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Supply Response of Thailand's Rice to the Price of Biofuel Crops*

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Abstract The increasing cost of rice production and the increasing price of energy crops in Thailand, both abetted by the energy crisis in the last 4 years made the rice farmers decide to switch to energy crops. In the long term, this could reduce Thai rice production. This paper mainly examines the supply of rice production in response to the changes in biofuel crops price and other related factors. The study forecasts a negative response in rice supply to the change in biofuel crops price as well as in the cost of chemical fertilizers. In contrast, the price of rice, irrigated area, public rice research budget and mechanization are positive significant factors affecting rice supply. The price policy would distort the market mechanism, which would reduce the competitiveness of Thai rice in the world market. The findings suggest that the government should apply non-price policies in order to increase rice supply and reduce its cost of production. Further development of the irrigation system and increasing support to research and development on rice genetic improvement are recommended.
Keywords: supply response, rice production, biofuel crops

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การตอบสนองของอุปทานข้าวไทยต่อราคาพืชพลังงาน*

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สมพร อิศวิลานนท์ ภาควิชาเศรษฐศาสตร์เกษตรและทรัพยากร คณะเศรษฐศาสตร์ มหาวิทยาลัยเกษตรศาสตร์

บทคัดย่อ ผลกระทบจากภาวะวิกฤตพลังงานในช่วง 3-4 ปีที่ผ่านมา ส่งผลให้ต้นทุนการผลิตข้าวของไทยปรับตัวสูงขึ้นมาก กอปรกับการเพิ่มขึ้นของราคาพืชพลังงานทำให้เกษตรกรหันไปปลูกพืชพลังงานเพิ่มขึ้น ระยะยาวอาจส่งผลให้การผลิตข้าวลดลง บทความนี้ศึกษาถึงการตอบสนองของอุปทานผลผลิตข้าวของไทยต่อปัจจัยด้านราคาพืชพลังงานและปัจจัยอื่นๆ ที่เกี่ยวข้อง ผลการศึกษายืนยันสมมติฐานที่ว่าราคาพืชพลังงานมีผลกระทบทางลบต่อการเปลี่ยนแปลงอุปทานผลผลิตข้าว เช่นเดียวกันกับปัจจัยด้านราคาปุ๋ยเคมี สำหรับราคาข้าว พื้นที่ชลประทาน งบประมาณวิจัยข้าวของรัฐ และเทคโนโลยีทดแทนแรงงาน พบว่าเป็นปัจจัยสำคัญเช่นกันหากแต่ส่งผลกระทบทางบวกต่อการเพิ่มอุปทานผลผลิตข้าว การใช้นโยบายด้านราคาเป็นการแทรกแซงกลไกตลาดข้าวอาจส่งผลเสียต่อความสามารถการแข่งขันของข้าวไทยในตลาดโลก รัฐบาลต้องใช้ความระมัดระวังอย่างมากในการใช้นโยบายดังกล่าว การศึกษาครั้งนี้เสนอว่ารัฐบาลควรเลือกใช้นโยบายที่ไม่ใช่ราคาเพื่อเพิ่มอุปทานและลดต้นทุนการผลิต โดยเฉพาะอย่างยิ่งในด้านการพัฒนาระบบชลประทาน การสนับสนุนงานวิจัย และการพัฒนาเทคโนโลยีปรับปรุงพันธุ์ข้าว

คำสำคัญ: การตอบสนองด้านอุปทาน การผลิตข้าว พืชพลังงาน

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Introduction

The oil crisis has directly affected the energy stability and economic and social development prospects of the country prompting the government to embark on a program to develop energy sources, particularly biofuels, to decrease the country's reliance on fossil fuel. The government strongly supports the development of ethanol and biodiesel as bioenergy forms (Department of Alternative Energy Development and Efficiency, 2007). The promotion of alternative energy production can effectively draw private sector investment in ethanol and biodiesel production. For this reason, the production of bioenergy from sugar cane, cassava and oil palm will sharply increase the demand and price of these crops.

Because of the agricultural land constraint, there is a change in comparative benefits, which in turn leads to the change in the production structure of agricultural crops. The rise in price of the energy crops motivated the farmers to grow more energy crops. According to the statistics from Office of Agricultural Economics (OAE), the area of the energy crops expanded from 18.60 million rai[1] in 2002 to 22.30 million rai in 2007. Expectedly, the share of other crops of the total cultivated area dropped.

As a staple diet of Thai people and a major source of income for farmers, who comprise the majority of the population, rice plays a vital role in the economy. The 25 percent of the entire labor force is shared by the rice farmers (NSO, 2008). The increasing in price trends of energy crops may disadvantage farmers to grow the rice crop and would soon reduce the rice supply. In order to assure food security, sustain rice exports and hold on to the export markets of the country, it is important to be able to predict the effects of price increases in energy crops on future changes in rice production. A study to provide the data for such a prediction would also be useful in the formulation of policies to mitigate the negative effects of the predicted changes.

In this regard, this study investigated the response of rice production to the change of rice price and energy crops price. The study of supply response can be carried out in two ways: direct and indirect analysis. Direct analysis can be done by using actual rice product as a proxy of planned production. Indirect analysis involves two steps which consist of the analysis of area equation and yield equation (Behrman, 1968). The indirect supply response model was used to investigate the response of rice supply to biofuel price in this paper. This is because the actual output often differs

[1] 6.25 rai = 1 ha

considerably from planned output because of importance of environmental factors which remain beyond farmers' control. The frequent large discrepancies between planned and actual rice production have led most econometric investigators of rice supply responses to approximate planned output not by actual output, but by area. The study of Thai rice supply responses which used indirect analysis are found in Behrman (1968), Prakongtanapan (1976), Triratvorakul (1984) and Isvilanonda and Poapongsakorn (1994).

The next section is a brief overview on the change of Thai rice production followed by the theoretical framework, method and data. The last section consists of the conclusions and recommendation.

Overview

From 1960 to 1980, Thailand invested significantly in agricultural development as prescribed in the economic and social development plans. Development in irrigation systems, adoption of modern rice varieties, increased use of chemical fertilizer, and mechanization boosted rice production from 14.23 million tons in 1971-1975 to 23.74 million tons in 1996-2000 and to 27.63 million tons in 2001-2007. The rate of this expansion was 2.51 per year during 1971-2007 (Appendix Table 1).

