticity Model

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

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

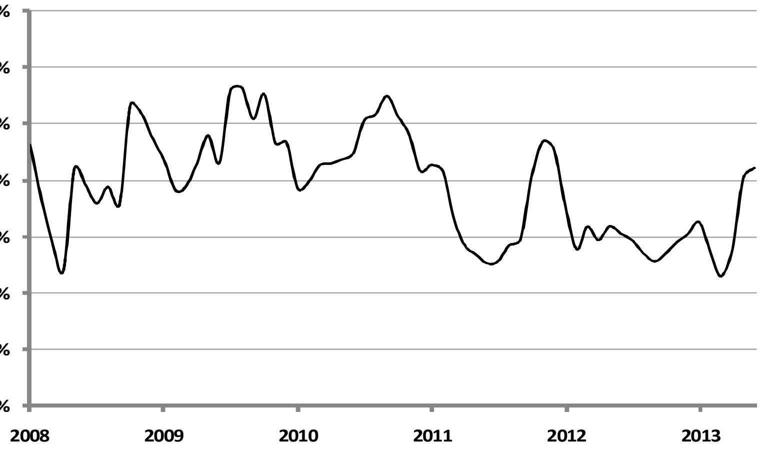
Number of observations	=	330	Log pseudo likelihood = 134.9912
Wald chi-squared (4)	=	42.12	Prob> chi-squared = 0.0000

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

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 $(U^{IS}_{j,t})$ 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 2. 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[9].

Figure 2. Estimated Uncertainty in 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 our heteroskedasticity assumption.

The sensitivity analysis of the contributions of the uncertainties on the values of inventory holding is conducted by back-testing the model with the actual uncertainty data from the previous year (July 2012 – June 2013). The actual uncertainties in ex-refinery price, oil fund, and futures price are shocked up and down by a given percentage in the range between -100% and +100%, each variable at one time and all variables at the same time. The impact of changes in those 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 3.32%, amounting to 23,232 million baht over the last year.

Figure 3 presents the sensitivity analysis on the impacts of increase and decrease market uncertainties on inventory holding value[10]. The estimation illustrates that the contribution of changes

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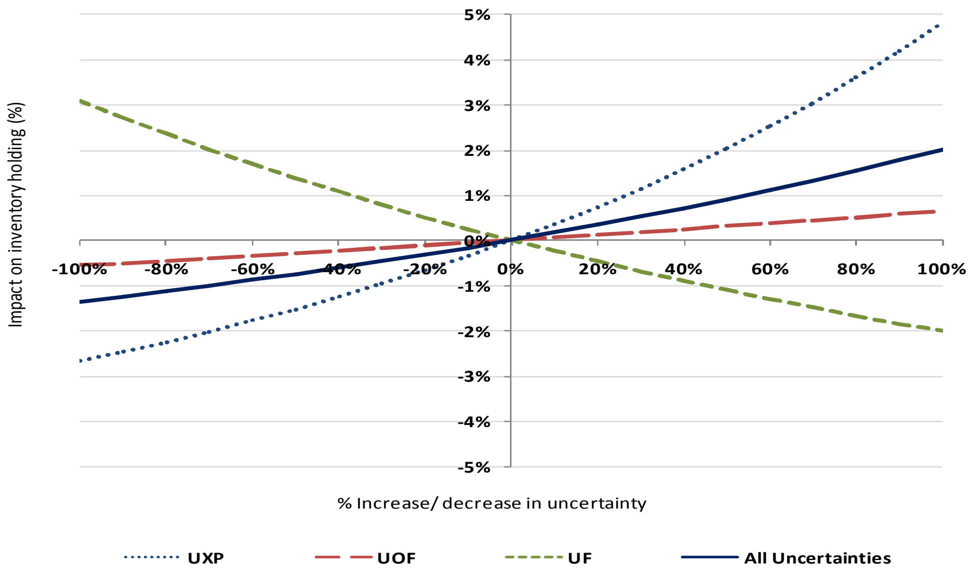
[9] From the authors' calculation, uncertainty in inventory management causes businesses to hold between 1.46% and 8.85% more of the IS ratio with an average of 4.18%. Assuming that sales are at their actual values and any increase in uncertainty causes an increase in inventory level only, the value of this buffer inventory averages to 60,500 million baht per year.

[10] 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.

in uncertainty in ex-refinery prices on the inventory management is stronger than the other two uncertainty variables. A 100% increase 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% increase in uncertainty in the 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. 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.

Figure 3. Sensitivity Analysis of Increase/ Decrease Uncertainty on the IS Ratio



The policy implications of the paper concern the roles of the oil fund mechanism and the existence of the futures market. The primary objectives of the oil fund are to stabilize petroleum price and promote usage of alternative energy products[11]. Although the uncertainty in the oil fund variable has a significant positive coefficient, 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 a side effect on uncertainty in petroleum inventory management. Our 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. The results of this study also 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 petroleum product producers to effectively plan and manage their inventories and sales. The hedging via futures contract might also result in reduction of the uncertainty in the ex-refinery price, in which the simulation

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

experiment highlights that a decline in ex-refinery price uncertainty can greatly reduce the degree of uncertainty in inventory management.

6. Conclusion

The study examines the relationship between uncertainties and the petroleum products inventory management, while investigating the determinants of uncertainty of inventory management. The GARCH-M framework allows us to quantify the effects of uncertainties in ex-refinery price, oil fund, and futures prices on inventory management in the context of Thai's petroleum market. The empirical results are statistically significant and have proper signs. It was found that the real interest cost of inventories holdings negatively affects the IS ratio as claimed in literatures. As predicted by the model, an increase in spot retail price associated with an increase in the IS ratio, while an increase in expected price is associated with a decrease in the ratio. The model produces a significant positive relationship between uncertainty in inventory management and the IS ratio. Businesses hold more inventories as they face higher uncertainty in inventory management. The sensitivity analysis shows that the uncertainty in ex-refinery price has an economically significant positive impact on inventory uncertainty. 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.

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Appendix 1

Estimated Partial Stock-Adjustment Model for Petroleum Products

$$I_{j,t} = 2.10624 + 0.00692S_{j,t} + 0.19414\left(S^{e}_{j,t} - S_{j,t}\right) + 0.98190I_{j,t}$$
$$(0.49) \quad (0.46) \quad (3.48)^{***} \quad (63.73)^{***}$$

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

$$RP_{j,t} = 6.1886 + 0.83958RP^{e}_{j,t} + \epsilon_{j,t}$$
$$(10.89)^{***} \quad (43.18)^{***}$$

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%.