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## Supply response function of oil palm in Thailand

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Phitthayaphinant, P., Somboonsuke, B. and Eksomtramage, T. (2013) Supply response function of oil palm in Thailand. *International Journal of Agricultural Technology* 9(4):727-747.

**Abstract** Thai farmers are currently more interested to engage and invest in oil palm cultivation in respond to demands for food and non-food products. This quantitative research was conducted to estimate structural parameters and elasticity of supply response function of oil palm in Thailand. Annual time-series data from 1988 to 2011 was used. Empirical equations were estimated using the seemingly unrelated regression (SUR). The results confirmed that adaptive expectation model is the best model. The statistically significant variables that determine area for oil palm plantation are : Thai oil palm plantation areas in the previous years, wages for agricultural labor, retail prices of chemical fertilizer in previous years, bank interest rate in previous years, government policy before and after the action plan for the development and promotion of biodiesel production and consumption, and risk of prices of oil palm fresh fruit bunch compared with prices of unsmoked rubber sheet grade 3 in previous years. The estimated short-run and long-run of these variables are found to be inelastic, except for wages for agricultural labor which is unitary elastic in the long run. The statistically significant variable that determines yield of oil palm is only retail prices of chemical fertilizer in the previous years.-It was estimated to be inelastic both in the short run and long run. The results are expected to be used by policy-makers to formulate appropriate policy options towards optimizing utilization of agricultural land for differently but equally important purposes for development in addition to production management of oil palm to meet domestic demands.

**Key words:** supply response, function, oil palm, seemingly unrelated regression

### Introduction

Thailand is an agriculture-oriented country. Agricultural sector contributes much to the Gross Domestic Product (GDP), employment, food and raw materials production for industries. Oil palm (*Elaeis guineensis* Jacq.) has been one of the most important commercial oil crops grown in Thailand because of its diverse advantages. Palm oil is used in a wide range of products

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such as food (cooking oil, margarine, sweet), manufactured goods (cosmetics, soap, candle), and as an alternative energy (biodiesel).

Oil palm starts to produce fruit after three years of its planting and remains productive for more than twenty-five years (Eksomtramage, 2011). Accordingly, investment in oil palm plantation is similar to investment in a capital asset because oil palm yields a continuous stream of returns like any other capital asset. Its production after the third year increases up to the 8-10<sup>th</sup> year, then remains at the same level with a certain amount of variations for a long time, but mostly falls off more or less rapidly from about the 20<sup>th</sup> year (Eksomtramage, 2011).

Areas for oil palm plantation have increased continuously due to its growing importance to the Thai economy. It has generated incomes. On the other hand, it has been criticized as a cause of environmental consequences. That is, increased areas for oil palm plantation has been associated with converting/clearing/destruction of primary forests, natural rainforest, peat swamp forest and encroachment of plantation into national parks or public lands, resulting in biodiversity losses, forest fire and greenhouse gas emissions (Kessler *et al.*, 2007; Dallinger, 2011 and Wicke *et al.*, 2011).

This research is an attempt to examine production decisions of oil palm in terms of areas and productivity, its price changes and selected non-price factors. Specifically, the research aims to quantitatively estimate structural parameters and elasticities of supply response function of oil palm in Thailand. Estimating supply response function of oil palm requires recognition of government plan and policy affecting oil palm farmers' decisions and their decision to change from one crop to another. Consequently, the results are expected to supplement policy-makers to formulate policy options for optimal land use and agricultural development.

## **Methods and materials**

This research used time-series data. The data were taken from both published and unpublished reports of Thai Office of Agricultural Economics (2010, 2011, 2012a, 2012b, 2012c and 2012d), Meteorological Department (2011), and Bank of Thailand (2012).

A distributed lag model to measure the responsiveness of area to price was suggested by Askari and Cummings (1977), Nerlove (1956, 1958 and 1979), Braulke (1982), Hartley *et al.* (1987), Nosheen and Iqbal (2008) and Maddala and Lahiri (2009). The model described dynamics of agricultural supply which was expressed as follows:

$$A_t = \alpha + \beta P_t^* + \gamma Z_t + U_t \quad (1)$$

Where  $A_t$  denoted an actual area in a current year,  $P_t^*$  was an expected price in a current year,  $Z_t$  was all other observed and presumably exogenous factors in a current year, and  $U_t$  was stochastic disturbance term or random error term with classical properties (assumed to be independent and normally distributed with zero mean and constant variance).

Price played a key role in several of the supply response mechanism which was assumed to be determined by several demand and supply characteristics. However, expected price in a current year was directly unobservable which was assumed to be formed as

$$P_t^* = P_{t-1} + \delta(P_{t-1} - P_{t-1}^*), \quad 0 < \delta \leq 1 \quad (2)$$

Where  $P_{t-1}$  stood for an actual price in a previous year,  $P_{t-1}^*$  was an expected price in a previous year, and  $\delta$  was a coefficient of expectation, reflecting response of expectation to observed prices.

Equation (2) presented a process of adaptive price expectation which indicated that an expected price in a current year fell somewhere in between the actual price in previous years and the expected price in previous years depending upon the elasticity of expectation. If  $\delta$  approached zero, there was no difference between an expected price in a current year and the actual price in previous year, while if  $\delta$  is equal to one, an expected price was identical to the actual price in a previous year.