Cultivated rice area increased from 50.94 million rai in 1971-1975 to 66.76 million rai in 2001-2007. The expansion rate during 1971-1980 was 2.27 percent per year but declined during 1981-2007 to 0.56 percent per year (Appendix Table 1) because of various constraints relating to the availability of agricultural lands. However, the promotion of Modern Rice Varieties (MVs) since 1969 helped relieve the pressure to expand as it enabled farmers to grow two rice crops a year, especially in irrigated areas. The MVs, which respond well to fertilization, became widely adopted. Consequently, the average rice production of the country increased from 280 kg per rai in 1971-1975 to 414 kg per rai in 2001-2007. But further yield increases are now constrained by limits in the current technology and recurring water shortages. In the future, should there be a decrease in cultivated area for any reason the rice output will inevitably decrease. Moreover, the technological and farm management innovations from the Green Revolution also benefited other agricultural crops. Crop diversification and intensification increased the agricultural crop mix, particularly in irrigated areas. As a result, the share of rice crop area declined from 60.80 percent in 1971-1975 to 51.20 percent in 2001-2007 (Appendix Table 2).

This change in the production structure indicates the Thai farmers based their decision on economic reasons; they shifted from growing low-return crops such as rice to higher value crops that were more profitable. This shift together with the rising trend in the price of fossil fuel gained support in many countries, especially the developed ones such as the United States and those in the European Union. Energy crops were extensively promoted as substitute to fossil fuel. The resulting use of maize, soybean, sugar cane and cassava to extract ethanol led to the rise in the prices of these commodities in the world market (Figure 1). The expansion rate of world price of grains, oil palm fresh fruit and soybean oil during 1980-2006 were between -0.12 to 2.29 percent per year but its increase during 2006-2007 to between 2.49 to 42.94 percent per year (Appendix Table 3).

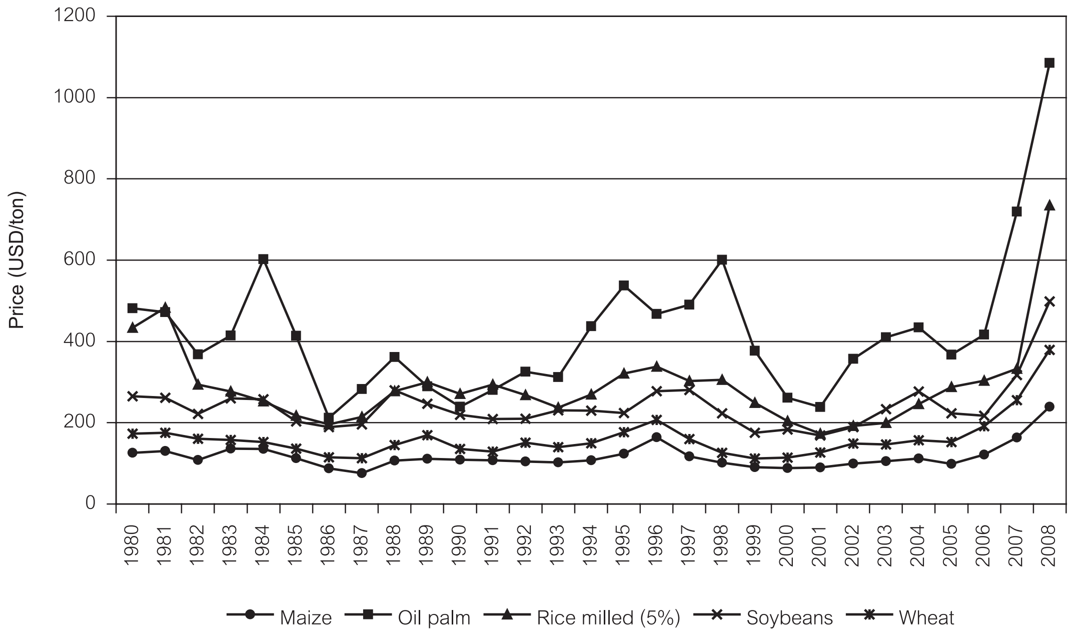

Figure 1 World price of grains and oil palm fresh fruit, 1980-2008
Source: www.imf.org/external/data.htm (accessed on June 21, 2009)

The increase in the prices of energy crops in the world market also caused the energy crop prices in Thailand to increase. Maize price increased from 4.14 baht per kg in 2002 to 6.89 baht per kilogram in 2007. OAE statistics showed that, during the same period, soybean price increased from 10.4 baht per kilogram to 15.12. The rising price trends in grain and energy crops raised concerns that the area cultivated to rice and thus rice production would shrink. If that happens, the country should prepare to deal with the problems this would create.

Theoretical Framework

The study of supply response can be carried out in two ways: direct or one step analysis and indirect analysis or two step analysis. Direct analysis can be done by using total rice product as a proxy of planned production. Indirect analysis involves two steps which consist of the analysis of area equation and yield equation (Behrman, 1968; Sadoulet and Janvry, 1995). This concept is based on the fact that the farmers have two procedures in increasing rice production. First, they decide to set planted areas. If the farmers would like to increase production, they will expand rice planted areas. Second, they will increase production by trying to increase yield per unit (Behrman, 1968). Thus, the equation for analyzing rice supply response will consist of two equations, area planted equation and yield equation which explained in this section.

The farmer decision-making behavior is to maximize their profits subject to the production function:

$$h(Q, X, Z) \tag{1}$$

where Q is the vector of output quantities

X is the vector of variable input quantities

Z is a vector of fixed factor quantities

Variable inputs are usually labor, fertilizer, water, pesticides, seeds, hours of rental factor use, and such other inputs which can be purchased in the desired quantities. Fixed factors are either private factors that cannot be acquired in the time span analyzed (i.e. land, equipment), public factors (infrastructure and extension services), or exogenous features (such as weather) (Sadoulet and Janvry, 1995).

If P and W are the price of outputs and inputs, the farmers' decision-making behavior will maximize profits by choosing the combination of variable inputs and outputs that will maximize profit, subject to the technology constraint:

$$\max_{X,Q}(PQ - WX) \quad \text{s.t.} \quad h(Q,X,Z) = 0 \tag{2}$$

where "W" is the price of variable inputs. The solution to this maximization problem is a set of output supply function:

$$Q = f(P,W,Z) \tag{3}$$

Equation 3 shows that the output supply (Q) is a function of its own price (P), price of variable inputs (W), and fixed factor (Z).

The production of agricultural crop is generated by the area harvested and the average yield per unit area. Thus, rice production can be expressed as

$$Q = A * Y \tag{4}$$

where Q is the total output, A is the area harvested, and Y is the yield per unit area.

A yield per unit area function can be derived from Equation 3 and 4.

$$Y = \frac{Q}{A} = y(P, Z, A) \tag{5}$$

We expect the relation between Y and A since increases in rice area involves bringing marginal land into production. A decrease in rice area will lead to a higher average yield because marginal land is moved out of rice production (Evans and Bell, 1978).