Equation (2) implied that farmers adapt their expectations of future price from the past experience, and they learned from their mistakes. By rearranging (2) it could be easily shown that the expected price in the current year is a proportion of both actual prices in the previous year and the expected price. Thus, expectations of price were weighted moving to average of past prices in which weights decline geometrically. Substituting (2) into (1) and rearranging gives,

$$A_t = \delta\alpha + \delta\beta P_{t-1} + \delta\gamma Z_{t-1} + (1-\delta) U_{t-1} + V_t \quad (3)$$

Where  $V_t = U_t - (1-\delta) U_{t-1}$  which was a adaptive expectation model.

A partial adjustment model was assumed that a planned or desired area in a current year ( $A_t^*$ ) was a function of actual price ( $P_t$ ) and all other exogenous factors ( $Z_t$ ). In general, it could be presented as follows:

$$A^*_t = \alpha + \beta P_t + \gamma Z_t + U_t \quad (4)$$

As a planned or desired area in a current year was directly unobservable; thus, Nerlove proposed the following hypothesis:

$$\begin{aligned} A_t - A_{t-1} &= \lambda(A^*_t - A_{t-1}) \\ A_t &= A_{t-1} + \lambda(A^*_t - A_{t-1}), \quad 0 < \lambda \leq 1 \end{aligned} \quad (5)$$

Where  $A_{t-1}$  denoted an actual area in a previous year, and  $\lambda$  was known as a coefficient of adjustment, reflecting a response of expectation to observed areas.

A coefficient of area adjustment indicated producers could adjust their area only a fraction  $\lambda$  of a desired level. A speed of adjustment in each period was represented by some fraction of the difference between desired and actual areas in a previous period. If  $\lambda$  approached to zero, an area remained unchanged from year to year, whereas  $\lambda$  is equal to one, the adjustment was instantaneous.

Typically, adjustment to the desired level was likely to be incomplete because of some restrictions such as physical and institutional constraints, fixed capital, labor (knowledge and skill), information, risk, and others which caused costs due to wrong decision. Thereby,  $\lambda$  might be less than one. Note also that  $\lambda$  provided a link between the short-run and long-run elasticities.

The estimated long-run elasticities of area response and yield response of oil palm in Thailand were obtained using the formula as follows:

$$E_l = \frac{E_s}{\lambda} \quad \text{and} \quad \frac{E_s}{\gamma}$$

Where  $E_l$  referred to the long-run elasticity,  $E_s$  denoted the short-run elasticity,  $\lambda$  stood for a coefficient of area adjustment ( $0 \leq \lambda \leq 1$ ) which was simply computed by one minus estimated coefficient of Thai oil palm plantation areas in a previous year, and  $\gamma$  stood for a coefficient of yield adjustment ( $0 \leq \gamma \leq 1$ ) which was simply computed by one minus estimated coefficient of Thai yields of oil palm in a previous year.

Rearranging (5) and substituting into (4) gave a partial adjustment model:

$$A_t = \lambda\alpha + \lambda\beta P_t + \lambda\gamma Z_{t-1} + (1-\lambda)A_{t-1} + \lambda U_t \quad (6)$$

Combining (1) and (4) gives the structural equation.

$$A^*_t = \alpha + \beta P^*_t + \gamma Z_t + U_t \quad (7)$$

Both desired area and expected price were directly unobservable. Substitution of (2) and (5) in (7) gave the reduced equation as follows:

$$A_t = \alpha_0 + \alpha_1 P_{t-1} + \alpha_2 A_{t-1} + \alpha_3 A_{t-2} + \alpha_4 Z_t + \alpha_5 Z_{t-1} + V_t \quad (8)$$

Where  $\alpha_0 = \delta\lambda\alpha$ ,  $\alpha_1 = \delta\lambda\beta$ ,  $\alpha_2 = (1-\delta) + (1-\lambda)$ ,  $\alpha_3 = -(1-\delta)(1-\lambda)$ ,  $\alpha_4 = \lambda\gamma$ ,  $\alpha_5 = -\lambda\gamma(1-\delta)$  and  $V_t = \lambda U_{te} - \lambda(1-\delta)U_{t-1}$

The concept of lags: an economic cause; for instance, a price change, produces its effect only after some lag in time. A distributed lag implied that the effect produced by an economic cause was noticed over more than one period. The distributed lags with respect to price changes were incorporated in this research.

For the achievement of the objective, annual time-series data from 1988 to 2011 (24 observations) were used. Whittaker and Bancroft (1979) and Nutt *et al.* (1986) mentioned that area response studies adopting econometric method uses at least 20 time-series observations to obtain parameter estimates. However, Whittaker and Bancroft (1979) indicated that a time period of such length raises concerns due to problems in measuring technological and structural changes in the area response coefficients.

The research needed to assume that (1) oil palm farmers attempted to maximize profit, and (2) oil palm market was perfectly competitive, individual oil palm farmer sold their outputs at given market prices or oil palm farmers were price takers. These assumptions of the traditional supply function were consistent with the fact, that the farmers grew oil palm as a commercial crop and not a subsistence crop. As a result, it was considered that they have to maximize revenues. Moreover, most oil palm farmers in Thailand are smallholders. This results to low quantity being supplied by individual oil palm farmer and does not affect price of oil palm fresh fruit bunch. Consequently, they were considered to be price takers.

Favorable price alone may not induce oil palm farmers to expand areas for oil palm plantation in order to attain desired targets. Sometimes response behavior of oil palm farmers may be influenced by non-price factors. This was observed in previous researches (Poomthong, 2000; Alias and Tang, 2005; Paksuchol, 2005; Moraes, 2006 and Boontongmai, 2007) in addition to supply theory (Tomek and Robinson, 1981; Samuelson and Nordhaus, 2005; Puttikorn *et al.*, 2006; Mankiw, 2007 and Netayarak, 2007), agricultural production theory with respect to competition (Snodgrass and Wallace, 1964 and Netayarak, 2007) and cobweb theory (Tomek and Robinson, 1981; Goodwin, 1994 and Netayarak, 2007).