Following Evans and Bell (1978), we can estimate supply elasticities by using a system of two behavioral equations and an identity:

$$A = a(P, W, Z) \tag{6}$$

$$Y = y(P, W, Z, A) \tag{7}$$

and identity is:

$$Q = A * Y \tag{8}$$

The total differentials of the system are (ignoring the Z's, for simplicity):

$$dA = a_P dP \tag{8.1}$$

$$dY = y_P dP + y_A dA \tag{8.2}$$

$$dQ = Y * dA + A * dY \tag{8.3}$$

Using Cramer's rule, we solve for $\frac{dQ}{dP}$ and fine:

$$\frac{dQ}{dP} = A * y_P + A * y_A * a_P + Y * a_P \tag{8.4}$$

Multiplying through by P/Q, we derive the production elasticity for price and other factor:

$$\begin{aligned} E_{Q/P} &= E_{Y/P} + E_{Y/A} * E_{A/P} + E_{A/P} \\ &= E_{Y/P} + E_{A/P}(1 + E_{Y/A}) \end{aligned} \tag{9}$$

$E_{Q/P}$, $E_{Y/P}$ and $E_{A/P}$ and are the elasticity of production, yield and acreage, respectively, for price. $E_{Y/A}$ is the elasticity of yield with respect to acreage.

From Equation 9, the response of production to price depends on the relative responses given above. All we know is that $E_{Y/P}$ and $E_{A/P}$ are positive and $E_{Y/A}$ is negative. If $E_{Y/P}$ equals 0, $E_{Q/P}$ will always be less than $E_{A/P}$. If $E_{Y/P}$ exceeds 0, $E_{Q/P}$ may be greater or less than $E_{A/P}$.

The implication is that in order for policymakers to achieve the desired production by increasing or decreasing rice production, they must be aware of the relative responses contained in expression 9.

Methods and Data

For empirical estimation for rice supply, the model used in this study is formulated in the form of a systems crop analysis for area response equations. In this system, wet season and dry season rice crops are separated into different commodities. After the estimation of area responses, the equation of yield response is estimated based on the rice production.

The Area Response Model

Economic theory states that farmers base their planting decisions on the expected price of their output, the expected price of competitive crops, cost of inputs, their own production capacity and risks involved.

The partial adjustment hypothesis provides a logical basis for the inclusion of lagged planted area as an explanatory force which captures the influence of a number of fixed factors of production. Such factors include specialized equipment for a particular crop, technical expertise and other facilities. The sum effect of such forces may induce the farmers to plant a level of area that is related to the area he planted in the previous year. The analysis of area response equation was carried out by using province cross section-time series data of 22 crops during 1989-2007. The 22 crops were divided into six groups consisting of wet season rice crop, dry season rice crop, energy crop (maize, sugar cane and cassava), oil palm, rubber, and other crops. Indetermining each crop price variable, divisia price index is used to calculate price index which is weighted by producer's price index (base year 2002).

According to Equation 6, because of the farmers have limited cultivated areas and production factors, the determination to grow any crops certainly leads to the changes of production of the whole system as well as production price. Because of this, TDRI (1988) applied system analysis to analyze supply response of Thai agricultural system. Isvilanonda and Paopongsakorn (1994) used the same concept to analyze Thai rice supply by setting rice acreage share function to depend on its own price, the price of other crops and shifter variable as follows:

$$\frac{A_0}{A_t} = f(P, W, Z) \tag{10}$$

In formulating the behavioral equation of the area share (which represent planted area), the partial adjustment model is employed. It is hypothesized that the planned area crop share (s*) is dependent on the set of relative output prices and relative input prices, and other supply shifters, particularly public investment in irrigation, research and extension. That is:

$$s^*_{jt} = a_j + \sum_i a_{ij} \ln P^*_{it} + \sum_k a_{kj} \ln W_{kt} + \sum_m a_{mj} \ln Z_{mt} + u_{jt} \tag{11}$$

where

s^*_{jt} is the planned area crop share

P^*_{it} is the in output price variables (rice price and competition crop price)

W_{kt} is the output price variables (fertilizer price, wage rate and quantity of power tiller)

Z_{mt} is the quasi-fixed factors (public investment in irrigation, research budget and rainfall quantity)

a_{ij}, a_{kj}, a_{mj} are the coefficients of independent variables

u_{jt} is the error term

It is further assumed that the process of area adjustment is taken as Equation 12.

$$s_{jt} - s_{jt-1} = \phi(s^*_{jt} - s_{jt-1}) \text{ and } 0 < \phi < 1 \tag{12}$$

Intuitively, the Equation 12 explains that the farmer is able to change the area share of a crop (s_{jt}) in any year only in a fraction of ϕ of the difference between the area share they would like to plant and the area share actually planted in the preceding year. By solving the Equation 11 and 12, we get:

$$s_{jt} = \alpha_j + \sum_i \beta_{ij} \ln P_{it-1} + \sum_k \gamma_{kj} \ln W_{kt} + \sum_m \omega_{mj} \ln Z_{mt} + \delta_j s_{jt-1} + \eta_{jt} \tag{13}$$

where i,j are the indexes of rice crop and other competing crops such as energy crop, other crops, tree crop, oil palm and rubber (i,j = 1 for rice crop, 2 for energy crop, 3 for other crops, 4 for tree crop, 5 for oil palm, 6 for rubber).

k is the index of variable input prices such as price of fertilizer, labor and quantity of power tillers (k = 1 for fertilizer price, 2 for wage rate, 3 for quantity of power tillers).

m is the index of fixed inputs such as irrigated area, rainfall quantity and rice research budget (m = 1 for irrigated area, 2 for rainfall, 3 for rice research budget).

$\alpha, \beta, \gamma, \omega, \delta$ are parameters

η_{jt} is error term

To estimate the rice area share equation in wet season, dry season and wet and dry season combined, S_{jt} which is set in Equation 13 are the vectors of each crop of the six crops area share. So, the error term for each crop equation is related to error term of other crop equation. To avoid this error, we estimate the system of area share equation with a seemingly unrelated technique. Some restrictions are needed to be imposed namely:

$$\sum \alpha_j = 1$$

$$\sum \beta_{ij} + \sum \gamma_{kj} = 0 \quad \text{both i and k}$$

$$\sum \omega_{mj} = 0$$

$$\sum \beta_{ij} = \sum \beta_{ji} \quad \text{all i and j}$$

The first three restrictions are to ensure that the shares, s_j, are always summed up to one. The last symmetry requirements flow ultimately from the symmetry of the bordered Hessian matrix which is obtained at one step in the derivation of the optimal supply function. It is required that $\sum \beta_{ij} + \sum \gamma_{kj} = 0$ and the symmetry conditions imply that the share of each area supply is homogeneous degree zero in the price of the variables (Isvilanonda and Poapongsakorn, 1994).