Model developments were adopted with adaptive expectation and partial adjustment models which used a concept of distributed lag. Seemingly unrelated regression (SUR) technique was employed to estimate parameters of system due to contemporaneous correlation in the errors across equations (Zellner, 1962). That is, error terms from one equation was often found to be correlated with error terms in another equation. The contemporaneous correlation was tested for independence of disturbances. Failure to account for this across equations, contemporaneous correlation in estimating a set of equations could invalidate properties of ordinary least square estimators (Salassi, 1995).

Oil palm is perennial tree which has gestation period (3 years). It can be harvest for a long time. Its harvest is based on law of diminishing returns. Therefore, supply response functions are divided into two equations including area response equation and yield response equation (Issariyanukula, 1992 quoted by Subhakit, 2000).

Structural models are systems of equations with each equation involving some relationships among exogenous and endogenous variables and parameters (Varian, 1992). Empirical supply response functions in terms of area response and yield response were specified in double logarithmic equations owing to a statistical fitness and a simple computation in determining elasticity. Short-run elasticity was equal to corresponding estimated coefficient. The implicit functional relationship of supply response could be expressed as:

#### Adaptive expectation model

$$\ln(\text{PPA}_t) = \ln(a_0) + a_1\ln(\text{PPA}_{t-1}) + a_2\ln(\text{WAG}_t) + a_3\ln(\text{WAG}_{t-1}) + a_4\ln(\text{FER}_t) + a_5\ln(\text{FER}_{t-1}) + a_6\ln(\text{INT}_t) + a_7\ln(\text{INT}_{t-1}) + a_8\text{BIP}_t + a_9\text{BIP}_{t-1} + a_{10}\ln(\text{PPF}_{t-1}) + a_{11}\ln(\text{RPU}_t) + a_{12}\ln(\text{RPU}_{t-1}) + a_{13}\ln(\text{RPR}_t) + a_{14}\ln(\text{RPR}_{t-1}) + a_{15}\ln(\text{QRA}_t) + a_{16}\ln(\text{QRA}_t) + U_1;$$

$$\ln(\text{YPR}_t) = \ln(b_0) + b_1\ln(\text{YPR}_{t-1}) + b_2\ln(\text{WAG}_t) + b_3\ln(\text{WAG}_{t-1}) + b_4\ln(\text{FER}_t) + b_5\ln(\text{FER}_{t-1}) + b_6\ln(\text{INT}_t) + b_7\ln(\text{INT}_{t-1}) + b_8\text{BIP}_t + b_9\text{BIP}_{t-1} + b_{10}\ln(\text{PPF}_{t-1}) + b_{11}\ln(\text{QRA}_t) + b_{12}\ln(\text{QRA}_{t-1}) + U_2$$

#### Partial adjustment model

$$\ln(\text{PPA}_t) = \ln(a_0) + a_1\ln(\text{PPA}_{t-1}) + a_2\ln(\text{WAG}_t) + a_3\ln(\text{FER}_t) + a_4\ln(\text{INT}_t) + a_5\text{BIP}_t + a_6\ln(\text{PPF}_{t-1}) + a_7\ln(\text{RPU}_t) + a_8\ln(\text{RPR}_t) + a_9\ln(\text{QRA}_t) + U_1;$$

$$\ln(\text{YPR}_t) = \ln(b_0) + b_1\ln(\text{YPR}_{t-1}) + b_2\ln(\text{WAG}_t) + b_3\ln(\text{FER}_t) + b_4\ln(\text{INT}_t) + b_5\text{BIP}_t + b_6\ln(\text{PPF}_{t-1}) + b_7\ln(\text{QRA}_t) + U_2$$

#### Pooled adaptive expectation model and partial adjustment model

$$\ln(\text{PPA}_t) = \ln(a_0) + a_1\ln(\text{PPA}_{t-1}) + a_2\ln(\text{PPA}_{t-2}) + a_3\ln(\text{WAG}_t) + a_4\ln(\text{WAG}_{t-1}) + a_5\ln(\text{FER}_t) + a_6\ln(\text{FER}_{t-1}) + a_7\ln(\text{INT}_t) + a_8\ln(\text{INT}_{t-1}) + a_9\text{BIP}_t + a_{10}\text{BIP}_{t-1} +$$

$$\begin{aligned}
& a_{11}\ln(\text{PPF}_{t-1}) + a_{12}\ln(\text{RPU}_t) + a_{13}\ln(\text{RPU}_{t-1}) + a_{14}\ln(\text{RPR}_t) + a_{15}\ln(\text{RPR}_{t-1}) + \\
& a_{16}\ln(\text{QRA}_t) + a_{17}\ln(\text{QRA}_{t-1}) + U_1; \\
\ln(\text{YPR}_t) = & \ln(b_0) + b_1\ln(\text{YPR}_{t-1}) + b_2\ln(\text{YPR}_{t-2}) + b_3\ln(\text{WAG}_t) + b_4\ln(\text{WAG}_{t-1}) \\
& + b_5\ln(\text{FER}_t) + b_6\ln(\text{FER}_{t-1}) + b_7\ln(\text{INT}_t) + b_8\ln(\text{INT}_{t-1}) + b_9\text{BIP}_t + b_{10}\text{BIP}_{t-1} + \\
& b_{11}\ln(\text{PPF}_{t-1}) + b_{12}\ln(\text{QRA}_t) + b_{13}\ln(\text{QRA}_{t-1}) + U_2
\end{aligned}$$