The Yield Response Model

A number of factors may be hypothesized to affect rice yields. Among the principal ones are: 1) economic factors, such as the output price which the farmers expected to receive and the cost of inputs that farmers pay which represented by input factors price. In this study we only use fertilizer price to represent input factor price because fertilizer is main cost for rice production, 2) technological factors, such as the production technology to farmers, and 3) physical factors, such as weather condition, amount of rainfall, and soil quality. The logical basis for inclusion of lagged yield variable is that it can be assumed as factors which include the variety of seed used, soil fertility and others.

According to Equation 7, the specification of this model is given by the following equation.

$$\log Y_t = \alpha_0 + \alpha_1 \log P_{t-1} + \alpha_2 \log A_t + \alpha_3 \log F_t + \alpha_4 \log I_t + \alpha_5 \log R_t + \alpha_6 \log RES_t \quad (14)$$

where P_{t-1} = the lag price of paddy

A_t = planted area on season t

F_t = fertilizer price during planting season t

I_t = irrigation area in planting season t

R_t = the average seasonal rainfall

RES_t = the lag of Investment on rice research by government

The determination of research budget variable will be considered according to the principles proposed by Pochanukul (1992). Pochanukul presents the idea concerning the measurement of the benefit of technological knowledge on Thai rice production that the analysis can be carried out by utilizing research budget as knowledge management. When RES represents technological knowledge at present, the value of RES can be obtained by applying the following formula:

$$RES_t = 0.2RES_{t-1} + 0.4RES_{t-2} + 0.6RES_{t-3} + 0.8RES_{t-4} + 1.0RES_{t-5} + 0.9RES_{t-6} + 0.8RES_{t-7} + 0.7RES_{t-8} + 0.6RES_{t-9} + 0.5RES_{t-10} + 0.4RES_{t-11} + 0.3RES_{t-12} + 0.2RES_{t-13} + 0.1RES_{t-14} \quad (15)$$

Provincial pooled data[2] of 22 crops for period 1989-2007 (exclude public research budget that we used data for period 1970-2007) were used in the analysis. Provincial area, production, farm price, fertilizer price, agricultural wage rate, quantity of power tiller, irrigated area, public research budget data obtained from OAE, Ministry of Agriculture and Cooperatives. The analysis was made on the wet season rice crop, the dry season rice crop and the two (both wet and dry season) crops combined.

Results

The results of this study are discussed in three sections: 1) the result of rice area response, 2) the result of rice yield response, and 3) the result of output elasticity of total rice supply. The explanation of the response in each part is divided into short-run and long-run responses.

[2] "Pooled data" have both cross-sectional and time-series dimensions.

The Area Response

According to Equation 13, in the six equations of cropping system model, dependent variables include share of wet season rice area (SHRW), share of dry season rice area (SHRD), share of energy crop area (SHENG), share of oil palm area (SHPO), share of rubber tree area (SHTR), and share of other crops area (SHOTH). Each of these six equations has the same independent variables which include lag of wet season rice price (PRW_{t-1}), lag of dry season rice price (PRD_{t-1}), lag of energy crop price index (PE_{t-1}), lag of oil palm fresh fruit price (PPO_{t-1}), lag of rubber price ($PRUB_{t-1}$), lag of tree crop price index ($PTRE_{t-1}$), and lag of other crops price index (PC_{t-1}). The variables used as representative of input price consist of the price of urea (PF_t), minimum wage rate in each province (W_t), and the quantity of power tillers per household (POW_t). In terms of quasi fixed factors such as weather and public policies, variance of rainfall quantity ($RAIN_t$) is used to represent weather condition. The ratio of irrigated area by rice area (IRR_t) and rice research budget (RES_t) are used to represent the public policies, and the last variable is share of previous rice cultivated area in the previous year (S_{t-1}).

By using Seemingly Unrelated technique (SUR) to estimate the crop system equations, the results of rice area share equation are shown in Appendix Table 4. The results show that the rice price variable has significant positive signs in total rice area equation, wet season rice area equation, and dry season rice area equation. This implies that if the rice price increases, rice cultivated area both in wet season and dry season will increase. On the other hand, the energy crop price has a significant negative sign. It implies that the energy crop price has negative impact on rice cultivated area both in wet and dry seasons. The coefficients of oil palm fresh fruit and rubber tree price variables have a significant negative sign for the dry season rice cultivated area only.

The result from the analysis of the relationship between input price and rice area change shows that fertilizer price has negative impact on the total rice area change. The coefficient values of fertilizer price variables calculated from the three equations of rice share area are significant. The wage rate variable has a negative but statistically insignificant impact on rice cultivated area in the three equations. The coefficient value of the proportion of power tillers per household variable, used to substitute man and animal labor, has significant positive impact on rice share area in three equations (total rice, wet season rice, and dry season rice share area equation).

The weather condition which is represented by variance of rainfall quantity has significant negative coefficient in total rice area and wet season rice area equations. This indicates that the more the rainfall quantity in that year deviates from the mean, the greater is the decrease in rice cultivated area. The coefficient of irrigation area and research budget variables in the total equation of rice cultivated area share and the equation of wet season rice area share has significant positive impact on change in rice cultivated area.

The short run elasticity of rice area is calculated by dividing the coefficient variable in Equation 12 by mean of rice area share. The result is shown in Table 1 (short run Ea). The short run elasticities of rice area planted with respect to its own lagged price are 0.173, 0.037 and 0.096 for total rice area, wet season rice area and dry season rice area, respectively. As all of own price elasticities are inelastic, it implies that farmers or producers are less responsive to price change in the short run. As indicated, a small percentage change in price of rice will result in a small change, in the same direction, in the current area planted. For example if the lagged price of total rice increases or decreases by one percent, there will be an increase or decrease of 0.173 percent in the current rice planted area.

Table 1 The short-run and long-run rice area elasticities

Variables	B Coef.	Mean of rice area share(S_{rice})	Short-run Eai	$(1-\delta_{t-1})$	Long-run Eai
Total					
Average rice price	0.093	0.537	0.173	0.738	0.235
Other crops price	n.s.	0.537	n.s.	0.738	n.s.
Energy crop price	-0.053	0.537	-0.099	0.738	-0.134
Oil palm fresh fruit price	n.s.	0.537	n.s.	0.738	n.s.
Rubber price	n.s.	0.537	n.s.	0.738	n.s.
Tree crop price	n.s.	0.537	n.s.	0.738	n.s.
Irrigated area	0.077	0.537	0.143	0.738	0.193
Rain STD.	-0.066	0.537	-0.124	0.738	-0.167
Research budget	0.085	0.537	0.159	0.738	0.215
Fertilizer price	-0.092	0.537	-0.172	0.738	-0.233
Agricultural wage rate	n.s.	0.537	n.s.	0.738	n.s.
Quantity of power tiller	0.067	0.537	0.124	0.738	0.168
Wet season					
Wet season rice price	0.016	0.422	0.037	0.659	0.056
Dry season rice price	n.s.	0.422	n.s.	0.659	n.s.
Other crops price	n.s.	0.422	n.s.	0.659	n.s.