Where  $\text{PPA}_t$  was Thai oil palm plantation areas as a proxy variable representing supply of oil palm (rai),  $\text{PPA}_{t-1}$  and  $\text{PPA}_{t-2}$  were Thai oil palm plantation areas in a previous year and lagged two years, respectively as proxy variables representing hope that they capture effects of farmers' knowhow and experience about oil palm cultivation (rai),  $\text{WAG}_t$  was an average wages for agricultural labor as a proxy variable representing prices of input (baht per day),  $\text{WAG}_{t-1}$  was an average wages for agricultural labor in a previous year (baht per day),  $\text{FER}_t$  was an average retail prices of chemical fertilizer as a proxy variable representing prices of input (baht per kilogram),  $\text{FER}_{t-1}$  was an average retail prices of chemical fertilizer in a previous year (baht per kilogram),  $\text{INT}_t$  was an interest rate as a proxy variable representing a macroeconomic policy in terms of monetary policy being cost of borrowing and opportunity cost to hold money (percent per year),  $\text{INT}_{t-1}$  was interest rate in a previous year (percent per year),  $\text{BIP}_t$  was a dummy/binary variable as a proxy variable representing government policy before and after an action plan for the development and promotion of biodiesel production and consumption,  $\text{BIP} = 0$  representing years before the action plan (1988 to 2004), and  $\text{BIP} = 1$  representing years after the action plan (2005 to 2011),  $\text{BIP}_{t-1}$  was a dummy/binary variable representing government policy before and after an action plan for the development and promotion of biodiesel production and consumption in a previous year,  $\text{BIP} = 0$  representing years before the action plan (1987 to 2004), and  $\text{BIP} = 1$  representing years after the action plan (2005 to 2010),  $\text{PPF}_{t-1}$  was an average farm prices of oil palm fresh fruit bunch in a previous year in lieu of expected price at harvest time which is not known at planting time (baht per kilogram),  $\text{RPFU}_t$  was a risk of prices of oil palm fresh fruit bunch compared with prices of unsmoked rubber sheet grade 3, based on variability of annual average farm prices as measured by standard deviation of a three-year average farm prices of oil palm fresh fruit bunch divided with standard deviation of a three-year average farm prices of unsmoked rubber sheet grade 3,  $\text{RPFU}_{t-1}$  was a risk of prices of oil palm fresh fruit bunch compared with prices of unsmoked rubber sheet grade 3 in a previous year,  $\text{RPF}_t$  was a risk of prices of oil palm fresh fruit bunch compared with prices of jasmine rice, based on variability of annual average prices as measured by standard deviation of a three-year average farm prices of oil palm fresh fruit bunch divided with standard deviation of a three-

year average prices of jasmine rice,  $RPF_{t-1}$  was a risk of prices of oil palm fresh fruit bunch compared with prices of jasmine rice in a previous year,  $QRA_t$  was annual rainfall as a proxy variable representing climate condition (millimeter),  $QRA_{t-1}$  was annual rainfall in a previous year (millimeter),  $YPR_t$  was Thai average yields of oil palm obtained as a proxy variable representing supply of oil palm (kilogram per rai),  $YPR_{t-1}$  and  $YPR_{t-2}$  were Thai average yields of oil palm obtained in a previous year and lagged two years as proxy variables representing expectation of oil palm profitability (kilogram per rai),  $t$  represented time trend in each variable ( $t = 1, 2, 3, \dots, 24$ ), and  $U_1$  and  $U_2$  were stochastic disturbance term.

Technology variable was not included in the model because the nature of technology made it difficult to quantify. Crop technology was comprised of a large number of variables including advances in herbicides and pesticides, new types of machinery, improved varieties, and better farm management practices (Whittaker and Bancroft, 1979). The previous supply response researches have largely relied on linear time trends to account for changes in technology. If technology did not advance linearly, then models accounting for technology with a linear trend were misspecified and likely contained biased parameter coefficients.

Estimated parameter coefficients ( $b$ ) of double logarithmic functional form represented the elasticities of statistically significant variables. Slopes of these variables were calculated using the formula (Gujarati and Porter, 2009):

$$b \times \frac{\bar{Y}}{\bar{x}}$$

Where  $\bar{Y}$  denoted an average of dependent variable, and  $\bar{x}$  denoted an average of independent variable.

## Results and discussion

The results of seemingly unrelated regression analysis in terms of area response and yield response of oil palm in Thailand are shown in Table 1 and 2, respectively. They can be discussed that adaptive expectation model is chosen as the most appropriate model to be used in calculating elasticities of supply because overall goodness of fit of the model measured by coefficient of multiple determination ( $R^2$ ) which is quite high. In addition, most signs of significant estimated coefficients are found to be logical and consistent with economic reasoning.



Adaptive expectation model of area response of oil palm in Thailand indicates that the statistically significant variables that determine area under oil palm plantation are Thai oil palm plantation areas in a previous year, wage for agricultural labor, retail prices of chemical fertilizer in a previous year, interest rate in a previous year, government policy before and after an action plan for the development and promotion of biodiesel production and consumption, and risk of prices of oil palm fresh fruit bunch compared with prices of unsmoked rubber sheet grade 3 in a previous year. The regression model with these explanatory variables can explain correctly 99.93 percent of the total variation in area for oil palm plantation which is appropriate to indicate overall fitness of estimated equation.

This imply that as the Thai oil palm plantation area in the previous year increases (decreases) by one percent (one rai), the area for oil palm plantation tends to increase (decrease) by 0.59 percent (0.64 rai), keeping other variables constant. As the wage for agricultural labor increases (decreases) by one percent (one baht per day), the area for oil palm plantation tends to increase (decrease) by 0.41 percent (7,977.98 rai), keeping other variables constant. The application of government policy before and after an action plan for the development and promotion of biodiesel production and consumption resulted to an increase in area for oil palm plantation by 0.08 percent (156,648.56 rai), keeping other variables constant. As the risk for prices of oil palm fresh fruit bunch as compared with the prices of unsmoked rubber sheet grade 3 in previous year increases (decreases) by one percent (one unit), area for oil palm plantation tends to increase (decrease) by 0.02 percent (279,729.57 rai), keeping other variables constant.

On the other hand, retail prices of chemical fertilizer in a previous year and interest rate in a previous year are negatively related to area for oil palm plantation. They imply that retail price of chemical fertilizer in a previous year increases (decreases) by one percent (one baht per kilogram), area for oil palm plantation tends to decrease (increase) by 0.18 percent (35,674.01 rai), holding other variables constant. Interest rate in a previous year increases (decreases) by one percent (one percent per year), area for oil palm plantation tends to decrease (increase) by 0.07 percent (13,734.22 rai), holding other variables constant.

The estimated short-run elasticity of area response of oil palm in Thailand with respect to Thai oil palm plantation areas in previous year is the highest, followed by wage for agricultural labor, retail prices of chemical fertilizer in a previous year, interest rate in a previous year, government policy before and after an action plan for the development and promotion of biodiesel production and consumption, and risk of prices of oil palm fresh fruit bunch

compared with prices of unsmoked rubber sheet grade 3 in a previous year, respectively.

Estimated long-run elasticity of area response of oil palm in Thailand was computed as follows:

$$\begin{aligned} \lambda &= 1 - \text{estimated coefficient of Thai oil palm plantation areas in a previous year} \\ &= 1 - 0.59 \\ &= 0.41 \end{aligned}$$

The result shows that oil palm farmers can realize desired equilibrium area level at 41 percent.

**Table 1.** Seemingly unrelated regression analysis results of area response of oil palm in Thailand

Variable	AE model <sup>1</sup>	PA model <sup>2</sup>	Pooled AE and PA model
C	4.21* (1.77)	3.74*** (3.40)	3.75** (2.58)
PPA <sub>t-1</sub>	0.59*** (3.50)	0.68*** (6.26)	-0.50** (-2.46)
PPA <sub>t-2</sub>	-	-	1.41*** (6.19)
WAG <sub>t</sub>	0.41*** (4.27)	0.36*** (3.23)	0.49*** (8.09)
WAG <sub>t-1</sub>	0.15 (0.82)	-	-0.13 (-1.06)
FER <sub>t</sub>	-0.06 (-0.76)	-0.04 (-0.67)	-0.19*** (-3.67)
FER <sub>t-1</sub>	-0.18** (-2.40)	-	0.008 (0.14)
INT <sub>t</sub>	-0.09 (-1.39)	-0.11*** (-2.61)	0.30*** (4.06)
INT <sub>t-1</sub>	-0.07* (-1.55)	-	-0.13*** (-4.32)
BIP <sub>t</sub>	0.08*** (2.83)	0.05* (1.64)	0.15*** (7.36)
BIP <sub>t-1</sub>	0.02 (0.55)	-	-0.07** (-2.66)
PPF <sub>t-1</sub>	0.03 (0.85)	0.008 (0.22)	0.01 (0.62)
RPFU <sub>t</sub>	0.01 (1.30)	0.01 (1.38)	0.02*** (3.81)
RPFU <sub>t-1</sub>	0.02*** (3.43)	-	0.05*** (8.15)
RPFR <sub>t</sub>	-0.01 (-1.40)	-0.008 (-1.17)	-0.03*** (-4.52)
RPFR <sub>t-1</sub>	-0.01 (-1.36)	-	-0.01* (-2.07)
QRA <sub>t</sub>	0.004 (0.06)	-0.05 (-0.77)	-0.16*** (-3.39)
QRA <sub>t-1</sub>	0.001 (0.02)	-	-0.36*** (-4.45)
R <sup>2</sup>	0.9993	0.9979	0.9997
Adj R <sup>2</sup>	0.9972	0.9965	0.9987
S.E. of regression	0.0322	0.0360	0.0220
D-W stat	2.6855	2.3995	2.9531

Note: <sup>1</sup>AE refers to adaptive expectation model, <sup>2</sup>PA refers to partial adjustment model, <sup>3</sup>\*\*\* p ≤ 0.01, \*\* p ≤ 0.05 and \* p ≤ 0.10

Number of year of oil palm farmers' absolute adaptation at 95 percent (N) can be calculated as follows (Tatipornkul, 1991):

$$\begin{aligned} N &= \frac{\log(0.05)}{\log(1-\lambda)} \\ &= \frac{\log(0.05)}{\log(1-0.41)} \\ &= \frac{\log(0.05)}{\log(0.59)} \\ &= 5.68 \end{aligned}$$

The result shows that oil palm farmers' adaptation to approach the desired area under oil palm plantation is 5.68 years.