Table 1 (Continued)

Variables	B Coef.	Mean of rice area share(S_{rice})	Short-run Eai	$(1-\delta_{t-1})$	Long-run Eai
Wet season					
Energy crop price	-0.093	0.422	-0.219	0.659	-0.333
Oil palm fresh fruit price	n.s.	0.422	n.s.	0.659	n.s.
Rubber price	n.s.	0.422	n.s.	0.659	n.s.
Tree crop price	n.s.	0.422	n.s.	0.659	n.s.
Irrigated area	0.085	0.422	0.202	0.659	0.307
Rain STD.	-0.049	0.422	-0.116	0.659	-0.177
Research budget	0.041	0.422	0.096	0.659	0.146
Fertilizer price	-0.050	0.422	-0.118	0.659	-0.178
Agricultural wage rate	n.s.	0.422	n.s.	0.659	n.s.
Quantity of power tiller	0.078	0.422	0.186	0.659	0.282
Dry season					
Wet season rice price	0.017	0.115	0.152	0.897	0.169
Dry season rice price	0.011	0.115	0.096	0.897	0.107
Other crops price	-0.026	0.115	-0.226	0.897	-0.252
Energy crop price	n.s.	0.115	0.000	0.897	0.000
Oil palm fresh fruit price	-0.025	0.115	-0.215	0.897	-0.240
Rubber price	n.s.	0.115	n.s.	0.897	n.s.
Tree crop price	n.s.	0.115	n.s.	0.897	n.s.
Irrigated area	0.002	0.115	0.019	0.897	0.021
Rain STD.	n.s.	0.115	n.s.	0.897	n.s.
Research budget	0.017	0.115	0.150	0.897	0.168
Fertilizer price	-0.019	0.115	-0.168	0.897	-0.187
Agricultural wage rate	n.s.	0.115	n.s.	0.897	n.s.
Quantity of power tiller	0.007	0.115	0.057	0.897	0.063

Notes: 1) n.s. is “not significant”
2) Eai is the rice cultivated area elasticity with respect to factor i

The short run elasticities of rice planted area with respect to its energy lagged price are -0.099 and -0.219 for total rice area and wet season rice area, respectively. All of the cross price elasticities are inelastic, which indicates that a small percentage increase in price of energy crops will result in a slight decrease in the current area planted to rice. For example, if the lagged price of energy crops price in wet season increases by one percent, there would be a decrease of -0.219 percent in the current rice planted area in wet season. This might be caused by the inability of farmers to adjust in the short run their planted area from rice to energy crops as they lack the knowledge and/or capital to grow the energy crop.

The long run elasticity of rice area is calculated by dividing the short run elasticity by the coefficient of adjustment, that is $(1-\delta_{t-1})$. The long run elasticity of rice area planted on total area, wet season area and dry season area with respect to lagged own price are 0.235, 0.056 and 0.107 which are inelastic. This is consistent with the economic principle that the farmers are more responsive to price change in the long run due to an allowable period of adjustment. The long run elasticity implies that a one percent increase in lagged price of rice will have a corresponding increase of 0.235, 0.056 and 0.107 percent in total rice area, wet season area and dry season area planted in current year. This also means that farmers base their long term production planting on expected price.

The long run elasticity of rice planted area for total rice and wet season rice with respect to lagged of energy crop price are -0.134 and -0.333 which is higher than short run elasticity. This is due to the price change in the long run allowable period of adjustment.

Rice Yield Response

The assumption of yield response equation is that rice yield depends on rice price, irrigation area, research budget, cultivating area, climatic condition and input price whose equation is in the form of logarithm (Equation 13). The weighted least squares method where the weight by the rice value share is use for the analysis. The estimated results were shown in Appendix Table 5. The analysis reveals that rice price has a significant positive impact on rice yield change in the three rice yield response equations. On the other hand, rice cultivated area has significant negative impact on rice yield.

In terms of variance of the rainfall quantity, only the total rice yield equation reveals significant coefficient value and has negative impact on rice yield. The coefficient value of the research budget variable has significant positive impact on rice yield in wet season, dry season and total rice yield equation (Table 2).

Output Elasticity of Total Rice Supply

The output elasticity of supply was calculated by using Equation 9. The results are shown in Table 3. The rice price elasticities in the short run were 0.259, 0.147 and 0.371 in total rice production, wet season rice production, and dry season rice production, respectively. The elasticities in the long run were 0.319 0.165, and 0.382, respectively. The price elasticity of rice supply indicates that rice price does have influence on rice production especially on wet season. When comparing rice production response to rice price during wet season and dry season, it was found that both in the short run and long run, rice supply responds more to rice price in the dry than in wet season.

Table 2 The short-run and long-run rice yield elasticities

Variables	Short-run and long-run yield elasticities (Eyi)		
	Wet season	Dry season	Total
Average rice price	0.111	0.284	0.090
Irrigated area	0.119	0.041	0.043
Rain STD.	n.s.	n.s.	-0.017
Research budget	0.183	0.181	0.121
Fertilizer price	-0.202	n.s.	-0.106
Agricultural wage rate	-0.097	-	-
Quantity of power tiller	-	-	-
Rice area	-0.023	-0.085	-0.022

Notes: 1) n.s. is "not significant"

2) Eyi is the rice yield elasticity with respect to factor i

3) The short-run and long-run elasticities of rice yield are equal because the rice yield in this year does not depend on the rice yield in previous year.

Table 3 The short-run and long-run output elasticities of total rice supply

Elasticities	Short-run			Long-run		
	Total	Wet season	Dry season	Total	Wet season	Dry season
Rice price	0.259	0.147	0.371	0.319	0.165	0.382
Other crops price	n.s.	n.s.	-0.207	n.s.	n.s.	-0.231
Energy crop price	-0.097	-0.214	n.s.	-0.131	-0.325	n.s.
Oil palm fresh fruit price	n.s.	n.s.	-0.197	n.s.	n.s.	-0.219
Rubber price	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Tree crop price	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Irrigated area	0.182	0.317	0.058	0.232	0.419	0.060
Rain STD.	-0.138	-0.114	n.s.	-0.181	-0.173	n.s.
Research budget	0.276	0.277	0.319	0.331	0.326	0.334
Fertilizer price	-0.274	-0.317	-0.154	-0.334	-0.376	-0.171
Agricultural wage rate	n.s.	-0.097	n.s.	n.s.	-0.097	n.s.
Quantity of power tiller	0.122	0.181	0.107	0.165	0.276	0.113

Notes: 1) n.s. is "not significant"

2) See the calculation of rice production elasticities in Appendix Table 6

Poapongsakorn and Isvilanonda (2008) reported that the results of the rice pledging program, which has been the main rice price policy in recent years, has had negative impacts on the rice market. They contended that this would seriously affect the competitiveness of Thai rice in the world market and cautioned the government to carefully use this policy.

The analysis of input price elasticity of rice supply reveals that the response of rice supply to the price of chemical fertilizer is in the opposite direction. The long run elasticity values were -0.334, -0.376 and -0.171 in total, in wet season and in dry season, respectively. This indicates that an increase in the price of chemical fertilizer results in the decline of rice production. The analysis of response of rice supply to the change of power tillers quantity per household shows that the rice production increases in the three rice equations if the proportion of power tillers per household increases. The more the wage rate increases, the more the farmers substitute man with machines. This results in a more efficient farming that leads to an increase in rice production.

The short run rice supply elasticity has positive response to the change in irrigation area on total rice supply (0.182), wet season (0.317) and dry season rice supply (0.058). In the long run, these elasticities change to 0.232, 0.419 and 0.060 for total rice, wet season rice and dry season rice.

Research budget for rice is considered a significant factor in rice production increase. The response of rice supply in total rice, in wet season and in dry season in short run was 0.276, 0.277 and 0.319, respectively. This indicates that investment in rice research is important for increasing rice production.

The response of rice production to the change in energy crops price, which consist of sugar cane, cassava and corn, and the response of rice production to the change in price of tree crop, oil palm fresh fruit, rubber and other crops price were calculated to obtain the coefficient value of the variables ($LnPE_{t-1}$), ($LnPTRE_{t-1}$), ($LnPPO_{t-1}$) and ($LnPRUB_{t-1}$) only in the equation of rice area response (Equation 13). Since the competitive crop variables are not available in the equation of rice yield response, it is hypothesized that the farmers will respond to competitive crop price only in the process of selecting areas for rice cultivation. Once the cultivation has been carried out, the change in competitive crop price will have no effect on the maintenance of rice production in the field. Only the rice price will cause a response from the farmers in this step.

The short run energy crop price elasticity of rice supply equals -0.097 and -0.214 in total and wet season rice supply. As the coefficient value of energy price variable in dry season equation is not significant, the calculation of elasticity cannot be carried out. The bigger response of the energy crop to the change in wet season rice supply than to the change in dry season rice supply reflects one crucial fact: most farmers will not grow an upland crop in an irrigated area. This might be because upland crops can grow in a drought area and is mostly grown in the northeast which is a non-irrigated area and only wet season farming can be carried out. The change in cultivated area will have more effect on the change of wet season rice production than that of dry season rice production.

The oil palm fresh fruit price elasticities of rice supply in the dry season were -0.197 and -0.219 in short run and long run, respectively. This implies that the increase in oil palm fresh fruit price results in the decrease of dry season cultivated areas and rice production. The magnitude of response will also increase in the long run. The coefficient value of rubber price variable in total rice area response equation, wet season and dry season rice area response equation are insignificant. Hence, they are not used in the calculation of elasticity. The obtained elasticity indicates that the change in price of oil palm fresh fruit has greater effects on dry season rice production than on wet season rice production. It is so because the rice yield in the dry season is higher than that in the wet season. Therefore the decrease in rice cultivated area will cause more decrease on the dry season than on the wet season rice production.

Conclusion and Recommendations

This paper analyzes the supply of rice production in response to the change in biofuel price. The indirect analysis of supply response is used for the estimate of the output supply elasticities. The results show the main factors affecting the rice supply response as follows:

1) The relevant commodity prices. This includes the prices of rice, para rubber, oil palm fresh fruit price and other energy crops. The energy crop price is negative impact on rice production in wet season and in wet and dry season combined and the magnitude of response will also increase in the long run. This implies that in the short run, the change of energy crop prices would not have much impact on rice production. But the effect would be significant in the long run due to the adaptation of production systems in response to such change. The results also show that the wet season rice supply would respond to energy crop prices more than dry season rice supply both in the short and long run.

2) Production input prices. An increase in the price of chemicals would reduce rice supply. Meanwhile agricultural wage input would not significantly affect rice supply largely because farmers have adopted farm machinery to replace manual labor. The study found that an increase in the number of machinery used contributes to a higher rice production. However, this can add to the energy cost to the rice farm, which is estimated at 20 percent of total cost.

3) Government investment on development of rice technology. This includes investment on irrigation projects and rice technology research. The study found that increases of these two factors would contribute to an increase of rice supply in the long run.

4) Change of weather condition. Weather variation negatively affects rice production. More than 70 percent of rice production in Thailand is from rainfed areas. The standard deviation of annual rainfall volume was used as a parameter; it was found that a high variation of this parameter would reduce rice production.

In sum, this study found that the positive significant factors affecting rice supply are irrigated area, number of machinery per household, research fund and rice price, respectively. Rice price would give the lowest effect compared to the first three non-price factors. Meanwhile, the negative significant factors affecting rice supply are weather condition, energy crop price and chemical price.

In connection with the above findings, the government must be careful in employing the rice price policy, especially the rice pledging program. The study suggests that maintaining the paddy pledging program will soon damage the Thai rice market resulting in the loss of Thailand's competitiveness in rice export (see also Poapongsakorn and Isvilanonda, 2008). In order to promote an increase in rice production in the long run, the government should adopt non-price policies. Developing the irrigation system and increasing the support for rice research and development particularly genetic improvement would improve rice supply, reduce production costs and enhance the competitiveness of Thai rice in the world market.

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Appendixes

Appendix Table 1 Average and growths of production, area, and yield of rice classified by wet and dry seasons, 1971-2007