Therefore, we obtain estimated long-run elasticity of area response of oil palm in Thailand as follows:

$$\ln(\text{PPA}_t) = 10.27 + 1.00\ln(\text{WAG}_t) - 0.44\ln(\text{FER}_{t-1}) - 0.17\ln(\text{INT}_{t-1}) + 0.20\text{BIP}_t + 0.05\ln(\text{RPFU}_{t-1})$$

The results obviously disclosed that the value of estimated short-run elasticity is relatively less than the value of estimated long-run elasticity, meaning that oil palm farmers have adjusted their production by planning in the long run but greater in the short run because majority of Thai oil palm farmers are small scale growers resulting to expansion of area under oil palm plantation is relative fixed from some resource constraints in the short run. However, oil palm farmers will have more experience to adapt their production level to signal market in the long run.

Estimated short-run elasticity of wage for agricultural labor is inelastic, being less than one, but its estimated long-run elasticity is unitary elastic, being equal to one. This is because oil palm cultivation is labor intensive both full time and part time from beginning of cultivation until harvesting. Most laborers are semi-skilled and/or unskilled. These employees tend to undervalue existing skills and qualifications. Thus, they decide to turn into non-agricultural sector. High wage will motivate them to be more mobile and migrate to agricultural sector in the long run.

The estimated short-run and long-run elasticities of retail prices of chemical fertilizer in previous year are inelastic. They imply that oil palm farmers are not much responsive to change in retail prices of chemical fertilizer in the previous year because chemical fertilizer is a major input for oil palm

cultivation and it is the main variable cost (Kiattichaiprasop, 2004). Chemical fertilizer is imported from abroad as such oil palm farmers can not control its price. Retail prices of chemical fertilizer relates to various factors such as exchange rate, prices of oil, tariff, and economic condition. In the long run, oil palm farmers may utilize bio-fertilizer as a substitute.

Estimated short-run and long-run elasticities of interest rate in previous year are inelastic. They imply that oil palm farmers are not much responsive to change in interest rate in previous year because oil palm plantation is a long-term commitment of land, labor, and capital to derive a future stream of net benefit. The first two years represent extensive cash outflows. The benefits start in approximately the third year onwards when oil palm trees start to produce output. The investment cost of oil palm plantation is rather high (Siripongsarajana, 1981; Wepattarameateekul, 1992; Namson, 2000; Detwarawit, 2001; Thorananoppakao, 2001; Longsa, 2003; Artayakul, 2004; Koetsap, 2004; Kiattichaiprasop, 2004; Tongnum, 2005; Srithep, 2006; Ploywilert, 2007; Preechachote, 2007; Kaewpradit, 2010; Peantong, 2010 and Petthong, 2011) and gained from the loan (Namson, 2000; Detwarawit, 2001; Tongnum, 2005; Preechachote, 2007 and Phaungpae, 2010). Accordingly, bank credit is an important source of financing to expand productive capacity. Lack of fund is a key barrier to expand area for oil palm plantation. Given available cash in hand, oil palm farmers can make decision either to save or to invest. If interest rate is higher than production return, oil palm farmers have been discouraged to increase their production. Furthermore, most oil palm smallholders face problems of loan repayment because they have low income (Kiattichaiprasop, 2004).

Estimated short-run and long-run elasticities of the government policy before and after the action plan for the development and promotion of biodiesel production and consumption are inelastic. This implies that oil palm farmers are not much responsive to the government policy. Undoubtedly, Thailand is an agricultural based country in which most of people are in agribusiness.

Consequently, energy crops are considered as a top priority. In terms of macroeconomic and socio-economic points of view, energy crops' development for imported fossil oil substitution will benefit all Thai people in the agricultural sector, consumers, and the natural environment. Palm oil is widely used as major raw materials for biodiesel production because oil palm has a high oil content and the highest potential of yield per unit area when compared to other oil crops (Hartley, 1988; Maiti *et al.*, 1988 quoted by Salunkhe *et al.*, 1992; Gascon *et al.*, 1989 quoted by Salunkhe *et al.*, 1992; Barison, 1996; Anyane, 1961 quoted by Bergert, 2000; Mattsson *et al.*, 2000; Ming and Chandramohan, 2002 and Corley and Tinker, 2003). Moreover, oil palm

produces an average yield of about five to ten times higher than yield from other leading oil crops combined with historically low prices, relative stability, and reported nutritional benefits (Bethe, 2010 quoted by Levin *et al.*, 2012). Consequently, royal Thai government continuously keeps on promoting for expansion of areas for oil palm plantation throughout different regions of Thailand to meet domestic demands for palm oil. The National Energy Policy Committee (NEPC) clearly regulates that biodiesel as fuel for diesel engines, is produced from chemical conversion of vegetable into methyl or ethyl ester (Vanichseni, 2003). However, it is currently well cognized that agricultural land is one of valuable natural resources which are vitally important for major crop production of the country. Available potential agricultural land has been dramatically decreased as it is significantly used for other competitive purposes such as for community and industrial development. As a result, appropriate agricultural lands for oil palm cultivation become scarcer.

The estimated short-run and long-run elasticities of risk of prices of oil palm fresh fruit bunch compared with prices of unsmoked rubber sheet grade 3 in previous year are inelastic. This implies that oil palm farmers are not much responsive to risk of prices in the previous year because both oil palm and rubber have been economic perennial crops of Thailand. This is the reason why most farmers choose oil palm cultivation (Somwong, 2009). Some farmers have grown oil palm since their predecessor (Kiattichaiprasop, 2004).

Characteristically, oil palms farmers' decisions about resource allocation are taken well before oil palm yield is generated since nature of biological processes are involved. Therefore, the realized oil palm yield and income may differ from the ones prevailing at the time from which their decisions were taken. Typically, resource allocation decisions are tied to expectation of final outcome and price.