Periods	Wet season	Dry season	Annual avg.	Wet season	Dry season	Annual avg.
	Average area (million rai)			Growth (%)		
1971-1975	48.94	2.00	50.94	3.22	20.02	3.79
1976-1980	55.31	3.13	58.44	1.07	8.34	1.23
1981-1985	57.69	4.00	61.69	-0.75	0.73	-0.67
1986-1990	57.88	4.44	62.31	1.00	6.57	1.29
1991-1995	55.88	4.31	60.19	0.24	15.91	1.15
1996-2000	56.88	6.75	63.63	-0.01	6.34	1.76
2001-2007	57.44	9.31	66.76	0.17	1.26	2.29
% Share	86.05	13.95	100.00	-	-	-
	Average annual growth rate (%)					
1971-1980	2.02	17.31	2.27	-	-	-
1981-2007	0.07	8.09	0.56	-	-	-
1971-2007	0.60	10.58	1.02	-	-	-
	Production (million ton)			Growth (%)		
1971-1975	13.20	1.03	14.23	1.52	18.79	2.75
1976-1980	14.32	1.78	16.10	3.58	9.28	3.88
1981-1985	16.54	2.34	18.88	1.00	7.33	1.63
1986-1990	16.59	2.53	19.12	3.39	1.83	2.85
1991-1995	17.44	2.94	20.38	1.78	16.43	3.66
1996-2000	18.76	4.98	23.74	0.99	6.80	3.83
2001-2007	21.27	6.26	27.63	4.17	1.37	2.68
% Share	77.35	22.65	100.00	-	-	-
	Average annual growth rate (%)					
1971-1980	26.00	1.77	2.78	-	-	-
1981-2007	6.51	1.95	2.41	-	-	-
1971-2007	11.78	1.90	2.51	-	-	-
	Average yield (kg/rai)			Growth (%)		
1971-1975	267	514	280	-1.74	-0.36	-1.06
1976-1980	282	570	275	2.32	7.50	2.43
1981-1985	259	586	306	1.62	7.41	2.23
1986-1990	256	570	306	2.43	2.59	1.82
1991-1995	310	682	338	1.60	10.06	2.64
1996-2000	330	734	373	0.96	0.40	1.36
2001-2007	372	672	414	3.98	0.05	3.00
Average annual growth rate (%)	1.77	0.20	1.65	-	-	-

Source: Data from OAE (in various issues)

Appendix Table 2 Average percentage share of rice area in total crop production in 1971-2007

Periods	Rice (million rai)			Upland crop			Tree crop				Vegetable	Total
	Wet	Dry	Total	Energy crop	Other	Total	Oil palm	Rubber	Other	Total		
1971-1975	60.8	2.4	63.2	15.1	7.5	22.6	0.0	10.6	2.7	13.4	0.8	100.0
1976-1980	57.3	3.1	60.4	19.2	7.1	26.3	0.1	9.8	2.8	12.6	0.7	100.0
1981-1985	53.4	3.7	57.1	22.4	7.6	29.9	0.4	9.4	2.6	12.4	0.6	100.0
1986-1990	52.1	4.1	56.2	24.4	6.1	30.5	0.7	9.2	3.0	12.9	0.4	100.0
1991-1995	51.6	4.0	55.6	23.9	5.2	29.0	0.9	11.0	3.1	15.0	0.4	100.0
1996-2000	51.7	6.7	58.4	21.1	3.5	24.6	1.5	12.1	3.0	16.5	0.5	100.0
2001-2007	51.2	8.3	59.5	18.5	2.3	20.8	3.4	13.0	3.0	19.3	0.3	100.0

Source: Data from OAE (in various issues)

Appendix Table 3 Average and growths of world price of grains, oil palm and soybean oil in 1980-2008

Periods	Maize	Oil palm	Rice milled (5%)	Soybean oil	Soybeans	Wheat
			Price (USD/ton)			
1971-1975	124.76	458.63	326.06	527.15	244.69	158.94
1976-1980	98.18	277.15	251.55	441.31	226.05	135.56
1981-1985	108.99	378.50	277.77	514.15	220.45	149.35
1986-1990	112.37	439.37	279.72	475.36	227.86	143.79
1991-1995	100.86	361.58	219.52	468.66	218.13	146.16
1996-2000	142.42	567.97	317.95	675.62	267.39	223.46
			Average annual growth rate (%)			
1980-2006	1.17	2.92	-0.12	1.82	0.38	1.39
2006-2008	28.91	42.94	7.49	28.13	21.69	29.44

Source: www.imf.org/external/data.htm (accessed on June 21, 2009)

Appendix Table 4 Estimated results of rice area share

Variables	SUR		
	Wet season	Dry season	Total
Constant	-4.160***	-0.271	-2.731***
	(-4.421)	(-1.048)	(-3.514)
$LnPRT_{t-1}$	-	-	0.093*
	-	-	(-1.619)
$LnPRW_{t-1}$	0.016*	0.017**	-
	(1.903)	(2.577)	-
$LnPRD_{t-1}$	0.005	0.011*	-
	(0.129)	(1.622)	
$LnPOTH_{t-1}$	-0.131	-0.026**	-0.143
	(-0.349)	(-2.557)	(-1.409)
$LnPTRE_{t-1}$	0.003	0.0001	0.004
	(-0.452)	(-0.128)	(-0.545)
$LnPE_{t-1}$	-0.093***	-0.026	-0.052*
	(-3.386)	(-1.240)	(-1.939)
$LnPPO_{t-1}$	-0.034	-0.025**	-0.001
	(-0.934)	(-2.502)	(-0.027)

Appendix Table 4 (continued)

Variables	SUR		
	Wet season	Dry season	Total
$LnPRUB_{t-1}$	-0.035	-0.028	-0.037
	(-0.543)	(-1.586)	(-0.617)
$LnPF_t$	-0.049*	-0.019	-0.092*
	(-1.628)	(-1.619)	(-1.751)
LnW_t	-0.060	-0.054	-0.138
	(-0.294)	(-1.332)	(-1.384)
$LnPOW_t$	0.078***	0.006***	0.067***
	(22.01)	(6.119)	(19.345)
$LnIRR_t$	0.085***	0.002*	0.077***
	(7.588)	(1.695)	(8.218)
$LnRES_{t-n}$	0.041***	0.017	0.085**
	(3.607)	(0.420)	(2.127)
$LnRAIN_t$	-0.049**	-0.007	-0.066**
	(-2.219)	(-1.178)	(-3.029)
S_{t-1}	0.341***	0.103***	0.262***
	(36.82)	(85.15)	(41.83)
Sample	1260	1260	1260
R^2 adj.	0.78	0.92	0 82

Note: * is significant at 90 %

** is significant at 95 %

*** is significant at 99 %

(…) is t-statistic

Source: Calculated based on data from OAE

Appendix Table 5 Estimated results of yield response equation

Variables	WLS		
	Wet season	Dry season	Total
Constant	1.853***	2.046***	1.888***
	(8.375)	(7.623)	(17.601)
LNPR	0.111*	0.284***	0.090*
	(1.854)	(5.073)	(1.742)
LNFER	-0.202**	-0.036	-0.106*
	(-2.783)	(-0.280)	(-1.762)
LNIRR	0.119***	0.042**	0.043***
	(7.419)	(2.496)	(3.056)
LNRAIN	0.003	-0.032	-0.017*
	(0.245)	(-1.391)	(-1.765)
LNRES	0.183***	0.181**	0.121***
	(8.572)	(2.522)	(7.849)
LNWAGE	-0.097*	-	-
	(-1.615)	-	-

Appendix Table 5 (continued)