If farmers are at risk, they are probably unwilling to grow only oil palm, and will prefer to trade some of their benefits from oil palm for greater benefits offered by rubber. It is possible that higher prices of oil palm fresh fruit bunch affect farmers' evaluation of their wealth, and they become more willing to adapt crop selection to take risk because farmers' aim to have stable increase in their income and to ensure sustainability of their livelihoods. However, government agencies currently promote expansion of area for oil palm plantation with respect to national alternative energy. That is, utilization of palm oil as raw material for biodiesel production resulting to increased demands for palm oil, and prices of palm oil remain high and satisfactory.

Adaptive expectation model of yield response of oil palm in Thailand indicates that the statistically significant variable in determining yields of oil palm is retail prices of chemical fertilizer in the previous year. The regression

model with these explanatory variables can be explained correctly by the 79.17 percent of the total variation in yields of oil palm, which is rather satisfactory to indicate overall fitness of the estimating equation used.

The results show an inverse relationship between retail prices of chemical fertilizer in a previous year and yields of oil palm. The findings imply that as the retail price of chemical fertilizer in a previous year increases (decreases) by one percent (one baht per kilogram), the yield of oil palm tends to decrease (increase) by 0.51 percent (123.19 rai), holding other variables constant.

The estimated long-run elasticity of yield response of oil palm in Thailand was computed as follows:

$$\begin{aligned}\gamma &= 1 - \text{estimated coefficient of Thai yields of oil palm in a previous year} \\ &= 1 - 0.08 \\ &= 0.92\end{aligned}$$

The result shows that oil palm farmers can realize desired equilibrium yield level at 92 percent. Therefore, we obtain estimated long-run elasticity of yield response of oil palm in Thailand as follows:

$$\ln(\text{YPR}_t) = 4.930.55 - \ln(\text{FER}_{t-1})$$

Estimated short-run and long-run elasticities of retail prices of chemical fertilizer in previous year are inelastic. This implies that oil palm farmers are not much responsive to change in retail prices of chemical fertilizer in the previous year because of limited capacity of oil palm smallholders. An increase of retail prices of chemical fertilizer result in an increase in variable cost. Hence, some oil palm farmers minimize utilization of chemical fertilizer due to their insufficient purchasing capacity. Decrease in chemical fertilizer usage consequently affects productivity of oil palm. Nonetheless, some oil palm farmers do not worry about increase in prices of chemical fertilizer.

These results can be concluded that elasticity of supply of oil palm in Thailand is inelastic which is consistent with characteristics of agricultural products. It signifies that agricultural productions spend a long time, and a major input of their production is land which is only suitable for some crop plantation.

It is noticed that farm prices of oil palm fresh fruit bunch is found to be statistically insignificant. It is possible that expansion of area for oil palm plantation results from the government's intervention through policy as well as prices of oil palm fresh fruit bunch is rather satisfactory. Furthermore, the government's intervention including creating distorted prices caused increase in

inefficiency in allocation of resources and expansion of area under oil palm plantation into the non-suitable soil and climate conditions. Accordingly, price policy is unfavorable way to encourage expansion of area under oil palm plantation and to control it effectively.

**Table 2.** Seemingly unrelated regression analysis results of yield response of oil palm in Thailand

Variable	AE model <sup>1</sup>	PA model <sup>2</sup>	Pooled AE and PA model
C	4.54*(1.74)	7.77*** (3.44)	7.29*(1.78)
YPR <sub>t-1</sub>	0.08(0.34)	-0.27(-1.16)	-0.03(-0.11)
YPR <sub>t-2</sub>	-	-	-0.20(-0.81)
WAG <sub>t</sub>	-0.14(-0.36)	0.37**(2.53)	-0.13(-0.35)
WAG <sub>t-1</sub>	0.50(1.36)	-	0.61*(1.57)
FER <sub>t</sub>	0.02(0.15)	-0.04(-0.26)	0.02(0.14)
FER <sub>t-1</sub>	-0.51***(-2.92)	-	-0.50***(-2.86)
INT <sub>t</sub>	-0.20(-1.09)	-0.09(-1.04)	-0.17(-0.92)
INT <sub>t-1</sub>	-0.08(-0.59)	-	-0.08(-0.64)
BIP <sub>t</sub>	-0.10(-1.01)	-0.08(-1.05)	-0.10(-0.98)
BIP <sub>t-1</sub>	0.17(1.35)	-	0.15(1.21)
PPF <sub>t-1</sub>	0.05(0.56)	-0.05(-0.46)	0.02(0.21)
QRA <sub>t</sub>	0.24(1.27)	0.11(0.62)	0.19(1.00)
QRA <sub>t-1</sub>	0.12(0.65)	-	0.05(0.23)
R <sup>2</sup>	0.7917	0.6788	0.7974
Adj R <sup>2</sup>	0.5645	0.5382	0.5340
S.E. of regression	0.0979	0.0360	0.1013
D-W stat	2.4183	2.3995	2.4971

Note: <sup>1</sup> AE refers to adaptive expectation model, <sup>2</sup> PA refers to partial adjustment model, <sup>3</sup>\*\*\* p ≤ 0.01, \*\* p ≤ 0.05 and \* p ≤ 0.10

## Conclusions and recommendations

Oil palm becomes the most principal cash oil crop in Thailand. Area for oil palm plantation has been steadily increasing for a long time, and further increase can be expected in the future owing to rising demand for vegetable oil and promotion of utilization of palm oil for biodiesel production. This research attempted to provide a deeper insight on supply response function of oil palm in Thailand. The results showed that adaptive expectation model is the most appropriate model. Area under oil palm plantation is mainly affected by Thai oil palm plantation areas in previous year, wage for agricultural labor, retail prices of chemical fertilizer in previous year, interest rate in previous year, government policy before and after an action plan for the development and

promotion of biodiesel production and consumption, and risk of prices of oil palm fresh fruit bunch compared with prices of unsmoked rubber sheet grade 3 in previous year. The influential factor determining change in yields of oil palm is only retail prices of chemical fertilizer in previous year.

The results of this research lead to proposing some important recommendations as follows:

(1) The Ministry of Labor and relevant agencies should consider providing housing and additional facilities for employees to ensure availability for farm work and improve their skills and competencies on the job and during work contracts.

(2) The results revealed that retail prices of chemical fertilizer can determine area for oil palm plantation and yield of oil palm. Low retail prices of chemical fertilizer appear to have been an important factor in the growth of oil palm production. Fertilizer subsidy to control prices remains a powerful policy instrument in improving trade for agriculture, enhancing oil palm production and its productivity, and balancing growth paths of domestic demand and supply of palm oil. It should be maintained in order to increase oil palm production. Providing chemical fertilizer at low prices to all oil palm farmers can be achieved promoting competition among private-sector input suppliers. Nonetheless, fertilizer subsidy should be implemented in the short term because if additional demand created subsidizing chemical fertilizer can not be met enhancing its supplies which may result to artificial shortages leading to a welfare loss to the society, as well as anomalies in the distribution system. Another reason of this is that chemical fertilizer is adverse on natural environment in the long term. In addition, Ministry of Agriculture and Agricultural Cooperatives (MOAC) should encourage and strengthen effective local group and/or co-operative to increase bargaining power with suppliers to be able to purchase cheaper chemical fertilizer. Furthermore, MOAC and relevant agencies such as Oil Palm Agronomical Research Center, Faculty of Natural Resources, Prince of Songkla University should focus on research and development investment in improving disease-resistant and high-yielding oil palm breeds. Moreover, oil palm farmers should minimize chemical fertilizer and promote efficient bio-organic fertilizer instilment to lessen negative impacts on natural environment, especially reduction of damaged soil nutrients (1) providing a training course on advantages of using bio-organic fertilizer and bio-organic fertilizer making process, (2) training and exploring local availability and manipulation of materials for making bio-organic fertilizer within the area, and (3) providing a training course on utilization of chemical fertilizer combine with bio-organic fertilizer to maximize benefits, and oil palm leaf and soil analysis techniques.



(3) The results reveal that interest rate determines area under oil palm plantation. Bank for Agriculture and Agricultural Co-operatives (BAAC) and financial institutions should provide financial incentives to those who will invest in oil palm cultivation considering an appropriate interest credit and loan which are in accordance with socio-economic conditions, cost of production, most oil palm farmers are willing to alleviate their debt problems. Additionally, MOAC should devote splendid funding incentives or subsidies such as provisions of disease-resistant and high-yielding palm seedlings, fertilizers, and other agricultural equipments to encourage expansion of areas under oil palm plantation and to reduce production cost. In addition, oil palm farmers should establish village fund for members in oil palm investment. This fund should come from a small percentage contribution of members through a sale of their products.

(4) The results reveal that government policy before and after an action plan for the development and promotion of biodiesel production and consumption and risk of prices of oil palm fresh fruit bunch compared with prices of unsmoked rubber sheet grade 3 determine area under oil palm plantation. MOAC should consider availability of potential lands that they are suitable for whether planting oil palm trees or rubber trees and encourage obvious zoning as national agenda. In addition, oil palm farmers should adopt an intensification program.

(5) The results reveal that inelasticity of supply response of oil palm in Thailand which implied that Asean Economic Community (AEC) scheme in 2015 may cause Thai oil palm to be unable to comparatively compete in production and marketing with Indonesian and Malaysian oil palm being the leading producers and exporters in the world market because Thai cost of oil palm production is comparatively higher than them. As a result, oil palm smallholders will be adversely affected from trade liberalization and risk from price volatility. The government policy towards oil palm should be distinguished into supply and demand side policies. In supply side, technology for oil palm cultivation should be improved for a subsequent reduction in production cost because it is expected that area under oil palm plantation can be expanded where oil palm is more profitable than competing crops. In the same time, policy options should focus on removing key farm-level constraints or at least making them less binding; for example, considering availability of abandoned paddy fields and abandoned areas to optimally improve oil palm cultivation as well as relocating unfavorable areas for oil palm cultivation to shift towards other crops and diversify crops in areas under oil palm plantation to avoid risk of prices changes. In addition, providing education opportunities for oil palm farmers on efficient oil palm cultivation management practices

including seedling selection, oil palm cultivation, providing solutions to disease and pest problems which would substantially improve prospects of oil palm production as well as old oil palms should be done. Oil palm trees aged more than 25 years must be replanted. Disease-resistant and high-yielding oil palm varieties, especially in palm agro-economic zone provinces of the South of Thailand which are appropriate areas for oil palm production should be developed. In the demand side, domestic market of palm oil should be expanded to promote utilization of palm oil in upstream industries.

### **Acknowledgement**

The authors would like to express gratitude for grants provided by the Prince of Songkla University (PSU) for carrying out studies. They also would like to thank Graduate School, PSU for financial support exercised under the Songklanakarin Graduate Studies Grant. Furthermore, this research was supported by Oil Palm Agronomical Research Center, Faculty of Natural Resources, PSU.

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(Received 22 November 2012; accepted 30 June 2013)