Variables	WLS		
	Wet season	Dry season	Total
LNPOW	-	0.055***	-
	-	(2.986)	-
LNA	-0.013	-0.084***	-0.022*
	(-0.941)	(-3.456)	(-1.850)
DUM_C	0.075**	0.204***	0.094***
	(2.156)	(2.910)	(3.155)
DUM_N	0.082***	0.164**	0.082**
	(2.32)4	(2.305)	(2.690)
DUM_NE	0.004	0.030	-0.036
	(0.103)	(0.402)	(-1.191)
Sample	1,260	1,260	1,260
R^2	0.995	0.984	0.997
F test	224.54***	63.34***	376.83***

Note: * is significant at 90 %

** is significant at 95 %

*** is significant at 99 %

(...) is t-statistic

Source: Calculated based on data from OAE

Appendix Table 6 Rice supply elasticities in short-run and long-run

Variables	B coef.	Mean of S_{rice}	Short-run			$(1-\delta_{t-1})$	Long-run			Supply elasticities	
			Eai	Eyi	Eya		Eai	Eyi	Eya	Short-run	Long-run
Total											
Average rice price	0.093	0.537	0.173	0.090	-0.022	0.738	0.235	0.090	-0.022	0.259	0.319
Other crops price	ns	0.537	ns	-	-0.022	0.738	0.000	-	-0.022	Ns	0.000
Energy crop price	-0.053	0.537	-0.099	-	-0.022	0.738	-0.134	-	-0.022	-0.097	-0.131
Oil palm fresh fruit price	n.s.	0.537	n.s.	-	-0.022	0.738	n.s.	-	-0.022	n.s.	n.s.
Rubber price	n.s.	0.537	n.s.	-	-0.022	0.738	n.s.	-	-0.022	n.s.	n.s.
Tree crop price	n.s.	0.537	n.s.	-	-0.022	0.738	n.s.	-	-0.022	n.s.	n.s.
Irrigated area	0.077	0.537	0.143	0.043	-0.022	0.738	0.193	0.043	-0.022	0.182	0.232
Rain STD.	-0.066	0.537	-0.124	-0.017	-0.022	0.738	-0.167	-0.017	-0.022	-0.138	-0.181
Research budget	0.085	0.537	0.159	0.121	-0.022	0.738	0.215	0.121	-0.022	0.276	0.331
Fertilizer price	-0.092	0.537	-0.172	-0.106	-0.022	0.738	-0.233	-0.106	-0.022	-0.274	-0.334
Agricultural wage rate	n.s.	0.537	n.s.	-	-0.022	0.738	n.s.	-	-0.022	n.s.	n.s.
Quantity of power tiller	0.067	0.537	0.124	-	-0.022	0.738	0.168	-	-0.022	0.122	0.165

Appendix Table 6 (continued)

Variables	B coef.	Mean of S_{rice}	Short-run			$(1-\delta_{t-1})$	Long-run			Supply elasticities	
			Eai	Eyi	Eya		Eai	Eyi	Eya	Short-run	Long-run
						Wet season					
Wet season rice price	0.016	0.422	0.037	0.111	-0.023	0.659	0.056	0.111	-0.023	0.147	0.165
Dry season rice price	n.s.	0.422	n.s.	-	-0.023	0.659	n.s.	-	-0.023	n.s.	n.s.
Other crops price	n.s.	0.422	n.s.	-	-0.023	0.659	n.s.	-	-0.023	n.s.	n.s.
Energy crop price	-0.093	0.422	-0.219	-	-0.023	0.659	-0.333	-	-0.023	-0.214	-0.325
Oil palm fresh fruit price	n.s.	0.422	n.s.	-	-0.023	0.659	n.s.	-	-0.023	n.s.	n.s.
Rubber price	n.s.	0.422	n.s.	-	-0.023	0.659	n.s.	-	-0.023	n.s.	n.s.
Tree crop price	n.s.	0.422	n.s.	-	-0.023	0.659	n.s.	-	-0.023	n.s.	n.s.
Irrigated area	0.085	0.422	0.202	0.119	-0.023	0.659	0.307	0.119	-0.023	0.317	0.419
Rain STD.	-0.049	0.422	-0.116	n.s.	-0.023	0.659	-0.177	-	-0.023	-0.114	-0.173
Research budget	0.041	0.422	0.096	0.183	-0.023	0.659	0.146	0.183	-0.023	0.277	0.326
Fertilizer price	-0.050	0.422	-0.118	-0.202	-0.023	0.659	-0.178	-0.202	-0.023	-0.317	-0.376
Agricultural wage rate	n.s.	0.422	n.s.	-0.097	-0.023	0.659	n.s.	-0.097	-0.023	-0.097	-0.097
Quantity of power tiller	0.078	0.422	0.186	-	-0.023	0.659	0.282	-	-0.023	0.181	0.276
						Dry season					
Wet season rice price	0.017	0.115	0.152	-	-0.085	0.897	0.169	-	-0.085	0.139	0.155
Dry season rice price	0.011	0.115	0.096	0.284	-0.085	0.897	0.107	0.284	-0.085	0.371	0.382
Other crops price	-0.026	0.115	-0.226	-	-0.085	0.897	-0.252	-	-0.085	-0.207	-0.231
Energy crop price	n.s.	0.115	0.000	-	-0.085	0.897	0.000	-	-0.085	n.s.	n.s.
Oil palm fresh fruit price	-0.025	0.115	-0.215	-	-0.085	0.897	-0.240	-	-0.085	-0.197	-0.219
Rubber price	n.s.	0.115	n.s.	-	-0.085	0.897	0.000	-	-0.085	n.s.	n.s.
Tree crop price	n.s.	0.115	n.s.	-	-0.085	0.897	n.s.	-	-0.085	n.s.	n.s.
Irrigated area	0.002	0.115	0.019	0.041	-0.085	0.897	0.021	0.041	-0.085	0.058	0.060
Rain STD.	n.s.	0.115	n.s.	-	-0.085	0.897	n.s.	n.s.	-0.085	n.s.	n.s.
Research budget	0.017	0.115	0.150	0.181	-0.085	0.897	0.168	0.181	-0.085	0.319	0.334
Fertilizer price	-0.019	0.115	-0.168	n.s.	-0.085	0.897	-0.187	n.s.	-0.085	-0.154	-0.171
Agricultural wage rate	n.s.	0.115	n.s.	n.s.	-0.085	0.897	0.000	n.s.	-0.085	n.s.	n.s.
Quantity of power tiller	0.007	0.115	0.057	0.055	-0.085	0.897	0.063	0.055	-0.085	0.107	0.113

Note: 1) n.s. is "not significant"

2) Eai is the rice cultivated area elasticity with respect to factor i

3) Eyi is the rice yield elasticity with respect to factor i

4) Eya is the rice yield elasticity with respect to rice cultivated area

Source: Calculated based on data from OAE